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Original Paper

Serious Motion-Based Exercise Games for Older Adults: Evaluation of Usability, Performance, and Pain Mitigation

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Abstract

Background: Many societies are facing demographic changes that challenge the viability of health and welfare systems. Serious games for health care and ambient assisted living (AAL) offer health benefits and support for older adults and may mitigate some of the negative effects of the demographic shift.

Objective: This study aimed to examine the acceptance of serious games to promote physical health in AAL environments. Since AAL environments are designed specifically to support independent living in older adults, we studied the relationship among age and user diversity, performance in the game, and overall usability and acceptance evaluation.

Methods: We developed a motion-based serious exercise game for prototypical AAL environments. In two evaluations, outside (n=71) and within (n=64) the AAL environment, we investigated the influence of age, gender, self-efficacy in interacting with technology, need for achievement on performance, effect of the game, usability evaluation of the game, and overall acceptance.

Results: Both games were evaluated as easy to use and fun to play. Both game interventions had a strong pain-mitigating effect in older adults (game 1: −55%, P=.002; game 2: −66%, P=.01).

Conclusions: Serious exercise games outside and inside AAL environments can contribute to individuals' health and well-being and to the stability of health care systems.

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KEYWORDS

serious games; exercise game; health care; pain; ambient assisted living; technology acceptance

Introduction

Background

Many societies are facing a demographic shift because of declining birthrates and increased life expectancy [1]. It is estimated that the proportion of people 65 years and older will increase from 17% as recorded in 2008 to an estimated 30% by 2060, and that the proportion of those 80 years and older will almost triple, from 5% to 14% [2], in the same time period. Given that the risk of acute and chronic illnesses increases with age [3-6], this means a shrinking workforce will be financially responsible for a growing number of older adults with ever greater medical and general care needs.

Two *possible* solutions to address these challenges are the *ambient assisted living* (AAL) *environments* and *serious games for health care*. AAL supports people in need of care through technology that can compensate for health-related restrictions, while increasing comfort and safety [7-10]. Serious games combine elements of play with serious goals, such as learning or exercising [11-14].

A challenge while designing information and communication technology–based health interventions is age-inclusiveness: Older adults often report lower performance and self-efficacy levels in their interaction with digital interfaces [15,16]. In addition, age-related physical limitations in motor ability, cognition, and visual acuity are further usage barriers [17,18].

In addition, it is possible that older adults may have different ideas about the content and style of games than those proposed by typically younger game designers [19-21]. Nevertheless, despite the common misconception that older adults are averse to new technology, most are open to innovation and willing to master new technologies—so long as they are comprehensible, aligned with their values, and address their wants and needs [22-24]. Consequently, there is a demand for helpful, easy to use, and well-designed assistive and autonomy-enhancing technologies. However, their success may well depend on being designed, developed, and evaluated with and by the target group, older adults.

This paper presents the iterative development of a serious game for older adults to increase physical fitness in the AAL environments, including two user studies. The paper begins by presenting background on aging, the effects of exercise, the benefits of serious games in health care, and AAL, as well as our research objectives. Next, we describe the design of the two game iterations, our experimental approach, and the participants. We then present the experimental findings of the participants' performance, the impact of the games, and an evaluation of the game interface usability. We end by discussing the results and their implications, future research questions, and limitations of this work.

Age, Health, and the Benefits of Exercise for Older Adults

Aging is associated with an increased likelihood of chronic illnesses or disabilities, such as mild cognitive impairment, dementia, or Alzheimer disease; ischemic heart disease; congestive heart failure, stroke, and diabetes mellitus [3,6,25,26].

Physical exercise can increase overall health and well-being, and it can reduce the risk of illnesses. Although exercise intensity, frequency, and duration can always be optimized, some activity is always considered better than none [27]. Only 150 min of medium-intensity exercise per week can produce positive effects on health and are recommended, in particular, for children, overweight people, and older adults [28] by the World Health Organization [29]. A combination of regular and life-long aerobic activities and resistance, flexibility, and balance exercises is suggested for people suffering from chronic syndromes [30].

The benefits of exercise are manifold. Strength training mitigates age-related decline in muscle mass, strength, and performance [31]. In addition, exercise can also reduce the probability of silent brain infarcts by 40% [32], has a positive influence on migraines [33], can mitigate the symptoms of depression [34], and can reduce drug abuse among the elderly [35]. It also improves executive function in healthy people [36,37], reduces the symptoms of mild cognitive impairment [38], and reduces the risk of mild cognitive impairment and dementia in later life [39].

However, despite its many benefits, physical activity is decreasing in North America, Europe, and many other countries [40]. Recent medical reports have shown higher incidences of hypertension, diabetes, and coronary or cerebrovascular diseases, and overall lower life expectancy [41,42]. These findings indicate that increasing physical activity—especially in older adults—merits serious attention, along with developing a better understanding of how to motivate people to engage in more frequent exercise.

Serious Games for Health Care and Design Guidelines

Serious games combine the motivational attraction of games in general and computer games in particular with serious activities and outcomes through play. They build on the Premack principle [43], that is, the likelihood of performing unpleasant activities—such as training or exercise—increases by linking them with pleasant activities—such as playing games.

Various scholars have defined the concept of serious games. An early definition by Abt [11] describes serious games as having "... an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement.". A similar definition stems from Michael and Chen [44], who defined them as "a game in which education (in its various forms) is the primary goal, rather than entertainment.". Bogost [12], in contrast, prefers the term *persuasive games* for games that use "procedural rhetoric to support or challenge our understanding of the way things in the world do or should work."

That said, the field of serious games, in general, and serious games for health care, in particular, is vast. As such, the following paragraphs seek to provide only a broad overview of the state of knowledge of the effects of serious games in health care.

As early as 1990, Whitcomb [45] studied computer games for older adults and argued that appropriately designed games increased reaction times, eye-hand coordination, and dexterity. He claimed that these gains were transferable and could also have real-life benefits, but he was critical that older adults appeared to enjoy few games, likely because of inappropriate sounds or speed, or poor visibility of the game elements.

King et al [46] developed a game-based system for patients with stroke to retrain movement abilities of the upper limbs. The rehabilitation task involved selecting on-screen objects with speed and accuracy using a gyroscope-based controller. Despite limited direct effects on motor performance, the game was found to be motivating, and it increased rehabilitation adherence.

Flores et al [47] found that patients perceived robotic rehabilitation systems as boring, and this reduced rehabilitation motivation and adherence. They identified a gap between available rehabilitation and commercial game titles. Although the latter were more entertaining, they were not adaptable to rehabilitation tasks. Rehabilitation games, in contrast, were usually developed by engineers and medical professionals with a strong focus on task fit, and they often lacked motivating play.

Gabrielli et al [48] evaluated several low-cost gaming platforms—such as Microsoft Kinect, Stifteo Cubes, and Simon's game—as rehabilitation instruments for patients with stroke. Although the systems were considered effective, the participants expressed a desire for greater accessibility, usability, and more motivating game play.

Several minigames for balance training in older adults were designed for the *Nintendo Wii Balance Board* [49]. Their evaluation underscored the importance of considering age-related and individual constraints when developing motivating and usable serious games in health care. Further research supported the claim that computer-mediated balance training increased mobility in older adults and—as a side effect—the multitasking abilities of the participants [50].

Serious games can also convey knowledge and improve the ability to cope with the disease. For instance, Fuchsloher et al [51] developed games for diabetes management in teenagers. They found that the game variant that explicitly featured diabetes content was perceived as more enjoyable than the variant which conveyed the same learning objective content albeit implicitly. Further, a meta-review of motion-based video games found that most motion-based video games yielded sufficient activity levels to meet the health and fitness guidelines [52].

Guidelines for the Design of Exercise Games

Older adults and chronically ill people have specific demands that must be considered when designing applications and serious games. These constraints include changing interests or values [19] over the life span, age-related acuity loss, motor speed and accuracy, restrictions on mobility, lower information-processing speed, and lower reaction times [17,18]. Consequently, contents, mechanics, and interfaces of serious games for health care should be tailored to the target audience.

Several guidelines facilitating the systematic development and customization of serious games for health care have emerged over the years. Weismann [53] studied the suitability of computer games for older adults in the 1980s. The guidelines he derived remain relevant. For instance, he suggested that games should be simple, and the next steps and the overall goals should be transparent. The visual complexity of the game should be appropriate, for example, by avoiding too many, too fast, or unrecognizable screen objects and symbols. Sound effects should be provided as auditory feedback, for rewards, or as cues that are clear and distinct. Also, control of the game character(s) should use natural mappings. The guideline also suggested that personalization by naming game characters and playing with peers increased the game's entertainment value.

Ijsselsteijn et al [54] added further requirements for older adults. They proposed that games should have visual settings that are easy to adjust to individual visual changes. They suggested that information should be given redundantly, for example, by using multiple output modalities (eg, combine visual feedback with auditory feedback). In addition, memory load and required cognitive processing should be kept low to deal with age-related cognitive decline (eg, remembering information from one screen to another should be avoided). Also, that the game should provide enough time to learn and rehearse the necessary skills. Finally, the authors suggested that to overcome the potential anxiety of some players, encouraging feedback should be provided from the outset.

Whitehead et al [55] formulated guidelines specifically for exercise games. For instance, they proposed that the game should monitor the correct execution of the intended body movements and incorrect or intentionally forged movements should not be accepted by the game (anecdotally, often observed in younger *Wii* players). They suggested that activities within the game should focus on larger muscles, such as the arm or leg gestures. Also, that getting experience in the game should be rewarded, as higher experience appeared to relate to higher physical benefits. Rewards should also incentivize long-term use, as continuous and long-term usage has more benefits than short and singular activity bursts. As exercise games can be exhausting, the games should also include recovery times between the active phases. Most importantly, the exercise game should provide an abstraction from the physical activity or health care context and must transfer the exercises in another, more playful, scenario.

Although the previous guideline involved general exercise games for health care, Gerling et al [17] developed seven recommendations specifically for exercise games for the elderly. They are summarized as follows: First, games should account for potential impairments and reduced abilities of the players. Second, they should be adaptable to individual limitations in the range of motion that players might have. Third, the games should alternate between physically demanding and more relaxing tasks or even breaks to prevent overexertion. Forth, to address varying player abilities, the games should dynamically adjust difficulty to provide an appropriate level of activity and challenge. Fifth, the game should provide clear instructions for gestures, and these should be intuitive or easy to learn and relate to real-world activities. Sixth, tutorials and hints should guide the players through the game and its tasks, and it avoid the feeling of being lost. Seventh, the game should be easy to set up and run, with complicated setup menus and calibration processes avoided.

Ambient Assisted Living

AAL is the seamless integration of sensors, actuators, and communication technology in the physical surrounding to enhance safety, quality of life, and independence in older adults [7,10,56,57] with the goal of facilitating *aging in place* [58]. Examples of AAL technologies include invisibly integrated sensors for fall detection, systems supporting the punctual and well-dosed intake of medication, communication channels to family or physicians, and assistive robots as supporting social actors [59-61]. The key, however, is ensuring that technology for aging in place is aligned with older adults' needs and wishes and, most importantly, for usage motivation that they accept it [62,63].

Objective and Aim of the Study

Although the AAL technologies are becoming a reality, they are entering our lives quite slowly. Neither their challenges and opportunities nor the wants and needs of future residents have been sufficiently studied [23,61,64-66]. This research gap is problematic as the perception and use of technology differ individually and are influenced by factors such as age, gender, chronic illnesses, or competence beliefs [15,16,23,66]. Therefore, this paper addresses the following aspect:

1. We present the iterative and participatory design process of a motion-based exercise game for older adults and its embedding into a prototypic AAL environment.
2. We analyze if and how user diversity influences the performance attained in the game, its impact on usability evaluation, and its relationship with the overall acceptance of the system. We specifically focus on the effect of age, as age is often linked to lower performance, perceived usefulness, and ease of use, as well as lower overall acceptance (see above).
3. As part of an exploratory study, we show that interacting with the game might have a pain-mitigating effect in older adults.

Methods

Overview

We present two studies to evaluate the effect and perception of serious games for health care. This section describes our AAL lab; the two game demonstrators outside and within the AAL environment; our experimental approach to study performance, acceptance, and effect of the games; as well as samples of both studies.

An Exploratory Lab for Ambient Assisted Living

In the above section, we introduced AAL as a technology-based approach to increase the autonomy, safety, and comfort of older adults or people with chronic illnesses. Many of these concept technologies are still under development and not readily available. To study how older adults interact with these novel technology-augmented habitats, whether they accept the tight integration of technology in their life, and how to tailor technology to their wants and needs, prototypic assistive technology was integrated and tested in living labs.

One such type of these prototypical living environments is the AAL lab located at Rheinisch-Westfälische Technische Hochschule Aachen University. It resembles a living room of approximately 25 m^2, with couches, a table, shelves, and lamps, and pictures on the walls. It was designed for patients with an artificial heart who might require tight monitoring of their vital signs, such as weight, body temperature, coagulation, and blood pressure [8]. As such, numerous sensors and actuators are invisibly integrated into the surrounding. When desired, a scale integrated unnoticeably in the parquet measures the weight of the residents, sensors in the floor can detect falls and request aid, and an invisible infrared camera detects possible infections from a distance by measuring body temperature [8]. In addition, several surfaces in the room serve as interactive media for prototyping and evaluating new applications, such as telemedical consultations on a large multitouch wall. More information about the prototypic lab can be accessed over the Web [67].

Realized Game Prototypes

Our goal was to augment the functional aspects of the AAL environment with hedonic and playful, yet medically useful activities. Therefore, we designed a motion-based exercise game for this living room using an iterative, user-centered, and participatory design process. As an intermediate step, we developed and evaluated a stand-alone exercise game and then adapted the game based on feedback to the AAL environment. Both games and their evaluations are presented in the following sections.

The first stand-alone motion-based exercise game was designed to be set up in a living room, a doctor's office, or in a retirement home. The second demonstrator is tightly integrated into the AAL lab and uses the input and output devices seamlessly embedded in the environment. Both games use a gardening scenario where the player must perform various movement gestures to collect different fruits and place them in a basket. Each fruit is linked to different gestures developed in collaboration with orthopedists and physiotherapists (details differed between the games, see below).

A Microsoft Kinect sensor tracks the player's position and body posture though a skeleton model. The player sees a representation of themselves in the garden environment, either as a virtual avatar in the first prototype or as a background-separated video image in the second prototype. Both games are loosely based on the game *GrabApple* that also uses a garden environment and fruit collection to stimulate movements for office workers [68]. The design and development process used the guidelines presented above [17,18,20,53,69]. Design decisions were assessed regularly. We paid particular attention to age-inclusive design, for example, using large and contrast-rich game elements and clear auditory feedback.

Physical Exercise Game Outside the Ambient Assisted Living Environment (Game 1)

We used the Unity game engine to build the first functional game prototype. A Microsoft Kinect sensor captured the players' body pose with 20 edges and mapped these to a virtual avatar presented in the garden environments. Players were instructed to collect different fruits and vegetables using movement gestures introduced over the course of the game (see Multimedia Appendix 1):

- The first level consisted only of Apples. These appeared on trees located in the garden and players collected them by moving one hand to the apple and then to a basket.
- The second level introduced Carrots as an additional object. In contrast to the apples, these appeared on the ground and could be collected by bending over and picking them up with the hand.
- The last level introduced Bananas as a third category. This level required moving one hand to the target, holding that posture for a short time (≥500 ms), and then placing the banana in the container.

More targets with additional movement gestures were implemented, but they were not part of the subsequent evaluation. Figure 1 shows two older persons interacting with the game.

Figure 1. Two players of the first game prototype in a doctor’s office grabbing an apple (left) and bending for a banana (right).

A challenge while building motion-based exercise games is to ensure that all players can reach all required positions and perform all gestures. Thus, a calibration screen at the start of the game collected information about the participant’s body height and range of motion by asking the player to reach out to specific positions. The game then scaled the environment to the player’s range of motion and ensured that the player could reach the game objects with similar effort.

Physical Exercise Game for the Ambient Assisted Living Environment (Game 2)

Using feedback from the first game’s evaluation, the second demonstrator was then integrated in the AAL environment and adapted given the constraints of the room (see Figure 2). For instance, as the Kinect Sensors were located near the ceiling, we temporarily removed the carrots (*bending* + *grabbing* gesture) and only used gestures performable in an upright pose (see Multimedia Appendix 1):

- Again, the game started with Apples in the first level. As with the first game, the player could collect apples by moving one hand to the apple and then moving the hand to a basket.
- Then the game introduced Bananas that required touching the object for a short time and then placing the fruit in the basket.
- The third level introduced Pears requiring a diagonal movement, that is, if they appeared on the right, they were grabbed with the left hand.

Reducing the gesture set because of technical constraints was obviously regrettable. However, we believe participants can still evaluate the game, and that foreseeable technical progress will make the sensors smaller and better integrated into the environment.

Figure 2. Player interacting with the exercise game in the ambient assisted living environment.

We also improved upon many issues observed when participants interacted with the first game. Three key aspects are illustrated below:

- Although the test persons found the calibration screen easy to use, they described it as unnecessary and not well integrated. We, therefore, replaced it with an implicit calibration mechanism. Through smart placement of the first-game objects and continuous measurement of the interactions, the user-adaptive scaling of the game environment can now be used from the beginning of gameplay.
- Despite a visual timer, some players reported difficulties keeping track of time in a given level when they became absorbed in the game. Thus, we changed the static horizon in the background and let it cycle through the day from midday sun to sunset. The participants found this method easier to comprehend, as they intuitively understood the day's end mapped to the end of the level.
- We frequently observed that players left the detection area of the Kinect sensor. The players disliked the textual hints or eventual error messages in the first game, as these disrupted the immersion. We addressed this problem by introducing clouds (and eventually lightning and thunderstorms) when the player moved too far to the left or right, thus helping to nudge the players back to the center.

Multimedia Appendix 2 presents the iterative design process of the game by showing the different research objectives at each development stage, the methods used, and the key insights addressed in later iterations. Multimedia Appendix 1 shows the gesture sets for both games.

Evaluation Framework

This section presents the framework we used to evaluate both game prototypes. We present the user factors, the within-subject variables (repeated measures), and the target variable used to evaluate the usability and social acceptance of the game.

We began the session by welcoming the participants to the study in the doctor's office or our living lab, offered beverages, gave an introduction to the study. This gave participants time to rest and become comfortable in the test setting. Next, we surveyed the participants on user factors.

User Factors

User factors were as follows:

- Age in years: We requested the participant's age to study its influence on performance, game evaluation, and projected acceptance.
- Gender: Gender is linked to usage, perceived ease of use, and self-efficacy in interacting with information and communication technology [70]. Thus, we wanted to evaluate whether gender also influenced game evaluation (dummy coded as male=1, female=2).
- Self-efficacy in interacting with technology (SET): Self-efficacy is the domain-specific belief, rooted in the perception of one's own competence, that one can be successful in a certain activity [71] and SET is usually correlated with age and gender on the one hand and determines our performance and our experience of competence in interacting with new technology on the other [15,70]. Consequently, we measured the participants' self-efficacy when interacting with technology using four 6-point Likert items on a scale developed by Beier [72] with internal reliability of alpha≥.830.
- Need for Achievement (NfA): We assume that a person's NfA is related to the attained performance in the games and wanted to evaluate if the NfA or the attained performance was related to acceptance. NfA was measured on six items on a 6-point Likert scale developed by Schuler [73]. The scale has internal reliability of alpha≥.899.
- Gaming frequency (GF): The participants were asked for their current GF across multiple games, game domains, and media, such as games of skill, board, and card games, and also games mediated through game consoles and mobile phones, as well as ball and outdoor games. The scale has internal reliability of alpha≥.730 and is strongly correlated with the single item "I enjoy playing games" (r=0.558, P<.001).

Repeated Measures Variables

We measured perceived pain (PAIN) and perceived exertion directly before and directly after the game, as well as attained performance across three levels of the games:

- PAIN: The participants reported their perceived level of pain for eight parts of the body on a 6-point scale before and after playing. The range was no pain to severe pain [74]. The scale measured reliability at alpha≥.786.
- Perceived exertion: We used a single-item scale developed by Borg [75] to assess perceived exertion just before and immediately after the game intervention. We did not measure heart rate directly so as to minimize stress in the participants, as some might feel uncomfortable with hard medical measures during the study. However, Borg scale has been found to be strongly correlated to actual heart rate [75].
- Performance: The players' performance in the game was measured using log files as collected objects per minute in the first, second, and third levels of the game. However, note that performance was not directly comparable across the games, as they differed slightly and required different movement gestures.

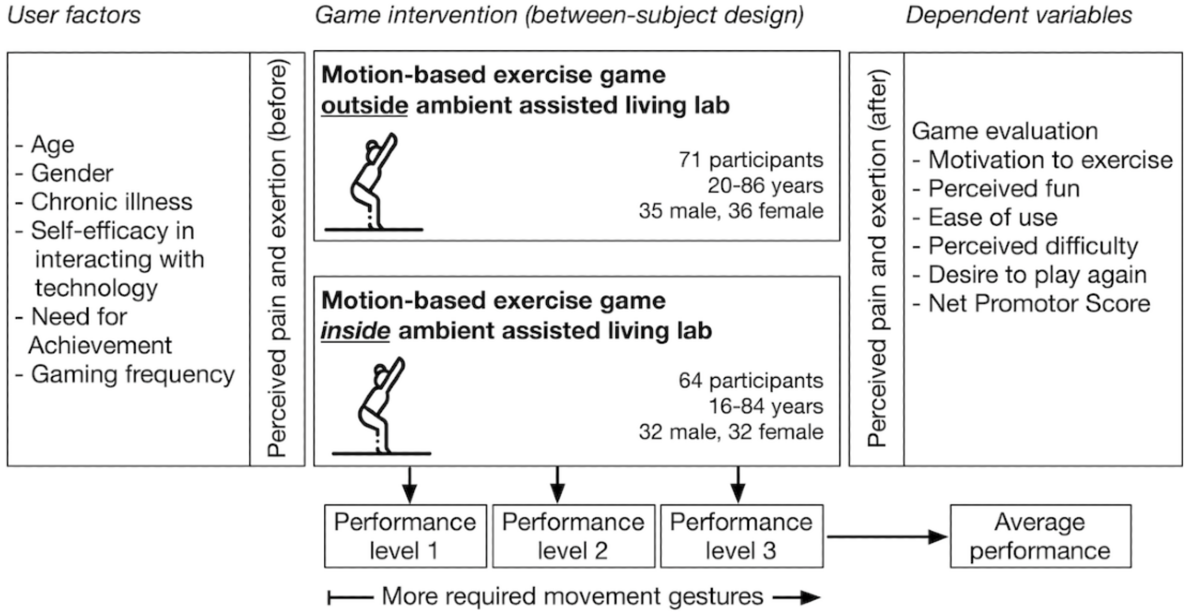
Dependent Variables

Dependent variables were as follows:

- Summative evaluation: The players of both games were asked to evaluate perceived fun, if they wanted to play the game again, or if they wanted to play these games in their home environment. In regard to the overall usability, we assessed whether participants were satisfied with the visual presentation, the visual and auditory feedback, if they understood the game concept, and if they felt in control while using the motion-based gestures. In addition, we asked if the game's overall difficulty and the difficulty of performing the gestures were well adjusted. These questions were measured on 6-point Likert scales.

- Net promoter score (NPS): Finally, we asked how likely the participants were to recommend the game to friends using an 11-point Likert scale developed by Reicheld [76]. He argued that products and services were often positively evaluated through social desirability. Hence, his NPS compares the shares of promoters (two highest response options) and detractors (lowest to ninth highest response options) [76], using a score between −100% and +100%. This score can be seen as an indicator of a game's acceptance by potential users. Figure 3 illustrates the research framework for assessing both motion-based exercise games.

Figure 3. Experimental framework for evaluating the impact and usability of both game prototypes.



Statistical Analysis

We used 6-point Likert scales to assess all subjective measures. To increase legibility, they were rescaled to percentages (0%–100%). We used bivariate correlations (Pearson r, Spearman ρ), χ2, univariate and multivariate analyses of variance (MANOVA), and multiple linear regression for data analysis. We used and reported Pillai value V for omnibus MANOVAs. For multiple linear regressions, we used the ENTER method, iteratively removing models with low standardized beta's, and excluded models with high variance inflation (≫1). We set the type I error rate (level of significance) to alpha=.05 and reported effect sizes as partial η^2. The error bars in the diagrams show the 95% CI. Missing values were deleted listwise on a per test basis.

To study the influence of age using factorial methods, we split both samples at the age median in a younger and older half. This can pool individuals together who may differ greatly with regard to attitudes and behaviors, current life situation, or individual aging. In addition, this approach increases the comprehensibility of the findings and is admissible. Correlation analyses with age as ordinal value supported all subsequent analyses.

Description of the Samples

Sample 1

Participants of the first study were recruited in an orthopedic practice in Germany. As the study has a usability focus, neither a medical indication nor a special effect was instructed. The sample comprised 71 participants (35 males, 49%; 36 females, 51%) age range 20 to 86 years (mean 48.4, SD 21.9). In all, 28% (20/71) participants reported a chronic illness, such as diabetes, asthma and allergies, hypertension, and/or back problems. Contrary to our expectations, age and chronic illnesses were unrelated in this sample (ρ=0.230, *P*=.06). The reported pain before the intervention appeared related to age (*r*=0.371, *P*=.002) and reported chronic illnesses (ρ=0.346, *P*=.03). Older people and people with chronic illnesses initially felt greater pain.

Age was neither related to SET (*r*=−0.223, *P*=.06) nor related to NfA (*r*=−0.135, *P*=.26), but it was linked to the reported GF (*r*=−0.591, *P*<.001). Hence, despite the scale's variety in different games, older people reported playing less than younger people.

Gender was linked to SET (ρ=−0.431, *P*<.001), with women reporting lower self-efficacy. Self-efficacy was neither related to GF (ρ=−0.151, *P*=.20) nor related to NfA (ρ=−0.172, *P*=.15). See Multimedia Appendix 3 for a summary of the sample's characteristics.

Sample 2

The second study took place in the AAL lab. A total of 64 volunteers (32 male, 32 female, 50% each), with age range 17 to 85 years (mean 43.2, SD 19.6), participated in the second study. None of the participants were part of the first study.

Similar to the first sample, 26% (17/64) participants reported a chronic illness (mainly asthma, hypertension, and diabetes), and the prevalence of chronic illnesses appeared to increase with age (ρ=0.406, *P*=.001). Reported pain before the game increased with age (*r*=0.425, *P*<.001) and chronic illnesses (ρ=0.343, *P*=.006).

Age was linked to lower SET (r=−0.548, P<.001), lower GF (r=0.569, P<.001), but it was unrelated to NfA (r=−0.145, P=.25). Also, there was a significant correlation between the participants' gender and SET (ρ=−0.331, P=.007), with women reporting lower self-efficacy. Multimedia Appendix 3 shows the characteristics of the second sample.

Results

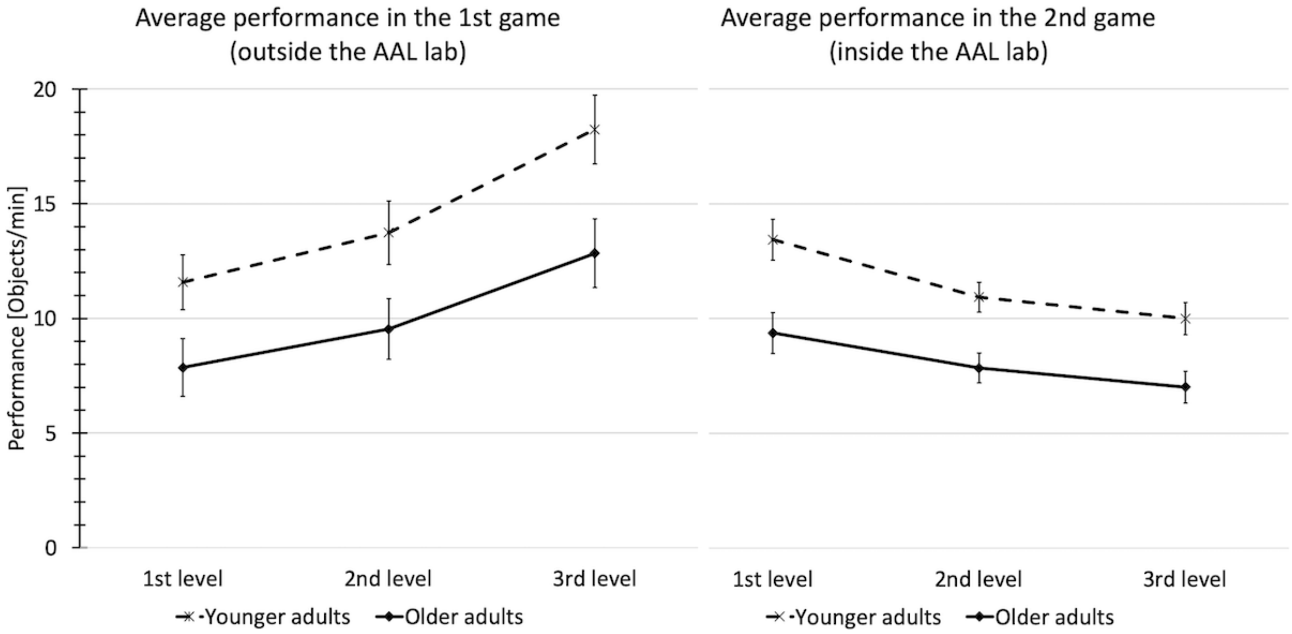
Overview

First, we analyzed performance in the game, how the performance evolved over the course of the game, and if user factors influenced attained performance. Second, we studied the games' effect on pain and perceived exertion. Finally, we presented results from the overall usability and acceptance evaluation of the games. Owing to congruence between the evaluations, the results for both games are presented directly one after the other.

Performance

In the first game, the players collected on average 9.7 (SD 4.1) objects per minute in the first level, 11.7 (SD 4.5) in the second, and 15.5 (SD 5.1) in the third and last level of the game. In the second game, players collected an average of 11.4 (SD 3.2) objects per minute in the first level, 9.4 (SD 2.4) in the second, and 8.5 (SD 2.5) in the third level (see Figure 4).

Figure 4. The influence of age on performance in both games across the three investigated levels. Left: Outside the ambient assisted living (AAL) environment. Right: Inside the AAL environment. Error bars indicate the 95% CI.



To understand if user factors relate to performance, we first calculated a single average performance score across the three levels for each player.

For both samples, correlation analyses identified age as the strongest predictor for performance (r=−0.564 and r=−0.710, respectively) with older adults being slower than younger adults. Two further consistent findings were the strong positive influence of SET (r=0.489 and r=0.562, respectively) and of prior GF (r=0.459 and r=0.552, respectively). People reporting higher technical competency and higher GF were faster. The influence of NfA was only significant in the second (r=0.314) but not in the first game (r=0.227, P=.06).

Performance was not affected by gender (ρ=0.184, P=.12) or the presence of a chronic illness (ρ=0.059, P=.63) in the first game, although it was in the second (ρ=−0.354 and ρ=−0.38, respectively), with women and the chronically ill being slower. Table 1 summarizes these findings.

Table 1. Significant correlations between user factors and average performance.

Factor	Performance in game 1	Performance in game 2
Age	−0.564	−0.710
Gender	—[a]	−0.354
Self-efficacy in interacting with technology	0.489	0.562
Need for achievement	0.227	0.314
Gaming frequency	0.459	0.552
Chronic illness	—	−0.382

[a]A value was calculated but not presented due to missing significance.

To identify which of the correlating variables had the strongest influence on performance, we then calculated two multiple linear regressions with average performance as dependent variable and the user factors as predictors. The regression models were significant for the first ($F_{6,61}$=10.446, P<.001) and second games ($F_{6,56}$=16.322, P<.001) and explained over 50.1% (r^2=0.507) and 66.2% (r^2=0.662) of the variance in performance, respectively.

For both games, age remained the strongest predictor of performance (beta=−.521 and beta=−.608, respectively), and gender was not significant in the first model (beta=−.182, P=.07), although it was in the second model (beta=−.271, P=.003). The last remaining predictor of performance in the second game was NfA (beta=.248). Tables 2 and 3 show the coefficients from the regression models. The prior influence of SET, GF, and chronic illnesses (identified by the correlation analyses), disappeared in the regression models that controlled for the other variables.

Table 2. Regression table for the dependent variable performance in the first game (outside the ambient assisted living environment; n=71; r^2=0.507; variance inflation ≤1.927).

Factor	B	SE	Beta	*t* value (*df*=65)	*P* value
(Constant)	19.534	3.823	N/A[a]	5.110	<.001
Age (years)	−0.102	0.024	−.521	−4.172	<.001
Gender	−1.501	0.807	−.182	−1.860	.07
Chronic illness	0.697	0.897	.073	0.777	.44
Self-efficacy in interacting with technology	0.314	0.489	.072	0.642	.52
Need for achievement	−0.848	0.694	−.115	−1.223	.23
Gaming frequency	0.976	0.602	.181	1.622	.11

[a]Not applicable.

Table 3. Regression table for the dependent variable performance in the second game (in the ambient assisted living environment; n=64; r^2=0.662; variance inflation ≤2.182).

Factor	B	SE	Beta	*t* value (*df*=58)	*P* value
(Constant)	25.248	3.166	N/A[a]	7.976	<.001
Age (years)	−0.157	0.031	−.608	−5.062	<.001
Gender	−2.698	0.872	−.271	−3.095	.003
Chronic illness	0.477	1.139	.041	0.419	.68
Self-efficacy in interacting with technology	0.018	0.444	.005	0.040	.97
Need for achievement	1.125	0.411	.248	2.737	.009
Gaming frequency	0.671	0.709	.109	0.947	.35

[a]Not applicable.

The high beta coefficient in the regression models showed that the influence of age on performance was strongest. An RM-MANOVA with both age groups as independent variables and performance across the levels as within-subject variable illustrates this effect. Figure 4 shows the significant effect of age group on average performance for the levels in the first ($F_{1,69}$=26.028, P<.001; η^2=0.277) and second games ($F_{1,62}$=48.175, P<.001; η^2=0.473).

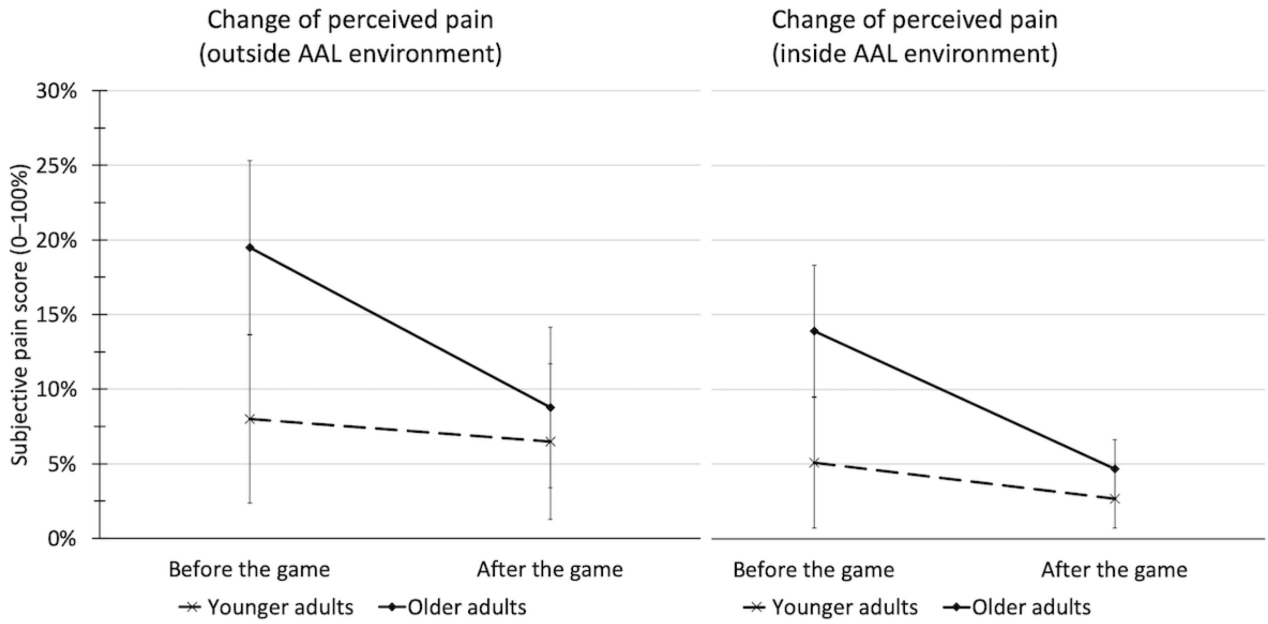
Perceived Exertion and Perceived Pain

Both games had a significant overall effect on perceived exertion and PAIN (game 1: V=0.242; $F_{2,63}$=10.044, P<.001; η^2=0.242; game 2: V=0.360; $F_{2,61}$=17.193, P<.001; η^2=0.360), and this effect interacted with age group (game 1: V=0.166; $F_{2,63}$=6.282, P=.003; η^2=0.166; game 2: V=0.172; $F_{2,61}$=6.326, P=.003, η^2=0.172), indicating a possible difference between younger and older participants.

With regard to perceived exertion, results differed between the studies. The change was different for younger and older participants in the first game ($F_{1,64}$=5.010, P=.03; η^2=0.073). Although exertion did not change for younger participants (26.5% to 25.6%), it reduced from 25.6% to 16.3% for older participants. A different picture emerged for the second game. Perceived exertion increased for both younger (14.4% to 19.4%) and older participants (19.4% to 24.4%; $F_{1,62}$=7.215, P=.009; η^2=0.104).

The analysis of the reported pain levels revealed a pain-mitigating effect for both games and both age groups. In the first game, reported pain levels of younger participants decreased slightly from 8.0% to 6.5%, whereas the pain levels of older participants almost halved (19.5% to 8.8%; $F_{1,64}$=10.570, P=.002; η^2=0.142). In the second game, the pain levels of younger players decreased from the already low 5.1% to 2.7% and those of older adults fell to a *third* from 13.9% to 4.7% ($F_{1,62}$=6.322, P=.02, η^2=0.093). Figure 5 illustrates this pain-mitigating effect of both games for both age groups.

Figure 5. Pain-mitigating effect of both exercise games (left: outside AAL lab; right: inside AAL lab) before and after the game for younger and older participants. Error bars indicate the 95% CI. AAL: ambient assisted living.



Usability and Acceptance

Usability and Acceptance Outside of the Ambient Assisted Living Lab (Game 1)

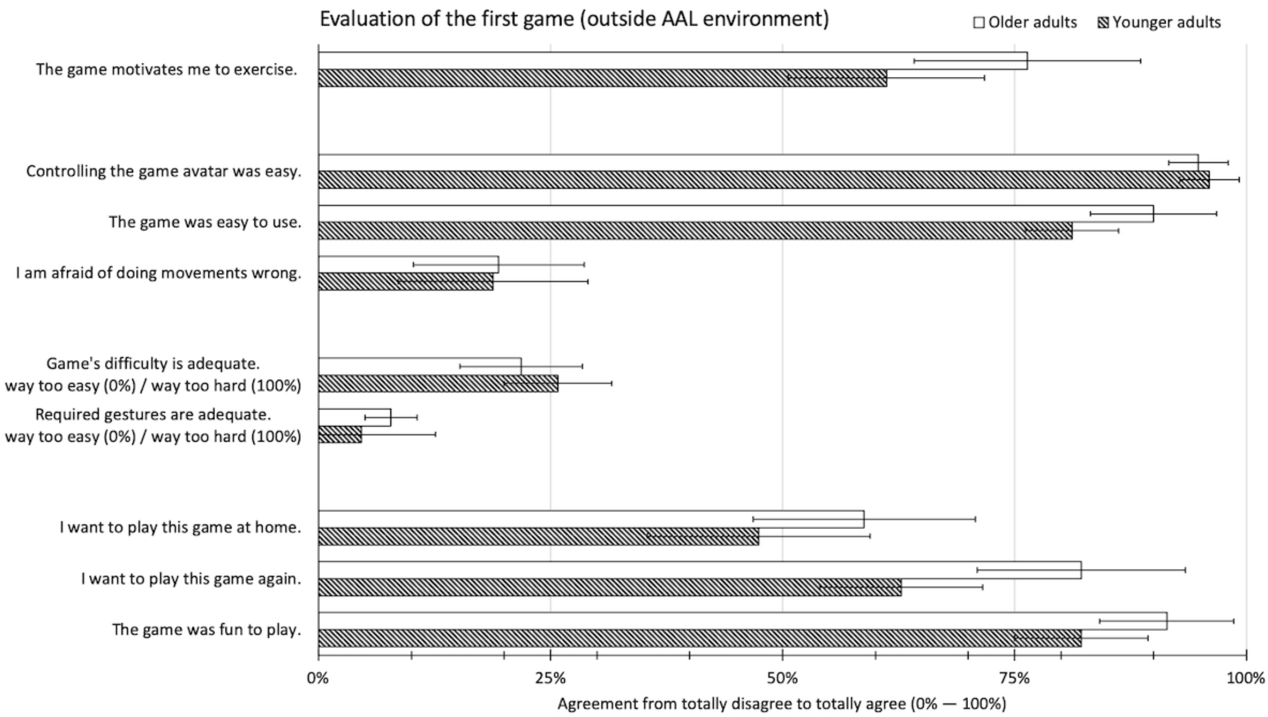
The overall evaluation of the first game prototype was very positive. All but one participant agreed or rather agreed that controlling the game avatar using motion tracking was easy, yielding a high average evaluation (95.4%, SD 9.1%). Likewise, participants found the overall game concept (95.4%, SD 14.0%) understandable, and they reported little to no difficulties to perform the required gestures (10.8%, SD 23.3%). Consequently, the overall usability of the game was found to be high (85.8%, SD 17.7%).

The participants considered the game's difficulty (27.2%, SD 18.5%) and the movement gestures (27.2%, SD 23.1%) as a little too easy (a score of 50% meant a balanced difficulty). Also, the reported motivation to exercise more often using the game was just slightly above the center of the scale (68.6%, SD 33.7%). Nevertheless, they reported fun and enjoyment playing the game (86.8%, SD 21.0%) and most expressed desire to play the game again (72.6%, SD 30.5%).

Figure 6 illustrates that these findings were largely similar for younger and older adults. Significant differences were found for the desire to play the game again ($F_{1,68}$=7.808, P=.007) and the overall usability evaluation of the game ($F_{1,68}$=4.584, P=.04). Both greater in older adults.

Finally, we analyzed Reichheld NPS [76] and found that the majority of participants indicated they would recommend the game to others (the two topmost answers are considered as *promoters*, n=34, 48%), whereas about a quarter were neutral (n=19, 27%), and another quarter would rather not recommend the game (lowest 6 answers on the 10-point scale, n=18, 25%). Consequently, the game achieved a positive NPS of 30% (scale range from −100% to +100%).

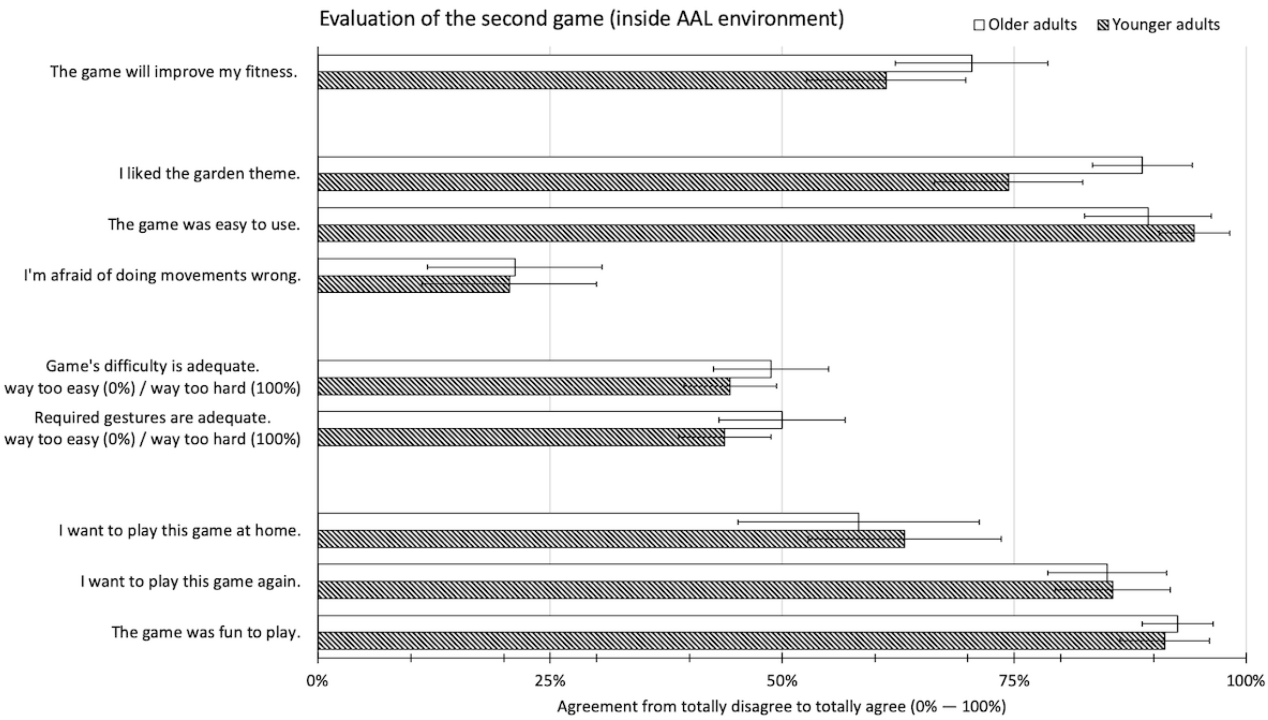
Figure 6. Usability evaluation of the first game prototype (outside the ambient assisted living environment) by age group. Error bars indicate the 95% CI.



Usability and Acceptance Within the Ambient Assisted Living Lab (Game 2)

The participants of the second study also evaluated the game positively. Most found the game easy to use (91.8%, SD 15.4%) and reported fun playing the game (91.8%, SD 12.2%). However, despite a high desire to play the game again (85.4%, SD 17.2%), the average desire of the participants to play this game in their own home was just slightly above the center of the scale (60.6%, SD 32.8%). In contrast to the first game, the difficulty of the game as a whole (46.6%, SD 16.0%) and the difficulty of the movement gestures, in particular, were perceived as balanced (46.8%, SD 16.8%, 50% indicates a balanced evaluation). Also, the participants found the game motivating to complete exercise (86.7%, SD 14.9%). Figure 7 illustrates the results.

Figure 7. Usability evaluation of the second game prototype (in the ambient assisted living environment) by age group. Error bars indicate the 95% CI.



Finally, the NPS of the second game reached 52.6% and was therefore slightly higher than for the first game. Specifically, out of 65 participants, 29 (46%) were counted as promoters, 25 (40%) as neutral, and 9 (14%) as detractors.

Discussion

Principal Findings

This paper presents two serious motion-based exercise games for older adults. The stand-alone application was evaluated in the office of an orthopedic practitioner. The second game was seamlessly integrated into a prototypical AAL environment. The evaluation of both games revealed both expected and unexpected results.

First, in addition to presenting serious motion-based exercise games, we demonstrated that these games could be integrated into future AAL environments with invisibly integrated sensors and actuators to interact with the game. Consequently, the residents of technology-augmented habitats might be able to use exercise games without requiring additional hardware, visible technology, or complex setup routines, which may—if integrated into their daily routine—result in a positive effect on their physical health.

Second, we learned that user diversity is essential when designing technology for older adults or people in need of care. In our case, SET was lower for older people in both studies, which may pose a significant barrier to successful interaction with and adoption of the technology. In the present case, performance appeared to be shaped by factors we investigated. At first sight, the correlation analysis showed that performance in the exercise games was linked to age, gender (women being slower), SET, NfA, and also prior GF. After controlling for covariances, age, gender, and NfA remained strong predictors. Nevertheless, the study revealed that performance does not determine overall intention to use the game in the future. Players may be slower or faster in the game, but this appears to have had no impact on the overall acceptance and the motivation to use the game.

Third, evaluation of the games' usability and social acceptance was not as clear as expected. In general, the evaluations of both games were positive, not only as indicated by the positive NPS but also by other metrics, such as the very high level of fun reported in the game and the high desire to play the game again. Independent of age, the players had little to no difficulties understanding the game concept or to successfully control the in-game avatar through the motion gestures captured by the Microsoft Kinect sensor. However, the participants reported a limited desire to use these motion-based exercise games in their very own home environment. We found, however, that the evaluation scores for the second game were higher than for the first. This finding suggests that a seamless integration of exercise games in the habitat might be preferred to currently existing gaming technologies that require additional hardware. Age played a role regarding social acceptance of the game, with older adults more open to the treatment. They perceived the game to be more fun and more motivating than younger adults. This might have been because of the fact that the game was specifically targeted at older adults. It is of concern, however, that prior GF is much lower for older adults. This would suggest that motion-based exercise games might be a suitable health-promoting intervention only for people who are already inclined to playing games. This, in turn, would require designing alternative health-promoting interventions that do not build on games but rather pleasant activities such as making music or art.

Fourth, we found that the perceived exertion (measured immediately before and after the game) changed. The change was only in line with expectations for the second game but not for the first. In the first game (outside the AAL environment), playing the game decreased perceived exertion in older adults, whereas it increased for both younger and older adults in the second game prototype (within the AAL environment). We speculate that this relates to the flow theory that postulates a required balance between challenge and skill [77]. The first game was found to be too easy and little challenging. Thus, people put some effort in it but probably not enough to influence exertion in younger players. In contrast, the second game was evaluated as well balanced. Accordingly, it required more effort to perform well, which yielded higher physical activity and higher perceived exertion for both younger and older players.

Fifth, the most remarkable finding was the decrease in PAIN, especially for older adults. The contrast is likely explainable as a ceiling effect given that reported pain levels before the intervention were higher for older participants than for younger participants, leaving little room for improvement. The reduction in PAIN is both astonishing and promising as it suggests that serious games may yield positive effects beyond those of increased physical fitness, physiological health, cognitive performance, and overall life expectancy as argued above [30,39,42]. Of course, a singular short-term intervention as part of a usability study should not be overinterpreted as having direct and long-lasting effects on health and pain. We rather think that the sharp pain mitigation is linked to Melzack and Wall's theory [78] that pain perception is subject to cognitive control and can be altered. Interacting with the exercise games was perceived as fun, entertaining, and distracting, which then—presumably—lowers PAIN in older adults. This suggests that serious exercise games can yield direct positive effects on physiological health though the benefits of exercise but potentially also on overall subjective well-being by engaging in a distracting, pleasant activity. However, future work should carefully investigate if the measured effect is derived from some therapeutic utility of the game on well-being or if this is rather a placebo effect. Even if these findings were because of a placebo effect, it still follows that it is important to provide physical activity avenues for older adults that are fun and motivating.

Future Research Questions

There is a variety of research questions that should be addressed in future work. We broadly identified and categorized six research areas.

Diversity of Gamers and Nongamers

While our game prototypes were in general evaluated very well, we found that prior GF influenced acceptance. Consequently, we have designed suitable exercise interventions that require physical activity but do not build on games as a persuasive, motivating element. It is also important to consider the large diversity in age, age-related changes in agility and flexibility, self-efficacy in exercising and SET, NfA, and presumably many other user factors. As such, guidelines for the design of motion-based exercise games in the sense of Gerling et al [17] should be continuously maintained and extended.

Variety of Game Designs

In our evaluations, we studied single-player motion-based exercise games in a garden environment. First, we need to explore many other game scenarios that might be more motivating for some players. In addition, exercise motivation also stems from social interactions and the strong power of personal social networks [79,80]. Consequently, serious exercise games should also include options for multiplayer interaction. In particular, we propose to study different types of multiplayer games on the two computer-supported cooperative work dimensions *collocated* vs *remote* and *collaborative* vs *cooperative play*.

Adaptive Game Environments

Although both of our games offered a limited form of adaptability (the game environment was rescaled to the players' height), current technology offers many other exciting opportunities to tailor the game experience to a variety of different users. For example, current sensor hardware enables us to detect the current pulse (as an indicator for exertion) from a distance. It is quite possible to build a balanced feedback loop that—within medically sound ranges—continuously adjusts the games' difficulty to the players' exertion. Also, the games might offer specific exercise targets to reflect individual training or the rehabilitation needs of the players.

Long-Term Effects and Transfer

The proposed health benefits of our games have not yet been formally shown but are deduced from related work. Future work must evaluate the long-term adherence and long-term effect of using these games, especially if they are embedded in technology-augmented habitats. In addition, the prototypes evaluated here showed pain-mitigating effects. Besides the proposed benefits on physiological health and well-being, research suggests that cognitive performance increases after 30 min of physical exercise [81] (see Background). This merits further research into how cognitive performance and executive functioning improve through the long-term and regular use of motion-based exercise games.

Incentives

This work suggests the benefits of exercise for individuals and for society as a whole (see Background). The societal benefits touch the ethical question of if and how the use of exercise games for prevention or rehabilitation can or should be incentivized beyond the persuasive power of the games itself. It should therefore be discussed if insurance or health care institutions can or should offer rewards for using these games or if nonusage can or should be penalized.

Privacy

Using digital systems leaves individual digital footprints that might be interesting for the individual and various stakeholders. As such, future work should address whether the players' activities can or should be tracked, stored, or shared and for how long. A discussion should also follow about data access, especially in relation to medical personnel and/or insurance carriers.

Limitations

This study is not without its limitations: First, the usability and acceptance evaluation and the measured effect on PAIN and exertion is based on a short-term intervention involving approximately 10 min of gameplay. Future work should evaluate if and for how long the positive effects on well-being persist, whether and by whom the games will be used over longer periods, and whether and to what extent health improves. Second, we frequently contrasted the effect of age on performance in and perception of the game using two age groups. However, pragmatically someone does not become old by virtue of crossing the arbitrary threshold of the median splits. Also, age and aging are more complex than just considering the biological age. We should therefore intensify the investigation of individual cognitive and physical changes on the performance, acceptance, and use of serious games by increasing sample size and user diversity.

Conclusions

The study shows that the serious exercise games developed can represent one approach to meet the challenges of demographic change and contribute to individuals' health and well-being. Due to the user-centered and participatory development approach, both games are usable and accepted by older people. The integration into AAL environments is possible and promises an easy integration of the games into the daily routine. A flabbergasting result of the studies is the indication of a pain-reducing effect of the games for older people, which, however, needs further investigation.

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Conflicts of Interest

None declared.

Multimedia Appendix 1
Illustration of the user-centered and participatory design process.
[PNG File , 2119 KB - games_v8i2e14182_app1.png]

Multimedia Appendix 2
Movement gestures in the games.
[PDF File (Adobe PDF File), 45 KB - games_v8i2e14182_app2.pdf]

Multimedia Appendix 3
Characteristics of the samples.
[PDF File (Adobe PDF File), 61 KB - games_v8i2e14182_app3.pdf]

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Abbreviations

AAL: ambient assisted living
GF: gaming frequency
MANOVA: multivariate analyses of variance
NfA: need for achievement
NPS: net promoter score
PAIN: perceived pain
SET: self-efficacy in interacting with technology

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Original Paper

Nutritional Education and Promotion of Healthy Eating Behaviors Among Mexican Children Through Video Games: Design and Pilot Test of FoodRateMaster

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Abstract

Background: Childhood obesity has risen dramatically in recent decades, reaching epidemic levels. Children need guidance on and support for maintaining a healthy diet and physical activity to ensure that they grow appropriately and develop healthy eating habits. Serious video games have shown positive effects on promoting the nutritional knowledge, and eating attitudes and behaviors of children; however, research about the usefulness of such games with younger children (8-10 years old) is sparse.

Objective: The objective of this study was to design and test the serious video game FoodRateMaster targeting children between 8 and 10 years old. The game includes nutritional information and behavior change techniques to help children improve their knowledge of healthy and unhealthy foods, increase their intake of healthy food, and reduce their intake of ultraprocessed food. In addition, FoodRateMaster was designed as an active game to promote physical activity.

Methods: An interdisciplinary team developed FoodRateMaster following an iterative methodology based on a user-centered design. A total of 60 participants (mean age 9 years, SD 0.8; 53% male) completed 12 individual gaming sessions in 6 weeks. A food knowledge questionnaire and a food frequency questionnaire were completed before and after game play. In addition, 39 of the participants' parents answered a parent perception questionnaire after the game play.

Results: Participants showed increased food knowledge from pregame (mean 56.9, SD 10.7) to postgame play (mean 67.8, SD 10.7; $P<.001$). In addition, there was a greater self-reported frequency in the consumption of cauliflower and broccoli ($P<.001$) and corn quesadillas ($P<.001$). They also indicated a lower self-reported intake of 10 unhealthy foods, including french fries ($P=.003$), candy and chocolate ($P<.001$), sweet soft cakes ($P=.009$), and soft drinks ($P=.03$). Moreover, most of the parents who answered the parent perception questionnaire agreed that their children showed greater interest in explaining why they should avoid some unhealthy foods (67%, 26/39), in distinguishing between healthy and unhealthy foods (64%, 25/39), and in the intake of fruits (64%, 25/39) and vegetables (59%, 23/39). Finally, 14 parents stated that they introduced some changes in their children's diet based on the comments and suggestions they received from their children.

Conclusions: In an initial evaluation, children between 8 and 10 years old indicated an increased level in nutritional knowledge and their self-reported frequency intake of two healthy foods, and a decreased level in their self-reported intake of 10 unhealthy foods after playing FoodRateMaster. Moreover, the participants' parents agreed that FoodRateMaster positively influenced their children's attitudes toward several healthy eating behaviors. These results support that health games such as FoodRateMaster are viable tools to help young children increase their food knowledge and improve dietary behaviors. A follow-up randomized controlled trial will be conducted to assess the medium- and long-term effects of FoodRateMaster.

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KEYWORDS

childhood obesity; serious game; game design; nutritional education; dietary intake; healthy eating behaviors

Introduction

Background

The incidence of childhood obesity has risen dramatically in recent decades, reaching epidemic levels [1,2]. In Mexico, 35.6% of school-aged children are overweight or obese [3]. Obesity in childhood can lead to a variety of clinical disorders with potentially severe consequences for emotional and physical health [4,5]. To reduce childhood obesity, it is recommended to increase the intake of healthy food (eg, fruits and vegetables) and reduce the intake of unhealthy food (eg, chips and soft drinks) [6]; however, many children fail to meet these recommendations. For example, only 43.5% of Mexican children meet the recommended intake of fruits, and 22% meet the recommended intake of vegetables [7]. In addition, almost 60% of Mexican children consume an excessive quantity of added sugars, and 79% exceed the recommended intake of saturated fat [8].

Children need guidance on and support for maintaining a healthy diet and physical activity to ensure that they grow appropriately and develop healthy eating behaviors [6]. Serious games are an emerging complementary intervention strategy to fulfill that need by providing exciting, innovative, and enticing methods for attracting attention, educating, and promoting changes in attitudes and human behaviors [9].

Serious video games can have positive effects on the nutritional knowledge, eating attitudes and behaviors, dietary intake, and physical activity of children [9,10]. For example, Johnson-Glenberg and Hekler [11] assessed the effects of the video game Alien Health among children aged 10 to 11 years. They identified that players of the game increased their nutrition knowledge and their knowledge regarding the US Department of Agriculture MyPlate guidelines [12]. A subsequent study showed that playing the video game Alien Health for an hour also resulted in better knowledge of the five most important macronutrients of foods among children aged 10-13 years [13]. Holzmann et al [14] demonstrated that 12 to 14-year-old children improved their nutritional and physical activity knowledge after playing the video game Fit, Food, Fun. Marchetti et al [15] assessed the effects of the video game Gustavo in Gnam's Planet among children aged 14 to 18 years, indicating that players increased their nutrition knowledge and intake of white meat, eggs, and legumes, and decreased their intake of sugar-containing packaged snacks.

Serious video games might also be an appropriate educational tool to change children's attitudes about food. Schneider et al [16] showed that students aged between 8 and 12 years playing the video game Fitter Critters for 1 week showed a significant increase in positive attitudes toward healthy eating and self-efficacy in making healthy food choices. Some studies have also explicitly examined whether playing serious video games changes children's eating behaviors and food intake. Baranowski et al [17] found that children aged 10-12 years who played the games Escape from Diab and Nanoswarm: Invasion from Inner Space increased their intake of fruits and vegetables. Another study showed that playing the video game Creature 101 resulted in significant decreases in the frequency and amount of consumption of sugar-sweetened beverages and processed snacks among children aged between 11 and 13 years [18]. Moreover, Sharma et al [19] found that subjects aged 9-11 years playing Quest to Lava Mountain for 6 weeks decreased their sugar consumption and increased their nutrition/physical activity attitudes. In addition, other studies have reported the design phase of video games such as Aquamorra [20] and Pickit! and Cookit! [21], or have described initial efficiency evaluation results for games such as the Space Adventure Game [22].

To successfully achieve knowledge improvement and behavior change in children, serious video games usually combine behavior change techniques such as motivational messages, personal goals, problem-solving, and self-control activities with gamification elements that try to improve engagement and "fun", such as stories, rewards, feedback, levels, and challenges [9].

Although positive results were obtained by the studies mentioned above, there is still a need to understand the application and limitations of such games as well as how to improve their effectiveness in consideration of the characteristics, capacity, and interests of children [9]. In particular, we identified that there is sparse evidence of the usefulness of nutrition health video games for children between 8 and 10 years old, even though it is during these years when the rates of overweight or obesity in children increase considerably [3]. Most of the video games mentioned above were evaluated with children aged 10 years or over, and the evaluations that included children between 8 and 10 years old also included older children, despite the differences in their cognitive and emotional development [23,24]. The late latency stage of children's development can be relevant to the design of serious video games because this is the stage when children start to show more independence from their parents and develop an intense interest in rules, behavioral standards, and learning new skills. In addition, children's self-control becomes far more reliable during this time, and they have an increased ability to remember, pay attention, think, reason, and concentrate [23,24].

Objective

The objective of this study was to design and test the serious video game FoodRateMaster with children between 8 and 10 years old. FoodRateMaster focuses on teaching children the nutritional differences between healthy and unhealthy food and the recommended ranges that can help them to determine if they should reduce or maintain the consumption of certain foods. To our knowledge, this study is the first to design and test a game for health that encourages children aged 8 to 10 years to interact with and apply these nutritional concepts.

The following hypotheses were established based on the notions that young children often lack an understanding of how to identify healthy and unhealthy food, and that exposure to a health video game will improve this knowledge and consequently their eating behaviors. We further assessed whether parents noted changes in their children's attitudes toward healthy eating behaviors and implemented any dietary changes as a result.

- Hypothesis 1: Participants will be able to correctly identify a greater number of healthy and unhealthy foods.
- Hypothesis 2: Participants will self-report an increased frequency in their intake of healthy food.
- Hypothesis 3: Participants will self-report a decreased frequency in their intake of unhealthy food.
- Hypothesis 4: Participants' parents will perceive improvements in their children's attitudes toward healthy eating habits.

Findings from this study will have important implications for young children, who will be provided with a greater understanding of and confidence in how to identify healthy or unhealthy food, which can lead to better overall health outcomes. This study thus offers practical solutions for health practitioners and educators who design programs to teach nutrition to young children.

Methods

Game Design and Development

To design FoodRateMaster, we used an iterative game design approach based on user-centered design methodology [25]. The methodology used has the following five steps (see Figure 1): (1) learning and behavior change planning, (2) game design, (3) prototype development, (4) play testing, and (5) evaluation. We conducted three design cycles before obtaining the version of FoodRateMaster evaluated in this study.

In Step 1, we conducted a literature review to position FoodRateMaster in the specialized serious game literature and nutrition knowledge. Additionally, we conducted several multidisciplinary design sessions with two nutritionists and a psychologist. These sessions aimed to establish or adjust the learning objectives, target behaviors, behavior change objectives, and behavior change techniques (BCTs) that could be integrated into the gameplay elements to support the behavior change objectives.

In Step 2, we conducted multidisciplinary design sessions with two nutritionists, one psychologist, one expert on human-computer interaction, and two video game designers. These sessions were conducted to propose design ideas along with game rules and mechanisms, and to define how to include the nutritional concepts and implement the selected BCTs into the gameplay elements. Based on these activities, we designed high-fidelity prototypes. We conducted 4, 2, and 2 multidisciplinary design sessions in cycles 1, 2, and 3, respectively.

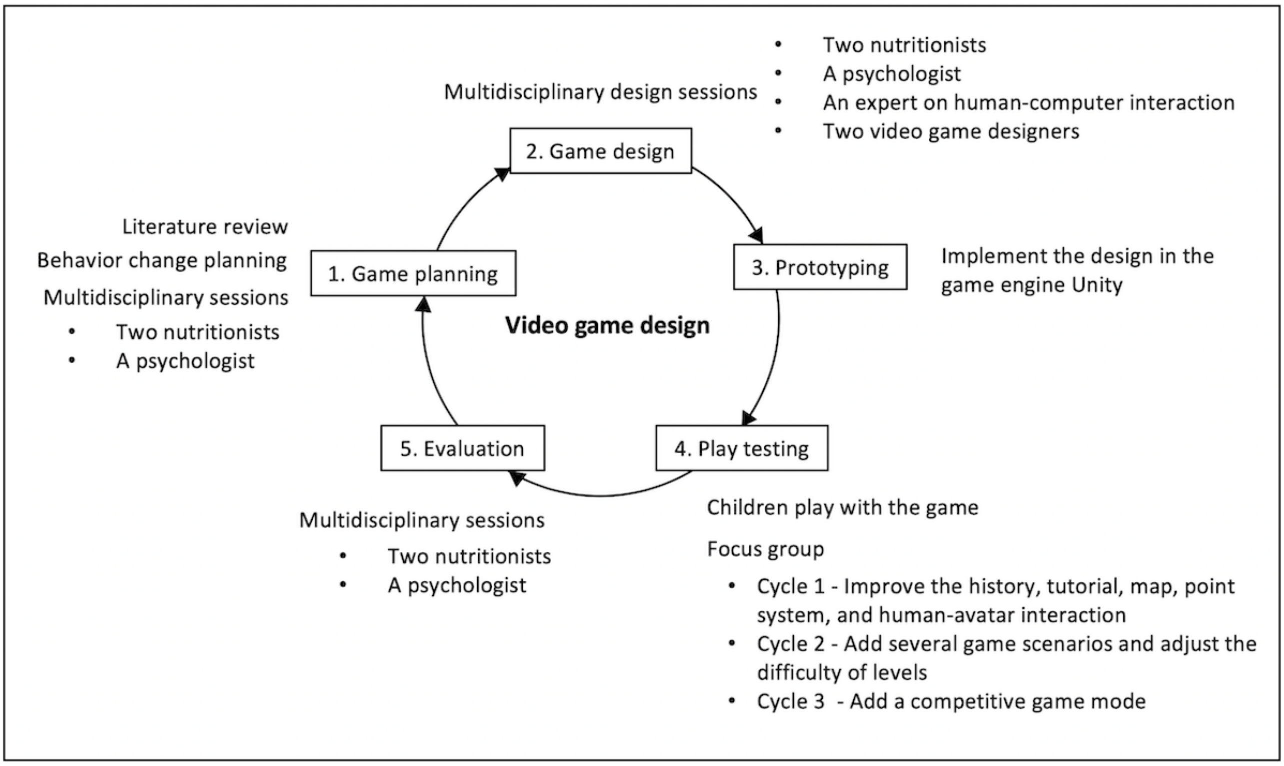
In Step 3, we implemented the high-fidelity prototype based on the game design obtained in the previous step in the video game engine Unity [26].

In Step 4, children played with the prototype. They subsequently participated in a focus group where they were encouraged to talk about their game experience (eg, instructions, activities, challenges, game flow, human-computer interaction, and engaging gameplay) and propose new game elements or features. Some suggestions from cycle 1 were to improve the history, tutorial, map, point system, and human-avatar interaction. The suggestions for improving and changing cycles 2 and 3 were to add a competitive game mode, add several game scenarios, and adjust the difficulty of levels. In cycles 1, 2, and 3, there were 5, 38, and 38 children who participated, respectively. The age range of all participants was 8 to 10 years. Different children participated in each cycle, and none of these children participated in the pilot test. The play duration was 10, 15, and 15 minutes for cycles 1, 2, and 3, respectively.

Finally, in Step 5, we conducted a multidisciplinary session with the same participants as in the Step 2 sessions to discuss and analyze the obtained results, the changes suggested for the game, and the new requirements obtained in the previous step. Based on this information, we elaborated a set of recommendations to improve usability, enjoyment, player experience, game mechanics, game elements, and learning and behavior change strategies.

From the design activities described above, we identified the following requirements for FoodRateMaster: (1) mimic popular scenarios where children obtain food and include popular Mexican food; (2) focus on helping children learn how to differentiate unhealthy from healthy food; (3) mimic traditional reward mechanisms and role models; (4) encourage healthy behaviors related to the understanding of nutrition information; (5) encourage physical activity; and (6) be engaging and easy to use.

Figure 1. Process of designing and implementing FoodRateMaster.



Description of FoodRateMaster

Overview of the Game

FoodRateMaster focuses on helping players understand the differences in the nutritional properties of healthy and unhealthy food, as well as the recommended ranges for food nutrients that can help them determine if they should reduce or maintain the intake of certain foods. The targeted healthy eating behaviors of FoodRateMaster are an increase in the intake of healthy food (eg, fruits and vegetables) and a reduction in the intake of ultraprocessed food (eg, snacks, sweets, soft drinks, and high-fat foods). FoodRateMaster was designed as an active game to make it more fun, improve user experience, and promote physical activity [27]. Active games require physical activity beyond that required by conventional handheld games and rely on technology that tracks body movements or reactions to progress in the game [28]. The players of FoodRateMaster need to perform basic physical movements such as squats, jumps, lateral body movements, and arm movements to avoid obstacles and classify food. To follow the body movements of the players, FoodRateMaster uses the Microsoft Kinect V2 sensor [29].

FoodRateMaster Mechanics and Features

The adventure of FoodRateMaster unfolds in a city where a secret agent has a mission to sabotage the plan of some evil chefs that took control of the city by giving delicious unhealthy food to children. The secret agent (an avatar controlled by the player's movements) has to visit 6 scenarios to review the menu provided by the chefs and determine if there is a need to maintain or reduce the intake of the foods offered. The food database of FoodRateMaster includes 259 items, 179 of which are classified as healthy (eg, vegetables, fruit, fish, and white meat) and 79 of which are classified as unhealthy (eg, chips, sugar-sweetened beverages, hot dogs, fried foods, and sugar-containing snacks). The classifications are based on a traffic light color coding of the nutrient content of the food developed by the Food Standards Agency (FSA) of the United Kingdom and the criteria for food and drinks described in the UK's guide for nutritional labels [30]. These labels show at a glance if the food has low (green), medium (yellow), or high (red) amounts of fat, saturated fat, sugars, and salt, thus helping people achieve a better food balance. Each scenario replicates a real place where children commonly consume food in Mexico, including (1) a grocery store, (2) lunch café, (3) home-cooking restaurant, (4) fast food restaurant, (5) menu-based restaurant, and, as a bonus level, (6) a food truck. FoodRateMaster incorporates a curve of increasing difficulty across the 6 levels of the game to encourage players to have fun throughout to the end of the video game. The player is invited to play several times, to obtain three stars in each level, and to unlock access to an exclusive game zone. This zone presents an additional scenario (the 6th level) and a competitive challenge section where the winner of the challenge receives both their own points and those of an opponent.

FoodRateMaster Structure

FoodRateMaster has the following three sections: Section 1, "Configuration and customization" (see Figure 2); Section 2, "Education" (see Figure 3); and Section 3, "Training" (see Figure 4). Table 1 describes the activities for players in each section.

Figure 2. Screenshots of the FoodRateMaster configuration/customization section. User menu (top left), game story (top right), avatar store and selection (bottom left), and scenario map (bottom right).

Figure 3. Screenshots of the FoodRateMaster educational section. Explanation of unhealthy food (top left), introduction to the tra c light color-coding system (top right), explanation of green levels (bottom left), explanation of red levels (bottom right).

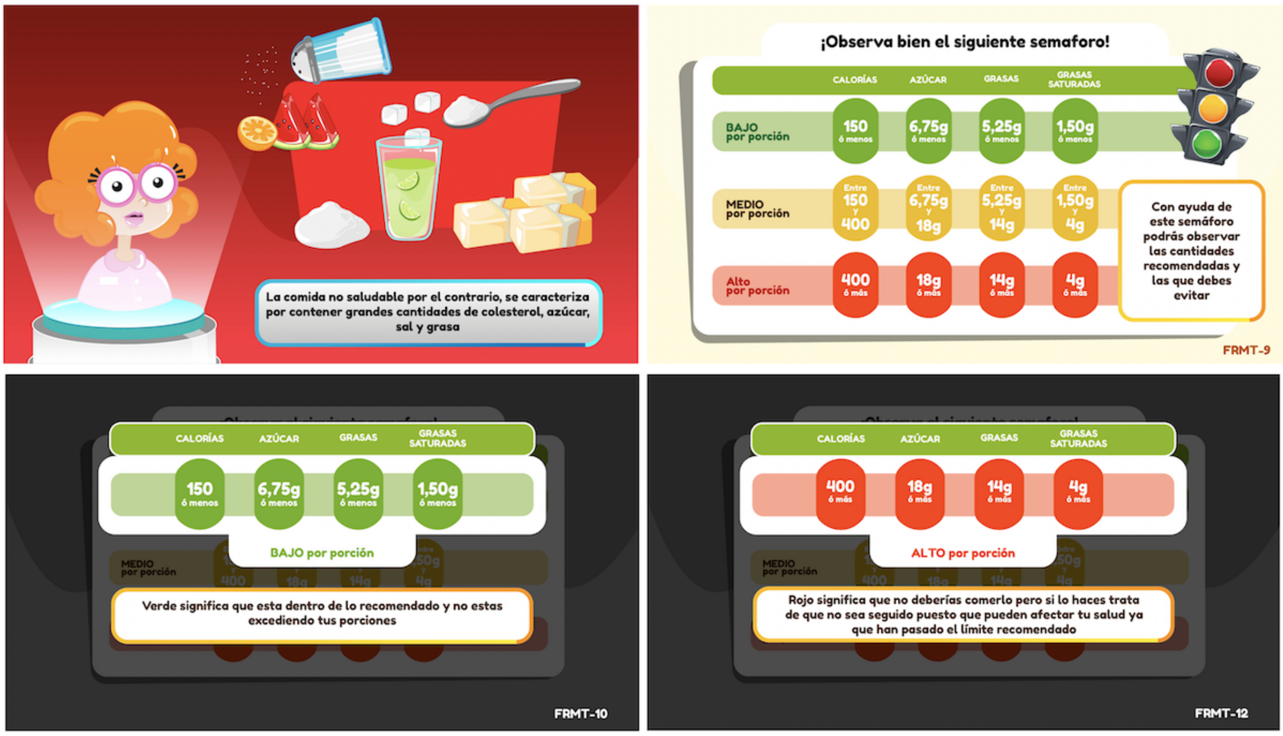


Figure 4. Screenshots of the FoodRateMaster training section. A game scenario (top), level results (middle left), error feedback (middle right), ranking of players (bottom left), and a validation question (bottom right).

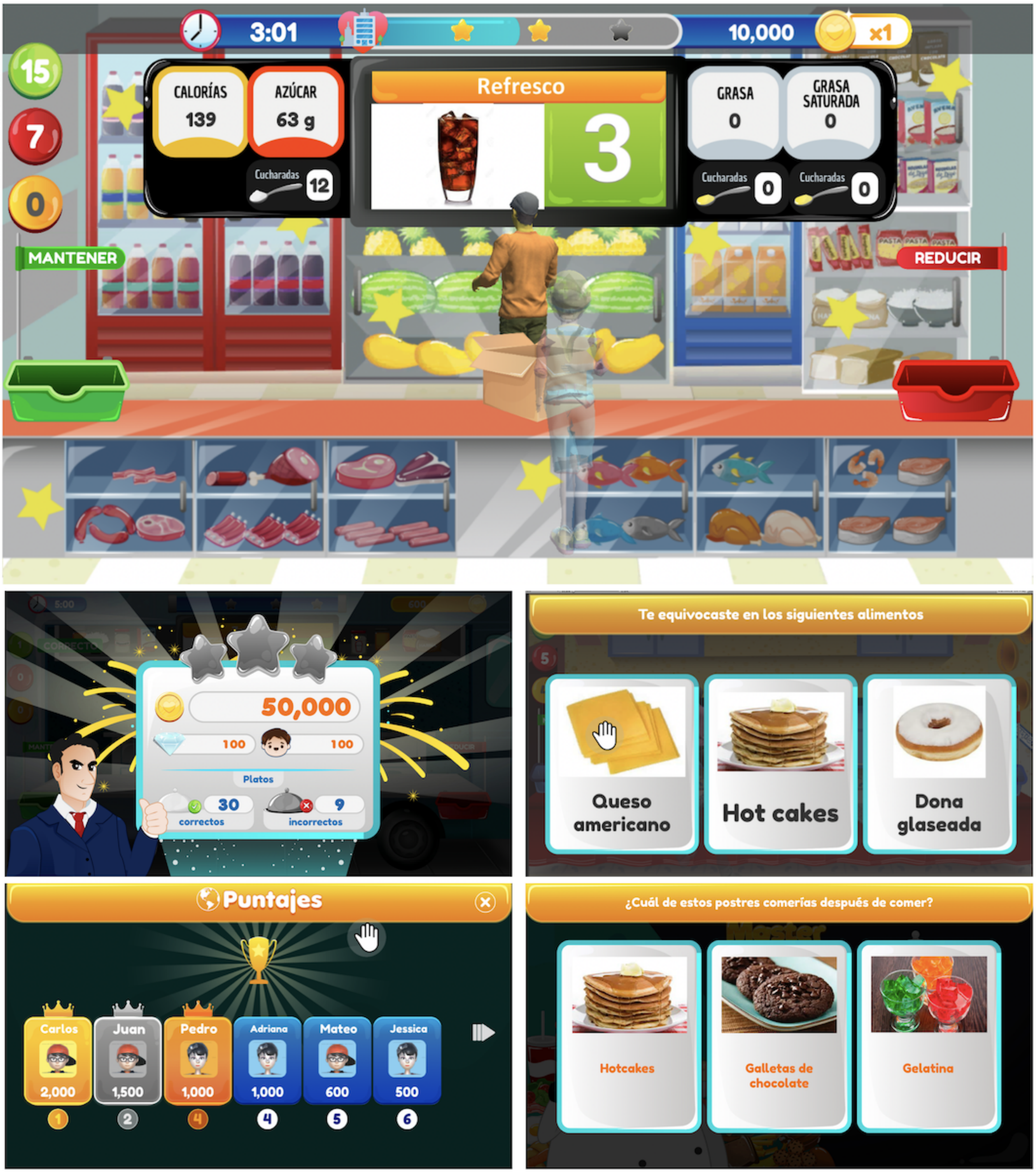


Table 1. Sections of FoodRateMaster.

Section	Description
Section 1: “Configuration”	Players log in, see the story of the game, select and buy avatars in the store, and select the scenario that they will play from the map.
Section 2: “Education”	Players learn about the characteristics of healthy and unhealthy food, and learn how to make healthier choices quickly and easily based on the traffic light color coding of the nutrient content of the food and drinks. Additionally, this tutorial explains the game goal, how to play the game, and what the game options, elements, indicators, and results section include.
Section 3: “Training”	In each scenario, an evil chef will prepare a menu, and the player, based on the nutritional information of the food, has to determine whether that food can be consumed (healthy) or whether its consumption must be reduced (unhealthy). The agent needs to take the healthy foods (only green labels) and put them into the “keep basket”. Additionally, the agent needs to take the unhealthy foods (yellow and red labels) and put them into the “reduce basket.” The player has to move his/her body to classify the food and avoid obstacles. During the game sessions, the game provides a bonus mechanism. The correct action of maintaining healthy food or reducing unhealthy food allows children to maintain a healthy lifestyle and therefore win points. Additionally, the player can earn extra points when he/she correctly replaces unhealthy food with healthy food. Otherwise, if the player makes too many errors, he/she will not win enough points to unlock the subsequent levels. Finally, the player arrives at the results screen, which specifies the points earned, the incorrect food classification choices he/she made, and his/her position in the global ranking of players. The player then answers some validation questions that help to identify what kind of food (healthy or unhealthy) they intend to consume in certain situations (eg, Which of the following foods would you eat after a meal?).

Behavioral Change Theories and Techniques

We included a set of BCTs in the gameplay elements of FoodRateMaster to create a stimulating and engaging environment in which key aspects of healthy behaviors and behavior-specific knowledge are being promoted and strengthened. A BCT is defined as “an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behavior” [31]. BCTs can be used alone, but the combination of several BCTs is frequently a keystone for effectiveness [32]. Figure 5 explicitly shows the relationship between the BCTs and gameplay elements. The BCTs included in FoodRateMaster are based on the work of Michie et al [31], and are grounded on the constructs of behavioral theory, cognitive theory, and social cognitive theory.

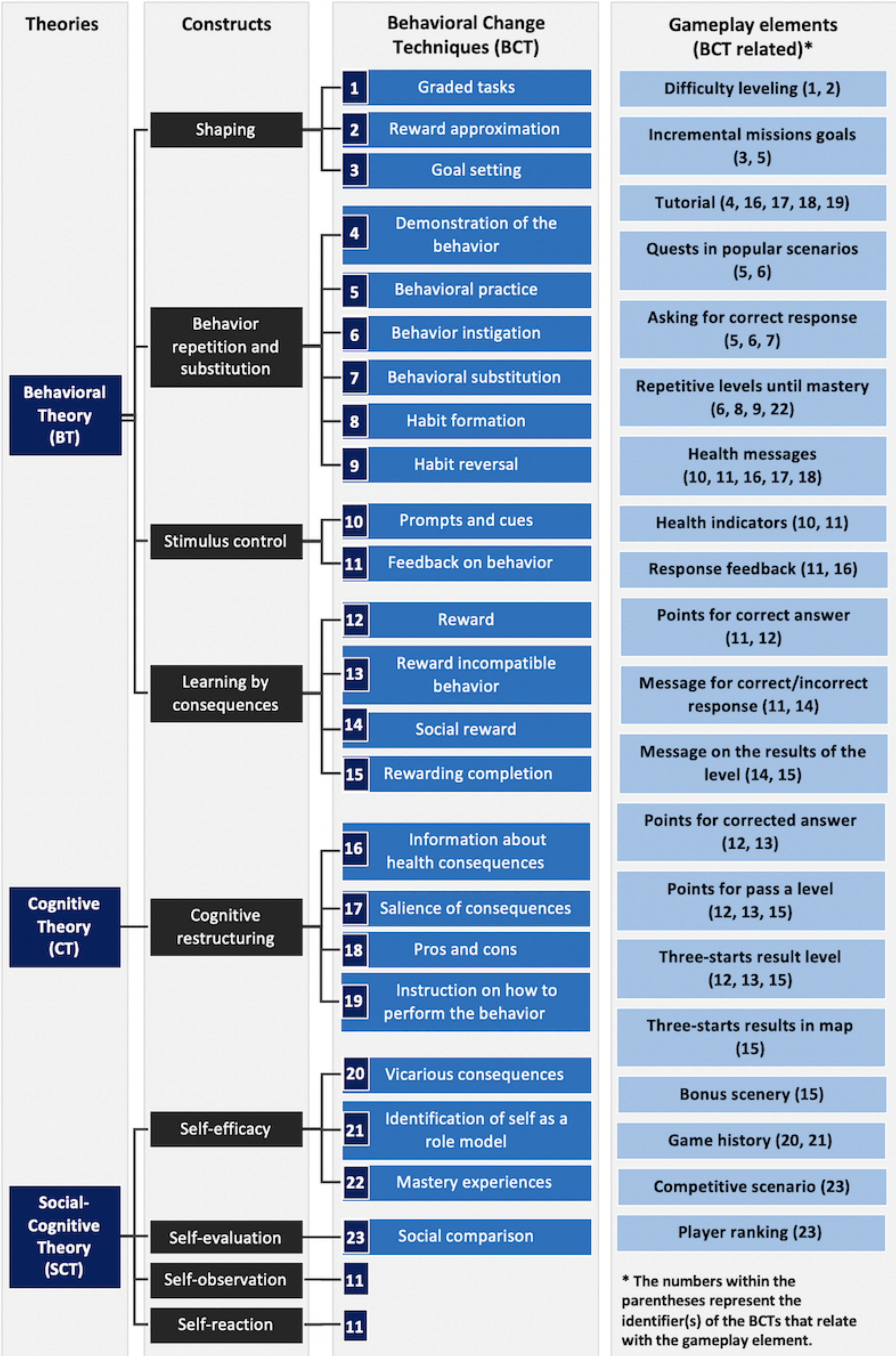
Behavioral theory suggests that the frequency, magnitude, and duration of a behavior (eg, exercising, consuming sugary drinks, or eating healthy) depends to a large extent on the consequences that the behavior produces or the elements of the context (eg, people, objects, and events) [33-35]. Thus, an essential feature of this approach focuses on the application of mechanisms or techniques that increase desirable healthy behavior and weaken or extinguish undesirable, troublesome, or unhealthy behaviors [36]. Behavioral therapy is primarily based on techniques such as shaping, stimulus control, behavior repetition and substitution, and learning by consequences [37,38].

Cognitive theory proposes that thoughts or cognitions play a definitive role in healthy behavior and in the general well-being of people [39,40]. This theory emphasizes how an individual processes, evaluates, and interprets reality, and how this information affects how the person behaves; the theory therefore focuses on reframing and correcting distorted thought patterns to facilitate behavioral change [41]. Cognitive therapy is based primarily on techniques such as cognitive restructuring, monitoring, and psychoeducation (ie, providing information about the problem).

Social cognitive theory emphasizes learning from the social environment and states that personal, behavioral, and environmental factors are interrelated and, in conjunction, influence behavior change [42]. Critical constructs of social cognitive theory are self-observation, self-evaluation, self-reaction, and self-efficacy.

Both behavioral and cognitive theories are supported by a large body of empirical evidence that supports their usefulness in the prevention and treatment of childhood obesity [43-45]. Similarly, social cognitive theory-based interventions have shown a positive effect on the prevention of childhood obesity [46].

Figure 5. Theory-based gameplay elements in FoodRateMaster.



Participants

A total of 62 Mexican children (29 girls, 33 boys) aged 8-10 years (mean age 9, SD 0.8 years) attending a primary school located close to our research institution in Tepic, Nayarit, Mexico participated voluntarily in the study. The only exclusion criterion was having physical limitations, because the participant had to interact with the game through full-body movements. The 62 participants answered the initial questionnaires, but 2 of them did not answer the posttest questionnaires and were excluded from the study, resulting in 60 valid participants. The number of participants was 11, 35, and 14 for the age groups of 8, 9, and 10 years old, respectively. In addition, 39 parents of the participants answered the perception questionnaire.

Procedures

We conducted a meeting with the school authorities and teachers to present FoodRateMaster, explain the objectives of the study, and verify that the children had not taken any nutrition education class that could influence the test. During this meeting, we obtained written authorization from the school authorities and teachers to conduct the study in their institution. Subsequently, a call for participants was administered by presenting FoodRateMaster to groups of children. In the presentation, we explained to the children the purpose of FoodRateMaster, its characteristics and elements, and the instructions about how to play the game. Written consent was obtained from the parents of the children who expressed their verbal interest in participating. The participants then completed the pretest questionnaire process as follows. During the first day, the facilitators grouped the participants by age (three groups) and asked them to complete the food knowledge questionnaire. The children took approximately 20 minutes to complete the questionnaire. Four days later, the children answered the food frequency questionnaire individually, which took approximately 30 minutes to complete. To improve the reliability of the data, children self-reported their food frequency intake. According to Kolodziejczyk et al [47], children's self-reporting of dietary intake is more valid than parental reporting. In addition, the application was conducted with the close support of a facilitator. In this way, children only had to focus on remembering how often they had consumed the given food within the last month. Every child took the time they considered necessary to answer each question.

After filling out the questionnaires, the participants completed 12 game sessions of at least 15 minutes per session. The total average time of play was 3.5 hours. We conducted all game sessions in 45 days. In one room, we set up three game stations, each of which included a 50-inch monitor, personal computer, Kinect sensor V2, and the FoodRateMaster video game. We ensured that the participants always felt comfortable with the game activities. The day after the last game session, we began administering the posttest questionnaires, which followed the same procedure as the pretest questionnaires. Moreover, we asked the parents to complete the parent perception questionnaire. This questionnaire was anonymous, and the parents were instructed to return it within 1 week.

All study procedures were approved by the institutional review board of the Centro de Investigacion Cientifica y de Educacion Superior de Ensenada (Tepic, Nayarit, Mexico). In addition, we carefully ensured the anonymity, confidentiality, and safeguarding of data. Only data such as age, sex, and grade level were captured, and we did not collect the name or other sensitive data of the children.

Measures

Food Knowledge Questionnaire

Figure 6 provides an example of the food knowledge questionnaire, which was developed by an interdisciplinary research team consisting of a nutritionist, a psychologist, and a computer scientist. The psychologist and the nutritionist also participated in some of the multidisciplinary design sessions. We developed this questionnaire because we did not find a validated questionnaire that evaluates this knowledge. This questionnaire included 90 foods, 49 of which were healthy and 41 of which were unhealthy. These foods were selected from interviews conducted with children before beginning this study. For each food, the participants were asked to indicate whether they considered the food to be (1) "healthy" (maintain or increase intake), (2) "unhealthy" (reduce intake), or (3) "I do not know." The classification of each food as healthy or unhealthy was made based on the traffic light color coding of the nutrient content of the food developed by the UK FSA [30]. The total result for this questionnaire was the sum of the questions answered correctly. We carried out a pilot test of the questionnaire with 5 children to evaluate whether they had any problems answering it. We did not find any such incidents during this pilot test.

Figure 6. Example of questions from each questionnaire.

Food knowledge questionnaire

Instructions. For each food, mark whether you consider the food to be (1) "healthy" (keep or increase intake), (2) "unhealthy" (reduce intake), or (3) "I do not know".

1.- French fries

healthy (Maintain or increase intake)	unhealthy (reduce intake)	I do not know

2.- Spinach

healthy (Maintain or increase intake)	unhealthy (reduce intake)	I do not know

Food frequency intake questionnaire

Instructions. Mark on the following scale your consumption of each of these foods in the previous four weeks.

1.- Guava

(0) never	(1) one or two times per month	(2) three or more times per month	(3) one or two times per week	(4) three or more times per week	(5) one or two times per day	(6) three or more times per day

2.- Soft drinks

(0) never	(1) one or two times per month	(2) three or more times per month	(3) one or two times per week	(4) three or more times per week	(5) one or two times per day	(6) three or more times per day

Parent perception questionnaire

Instructions: For each of the following statements, mark the box that best matches your opinion.

Statement	Strongly disagree	Disagree	Undecided	Agree	Strongly agree
After completing the game sessions, my child:					
1. Showed a greater interest in distinguishing between healthy and unhealthy foods					
2. Explained why we should avoid some unhealthy foods					

Food Frequency Questionnaire

As with the knowledge questionnaire, we did not find a valid food frequency questionnaire (FFQ) for school-age Mexican children. Therefore, a nutritionist and a computer scientist adapted the FFQ for children 7-10 years old developed by Hinnig et al [48] and the FFQ for assessing dietary intake in children and adolescents in South America developed by Saravia et al [49] to the diets of school-aged Mexican children (Figure 6). In addition, we considered the characteristics of the highest validated FFQ for children identified by Kolodziejczyk et al [47]. The adapted questionnaire includes 78 foods that were selected from interviews conducted with children prior to this study. Many of these foods are also included in the reference questionnaires. For each food, the participants were asked to mark on a 7-point scale the frequency of their consumption of the foods in the previous 4 weeks as follows: (0) "never," (1) "one or two times per month," (2) "three or four times per month," (3) "one or two times per week," (4) "three or more times per week," (5) "one or two times per day," and (6) "three or more times per day." The items in this questionnaire were not interrelated and were analyzed individually. We also carried out a pilot test of this questionnaire with 5 children to evaluate whether they had any problems answering it. We did not encounter any such incidents during this pilot test.

Parent Perception Questionnaire

We developed the parent perception questionnaire to determine whether the participants' parents perceived a positive change in their children's attitudes toward 13 healthy eating behaviors after playing all of the game sessions. A nutritionist and a computer scientist developed this questionnaire. The first four questions were related to the following behaviors: distinguishing healthy and unhealthy foods, avoiding unhealthy foods, suggesting dietary changes for healthy eating, and reducing salt and sugar consumption. Of the remaining nine questions, four of them refer to behaviors associated with an increase in the intake of healthy foods (eg, consuming fruits and vegetables) and five refer to a reduction in the consumption of unhealthy foods (eg, reduce soft drink consumption). These healthy eating behaviors were selected because they are the most commonly recommended behaviors for healthy eating, and they are encouraged in FoodRateMaster. We asked the participants to indicate on a 5-point Likert-type scale ranging from (1) "totally disagree" (1) to "totally agree" (5) according to the level to which they believe that their child fits each statement. The items on this questionnaire were not interrelated and were analyzed individually. Additionally, this questionnaire included a final question asking the parents if they introduced any changes in the diets of their children due to the comments/suggestions from the children themselves. If the response to this question was "yes," the parents were invited to write a free text explaining what changes they introduced.

Data analysis

A Wilcoxon signed-rank sum test was used to determine whether the total number of correctly identified healthy and unhealthy foods differed from pre to post game play. We also conducted similar analyses for healthy and unhealthy food and the food categories. The food knowledge data (continuous variable) is presented as mean and SD. We used this nonparametric test because this variable did not exhibit a normal distribution. The Wilcoxon signed-rank sum test was also used to identify significant differences between the pretest and posttest results for the frequency of the consumption of the 78 foods included in the FFQ. We report the food frequency (categorical variable) as the median and interquartile range. We used this nonparametric test because this variable is ordinal. Finally, to determine whether the participants' parents perceived changes in the attitudes of their children, we calculated the medians and interquartile range values, and the percentage of participant agreement as the average of the sums of percentages of participants who answered with option 4 "partially agree" or option 5 "totally agree" in each item of the subscale. We conducted the statistical analyses in the software SPSS version 25 (SPSS Inc, Chicago, IL, USA).

Results

Food Knowledge

The first hypothesis predicted that following game play, participants would be able to correctly identify a greater number of healthy and unhealthy foods. Indeed, participants increased the number of foods they correctly identified from pregame tests. We also identified significant differences in the food classification of both healthy and unhealthy foods, but the players' improvement in correctly identified foods was more significant with healthy than with unhealthy food. Overall, we identified significant differences in the knowledge of players in almost all food categories except for the category of sugar with fat. Table 2 summarizes the complete results.

Table 2. Pretest and posttest results of the food knowledge questionnaire.

Food group	Questions, N	Pretest, mean (SD)	Posttest, mean (SD)	*P* value[a]	Change
All foods	90	56.95 (10.71)	67.88 (10.71)	<.001	+19%
Healthy and unhealthy foods					
Healthy foods	49	29.13 (6.47)	35.72 (7.03)	<.001	+23%
Unhealthy foods	41	27.67 (9.01)	32.37 (6.43)	<.001	+16%
Food category					
Animal-derived food	5	1.70 (1.28)	2.57 (1.24)	<.001	+47%
Cereals with fat	16	10.83 (3.46)	13.00 (2.54)	<.001	+19%
Fast food	3	2.10 (1.07)	2.38 (0.83)	.002	+14%
Fat-free cereals	8	4.27 (1.34)	5.25 (1.34)	<.001	+23%
Fat-free sugar	10	7.38 (1.65)	8.58 (1.65)	<.001	+16%
Fruit	7	6.07 (1.02)	6.58 (0.94)	<.001	+9%
Legumes	3	1.73 (0.63)	2.03 (0.78)	<.001	+18%
Oils and fats	6	3.97 (1.34)	5.00 (0.99)	<.001	+27%
Prepared food	23	11.68 (3.42)	14.98 (3.70)	<.001	+24%
Sugar with fat	3	2.15 (0.90)	2.30 (0.72)	.22	—[b]
Vegetables	6	4.92 (1.29)	5.40 (0.98)	<.001	+11%

[a]*P* value of <.05 was considered statistically significant.

[b]Not applicable.

Food Frequency Intake

Hypothesis 2 surmised that participants would exhibit an increased self-reported food frequency intake of healthy food. Indeed, the participants indicated a greater self-reported food frequency intake of cauliflower, broccoli, and corn quesadillas. Therefore, hypothesis 2 was confirmed. In addition, hypothesis 3 surmised that participants would exhibit a reduced self-reported food frequency intake of unhealthy food. After game play, participants indicated a reduced self-reported frequency intake of french fries, pancakes, brownies and donuts, candy and chocolate, crackers, wheat tortillas, crepes, sweet soft cakes, sweet cookies, hamburgers, and soft drinks. These results also confirm hypothesis 3. Table 3 summarizes the complete results on food frequency intake.

Table 3. Pretest and posttest results of the food frequency questionnaire.

Food	Pretest score[a], median (IQR)	Posttest score, median (IQR)	*P* value[b]	Change
Healthy food				
Cauliflower, broccoli	0 (0-3)	3 (1-4)	<.001	increase
Corn quesadillas	0 (0-3)	3 (1-3)	<.001	increase
Corncob	3 (1.25-5)	3 (1-3)	<.001	decrease
Guava	1.5 (0-4.75)	0 (0-2)	<.001	decrease
Unhealthy food				
French fries	1 (0-3)	1 (0-1)	.003	decrease
Crackers	3 (0-3)	1 (0-1.75)	.004	decrease
Wheat tortillas	3 (0.25-5)	2 (0-3.75)	.03	decrease
Pancakes, brownies, donuts	3 (1-5)	1 (0-3)	<.001	decrease
Crepes	1 (0-3)	1 (0-1)	.01	decrease
Candy, chocolate	4 (1.25-5)	1.5 (0.25-2.75)	<.001	decrease
Sweet soft cakes	1 (0-3)	0 (0-1)	.009	decrease
Sweet cookies	3.5 (3-5)	3 (2.25-4.75)	.02	decrease
Soft drinks	3 (0-4.75)	1 (0-3)	.03	decrease
Hamburgers	1 (0-3)	1 (0-2)	.02	decrease

[a]The scores are (0) “never,” (1) “one or two times per month,” (2) “three or more times per month,” (3) “one or two times per week,” (4) “three or more times per week,” (5) “one or two times per day,” and (6) “three or more times per day.”

[b]*P* value of <.05 was considered statistically significant.

Parent Perceptions

Finally, hypothesis 4 surmised that the participants’ parents would perceive improvements in their children’s attitudes toward healthy eating behaviors. Most of the participants’ parents (>50%) agreed that they perceived improvement in the attitudes of their children toward 6 of the 13 healthy eating behaviors after playing the game (see Table 4). In particular, most of the parents agreed that after playing the game, their children showed a greater interest in explaining why they should avoid unhealthy foods, distinguish between healthy and unhealthy foods, increase their intake of fruits and vegetables, reduce their intake of soft drinks, and suggest changes in the intake of some foods that they usually eat. The remaining behaviors did not reach 50% parental agreement. Additionally, a total of 15 parents answered the final question related to the introduction of any change in the regular diet of their children due to the comments/suggestions the children made (see Textbox 1). Nine comments were related to a reduction of unhealthy food intake, five were related to an increase in healthy food intake, and one was related to the learning of content but not the intention of changing eating behaviors.

Table 4. Parent perception questionnaire responses (N=39).

After completing the game sessions, my child:	Score[a], median (IQR)	Agree[b], n (%)
Showed greater interest in distinguishing between healthy and unhealthy foods	4 (2-5)	25 (64)
Explained why we should avoid some unhealthy foods	4 (3-5)	26 (67)
Suggested changing the consumption of some foods that we usually eat	4 (1.5-4)	20 (51)
Showed greater interest in the reduction of salt and sugar within foods	3 (2-5)	19 (49)
Showed greater interest in the consumption of legumes	3 (2-5)	19 (49)
Showed greater interest in the consumption of seafood	3 (2-5)	19 (49)
Showed greater interest in the consumption of vegetables	4 (2.5-5)	23 (59)
Showed greater interest in the consumption of fruits	4 (2-5)	25 (64)
Showed greater interest in reducing the consumption of fried foods	3 (2-4)	16 (41)
Showed greater interest in reducing the consumption of soft drinks	4 (2.5-5)	21 (54)
Showed greater interest in reducing the consumption of fast food	3 (2-5)	19 (49)
Showed greater interest in reducing the consumption of candy and chocolate	3 (2-4)	17 (44)
Showed greater interest in reducing the consumption of cookies and pancakes	3 (2-4)	18 (46)

[a]Scores are based on a choice of the following options: 1, strongly disagree; 2, disagree; 3, undecided; 4, agree; 5, strongly agree.
[b]Responded 4 (agree) or 5 (strongly agree).

Textbox 1. Collected comments from the parent perception questionnaire.

- Related to the consumption of healthy food

"I noticed that he more easily accepts the fruits and vegetables that he has to eat."

"My child now better accepts the consumption of vegetables. I noted that he is now more sensitive to obesity, and I heard him say that he should exercise more."

"My child now eats vegetables and meat better."

"Yes, now he is getting used to eating more fruits and vegetables."

"Now we try to have a healthier diet all the time and inform our children about the properties of food."

- Related to the consumption of unhealthy food

"I am now trying to reduce the use of sugar, salt, and fat when cooking."

"We have reduced the consumption of sodas, candies, sugar-sweetened bread, and snacks."

"We now avoid the consumption of hamburgers, hot dogs, and soft drinks."

"My son no longer shows so much interest in or taste for candies or chocolates."

"Now my child drinks less soda."

"Now my child eats fewer french fries and chips."

"We have reduced the consumption of salt and fast food."

"I think that every child is attracted to junk food, but now [he/she] only occasionally consumes junk food."

"Now my child drinks less soda and sugar-sweetened beverages than before."

- Related to learning but not to the intention of changing food behaviors

"He told me about the game, and it is about what does and what does not benefit his body, but he does not have an interest in changing his eating habits. Every day is a constant struggle to try different fruits and vegetables."

Discussion

Principal Findings

The findings from this study support the ability of FoodRateMaster to help improve the nutritional knowledge and dietary intake of children between 8 and 10 years old, which corresponds to the age range at which the rates of overweight or obesity in children increase considerably [3]. In addition, parents perceived positive changes in their children's attitudes toward healthy eating behaviors after game play.

Food Knowledge

The results obtained in this study show that children aged between 8 and 10 years old significantly improved their food knowledge after playing FoodRateMaster. This result supports prior evidence about the usefulness of serious games to improve food nutrition knowledge (eg, [11,15]). In particular, we identified a greater increase in the ability to correctly identify healthy food than in the ability to correctly identify unhealthy food. This demonstrates that it is challenging to change the opinion of children about unhealthy food that is wrongly perceived as healthy. Previous studies suggest that this situation might occur because children heavily rely on visual aspects to assess the healthiness of a food product and because they have difficulty classifying the combined and transformed food products with which they are most likely to be presented in their everyday lives [50]. Transformed foods are defined as foods in which a sign of human intervention can be traced (eg, mayonnaise, sweet cookies, and hamburgers) [51]. Additionally, our findings suggest that knowledge improvement varies between different food categories. The categories that showed the least improvement were fruits/vegetables and fast food. We attribute these results to the fact that these foods are frequently publicized as healthy and unhealthy food, respectively. The categories with the most significant improvement were animal-derived food, oils and fats, prepared food, and cereals without fat. These findings suggest that future initiatives should concentrate on the greater exposition of food categories, which can contribute to correct identification.

Food Frequency Intake

We also obtained positive results when assessing the changes in the food frequency intake of healthy and unhealthy foods. A statistically significant change was found in the frequency of consumption of 14 of 78 foods. Most of these changes (10 of 14) consisted of the reduced consumption of unhealthy foods such as soft drinks, pancakes, donuts, brownies, and candy, especially since these foods are usually consumed in both the schools and homes of Mexican children [8]. These results support the usefulness of serious games in improving dietary intake and are consistent with previous studies (eg, [15,18]). Complementarily, only two changes were associated with the increasing consumption of healthy food (eg, cauliflower and broccoli). Previous studies suggest that this situation occurs because providing children with information or visual exposure to foods alone may not be a sufficient mechanism for increasing children's preference and consumption of healthy foods [52,53]. A strategy that is more effective for increasing children's preference of healthy foods is repeated exposure to these foods [52]. These findings suggest that future initiatives should include other BCTs that could be effective in improving children's intake of fruits, vegetables, and other healthy foods (eg, self-monitoring, social support, goal setting, goal review, and action planning). It is also important to note the decrease in the consumption of guava (a local fruit) and corn on the cob, both of which are foods that are classified as healthy. This reduction might be caused by the coincidence of the end of the harvesting season of these foods during the study period.

Parent Perceptions

The feedback collected from the participants' parents provides a complementary source of information, as the parents are responsible for the type of foods the children usually consume. Therefore, it is important to determine whether the parents noted any change in the attitudes of their children toward the intake of healthy and unhealthy food. The most relevant feedback collected from the parents (ie, higher percentages of agreement presented in Table 4) indicates that most of the parents agreed that after playing the game, their children showed greater interest in the following six healthy eating behaviors: explaining why they should avoid some unhealthy foods, distinguishing between healthy and unhealthy foods, increasing their intake of fruits and vegetables, reducing their intake of soft drinks, and suggesting changes in the intake of some foods that they usually eat. These results support the argument that FoodRateMaster can influence children's attitudes toward healthy eating behaviors. Conversely, the percentage of parents who agreed that they perceived changes in their children's attitudes did not exceed 50% for the remaining seven healthy behaviors. According to Ledoux et al [54], one explanation for this result is that the expectations parents have of their children influence the way they interpret their children's behaviors, and many expectations that parents have of their children may be unrealistic. In addition, 14 parents commented that they introduced some changes in their children's diet based on the comments and suggestions they received from their children (eg, "Yes, now he is getting used to eating more fruits and vegetables" or "Now my child drinks less soda"). These results support the argument that FoodRateMaster can influence children to involve their parents in changing their healthy and unhealthy eating behaviors. Interventions in which parents are actively involved in the improvement of their child's dietary intake are more likely to result in positive outcomes [55].

Limitations and Future Work

The project was evaluated in an uncontrolled clinical trial involving a small number of participants. Therefore, the results should be interpreted with caution. However, given that our main objective was to carry out a pilot study to explore the feasibility of FoodRateMaster to support nutritional learning and changes in food eating behaviors of children aged between 8 and 10 years, we believe that our results are valuable for researchers exploring the design of this type of serious game for players in that age range. A controlled clinical trial with a much larger population is necessary to prove the effectiveness of FoodRateMaster and is part of planned future work.

Another limitation of this study was the short evaluation period. The children answered the posttest questionnaires 4 days after the game sessions were complete. Medium-term and long-term effects of FoodRateMaster were not addressed herein and could constitute insights for future research. One possibility would be to increase the time lag between exposure and measurement to account for medium-term effects. Another suggestion would be to evaluate the long-term effects by using a longitudinal design with repeated exposure effects. In addition, it would be interesting to expand the population involved in this pilot study and conduct a long-term study to analyze the effect of FoodRateMaster in children who are overweight or obese.

In addition, the food frequency intake was based on self-reported data. The results may be biased by well-known limitations of FFQs, such as the difficulty in remembering experiences or events and the exaggeration or underreporting of food intake [56]. However, an FFQ is the most commonly used method for such assessments owing to its ease of use and its reliability and validity in capturing such information. There is also evidence that the self-reporting of dietary intake by children is more valid than parental reporting [47]. In addition, the present study did not examine changes in the number of servings consumed by children. Instead, only changes in food frequency intake were considered. Therefore, it would be interesting to address this nutritional assessment comparison before and after game exposure to better evaluate positive or negative changes in food servings. However, the most accurate instruments to measure food intake in children are those that do not include the number of servings [47].

Moreover, we only obtained data on the extent to which parents perceived any change in the attitudes of their children toward healthy eating behaviors, and we did not capture information that could help to explain this perception. In a future evaluation, we will include questions that will help us to identify the specific aspects that influence this perception.

Conclusions

In this study, extensive formative research was conducted by a multidisciplinary team to design and develop FoodRateMaster, a health video game for nutritional education and the promotion of healthy eating behaviors among young children. Compared to the initial evaluation, children aged between 8 and 10 years indicated an increased level of nutritional knowledge and self-reported frequency intake of two healthy foods, and a decreased level of self-reported intake of 10 unhealthy foods after playing FoodRateMaster. Moreover, the participants' parents agreed that FoodRateMaster positively influenced their children's attitudes toward several healthy eating behaviors. These results support that a health game such as FoodRateMaster is a viable tool to help children aged between 8 and 10 years old to increase their food knowledge and improve their dietary behaviors.

The results from this study also suggest that greater exposure to some food categories may be needed to increase children's knowledge about healthy and unhealthy foods. In addition, future versions of FoodRateMaster should include other BCTs that can be useful in improving children's intake of fruits, vegetables, and others healthy foods. For future research, we are planning to conduct a randomized controlled trial to evaluate the medium-term and long-term effects of FoodRateMaster.

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Authors' Contributions

IEC designed the study, provided support in designing FoodRateMaster, wrote the first draft, incorporated changes from all coauthors, and completed the data analyses. EPB developed FoodRateMaster and contributed to editing the manuscript. JLS conducted data collection and processing and contributed to editing the manuscript. JMM assisted with the analysis and interpretation of the data and contributed to editing the manuscript. EDP and LEZ participated in the psychological and nutritional theoretical foundations of FoodRateMaster, respectively. Additionally, they participated in the design of FoodRateMaster and contributed to editing the manuscript.

Conflicts of Interest

None declared.

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Abbreviations

BCT: behavior change technique
FFQ: food frequency questionnaire
FSA: Food Standards Agency of the United Kingdom

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Review

Investigating Serious Games That Incorporate Medication Use for Patients: Systematic Literature Review

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Abstract

Background: The United States spends more than US $100 billion annually on the impact of medication misuse. Serious games are effective and innovative digital tools for educating patients about positive health behaviors. There are limited systematic reviews that examine the prevalence of serious games that incorporate medication use.

Objective: This systematic review aimed to identify (1) serious games intended to educate patients about medication adherence, education, and safety; (2) types of theoretical frameworks used to develop serious games for medication use; and (3) sampling frames for evaluating serious games on medication use.

Methods: PubMed, Scopus, and Web of Science databases were searched for literature about medication-based serious games for patients. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed for article selection.

Results: Using PRISMA guidelines, 953 publications and 749 unique titles were identified from PubMed, Scopus, and Web of Science. A total of 16 studies featuring 12 unique serious games were included with components of medication adherence, education, and safety, published from 2003 to 2019. Of the 12 games included, eight serious games were tested in adolescents, three games were tested in young adults, and one game was tested in adults. Most studies (n=11) used small sample sizes to test the usability of serious games. Theoretical frameworks identified in the 12 serious games included information, motivation, and behavior theory; social cognitive theory; precede-proceed model; middle-range theory of chronic illness; adult learning theory; experiential learning theory; and the theory of reasoned action. Existing reviews explore serious games focused on the management of specific disease states, such as HIV, diabetes, and asthma, and on the positive impact of serious game education in each respective disease state. Although other reviews target broad topics such as health care gamification and serious games to educate health care workers, no reviews focus solely on medication use. Serious games were mainly focused on improving adherence, whereas medication safety was not widely explored. Little is known about the efficacy and usability of medication-focused serious games often because of small and nonrepresentative sample sizes, which limit the generalizability of existing studies.

Conclusions: Limited studies exist on serious games for health that incorporate medication use. The findings from these studies focus on developing and testing serious games that teach patients about medication use and safety. Many of these studies do not apply a theoretical framework in the design and assessment of these games. In the future, serious game effectiveness could be improved by increasing study sample size and diversity of study participants, so that the results are generalizable to broader populations. Serious games should describe the extent of theoretical framework incorporated into game design and evaluate success by testing the player's retention of learning objectives.

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KEYWORDS
games; medication adherence; patient safety; video games; systematic review

Introduction

Background

An estimated 117 million Americans currently live with one or more chronic conditions, many of which require medication management [1]. Using many medications for chronic conditions is accompanied with a high risk of medication errors, insufficient knowledge about appropriate use, and inadvertent adverse drug events. In the United States, a leading reason for injuries and death is because of the estimated 1.5 million medication errors [2]. Common mistakes made by patients or caregivers outside of the hospital include taking a medication twice by accident, an incorrect dose, or the wrong medication [2].

A common barrier to chronic disease management for many patients is medication adherence. Approximately 50% of patients do not take prescribed medication appropriately and consistently [3]. Medication adherence or taking medications correctly is generally defined as the extent to which patients take medication as prescribed by their doctors [4]. Patients, health care providers, and hospital systems would benefit immensely from helping patients use medication correctly, consistently, and safely. The health care system would benefit from gaining the estimated US $100 to US $300 billion every year because of nonadherence alone [5]. Patient knowledge on safe medication practices is critical in preventing unnecessary patient harm. For example, recent reports from Poison Control state that approximately 60,000 children were sent to the emergency room every year because of taking medications without adult supervision [6]. These findings show opportunities for patient education on safe medication use, storage, and disposal, particularly for young people and their family caregivers.

Technology has a significant impact on education and health behavior reinforcement both in patients and providers [7]. Devices such as mobile phones relay information, reinforce norms, and influence behaviors such as medication adherence [7]. The appeal of technology, particularly gaming, makes serious games an ideal approach to portray medication information [8]. Technology-based *serious games* are a novel method of delivering interactive health behavior education through skill-building exercises [9,10]. Serious games are digital tools that offer engagement activities through a responsive narrative to educate participants through role-play and practicing skills. Unlike traditional video games, serious games act to convey meaningful information through interactive environments similar to real-life situations [11,12]. The use of serious games on computer and mobile phone platforms to promote awareness of health issues has increased in popularity over the past decade [13]. Technology is readily accessible in the United States, with 89% of households owning a computer or mobile phone device and 81% of households having an internet subscription [14]. Serious games teach specific skills or learning objectives and are created for educational purposes rather than entertainment [15].

Serious games have proven to be successful at educating users on various topics, including health, languages, computer science, mathematics, and geography [16]. Web game-based learning has been shown to positively affect user attitudes toward learning as well as increase the retention time of acquired knowledge [7]. Current serious games focus on specific disease states, making it difficult to generalize objectives to medication use [17]. Serious games have been reported to be desired for learning by patients. In one study, children picking up prescriptions in the pharmacy were reported to have asked for interactive games to learn about their medications [18].

Some existing systematic reviews examining the use of serious games include little information about medication use targeting specific disease states, such as diabetes [19,20], HIV prevention and care [21], asthma management [22,23], and epilepsy [24]. Other systematic reviews include broad search criteria, such as serious game use in health care [25], health care gamification [24], and serious games for young people living with long-term medical conditions [17].

Objectives

The primary objective of this study was to assess the extent of serious games intended to educate patients about medication use and safety. In particular, this systematic review aimed to explore (1) serious games intended to educate patients about medication adherence, education, and safety; (2) types of theoretical frameworks used to develop serious games for medication use; and (3) sampling frames for evaluating serious games on medication use.

Methods

Search Strategy

A literature search was conducted using PubMed, Scopus, and Web of Science databases. The key terms included in the search were (serious game OR serious-games OR serious video-games OR serious games OR serious digital games OR serious electronic games OR serious gaming OR video game OR video-game) (drug OR drugs OR medication OR medications OR prescription OR prescriptions) (treatment OR therapy). Search results from each database were exported to Microsoft Excel, merged, and sorted for removal of duplicate citations.

Study Selection

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Only original research articles were included in this systematic review. Initial screening of all abstracts and titles was conducted independently by SL and SB to determine whether to include or exclude an article based on selection criteria. Inclusion criteria were original research studies published in English for patients as end users involving a serious game, which focus on medication use and safety, addressing at least one of the following topics: (1) medication safety, (2) medication adherence, and (3) medication education. During the abstract and title screening phase, a level of agreement on inclusion and exclusion was achieved among the authors. A third author, HS, reconciled disagreements to achieve mutual consensus before moving to full-text review. Full-text articles were assessed for inclusion, and reasons were documented for all excluded papers.

Definitions of key terms are as follows:

- *Serious games*: A digital or computerized game designed for patients to increase their knowledge and awareness about medications or help them with medication use and safety.
- *Games for medication adherence*: Games that promote players to take medication at least as prescribed.
- *Games for medication education*: Games that teach players how medications work in the body or why the medication is an important component of patients' treatment plan.
- *Games for medication safety*: Games about taking and handling medications in the proper way or safely to prevent medication errors.

Data Extraction

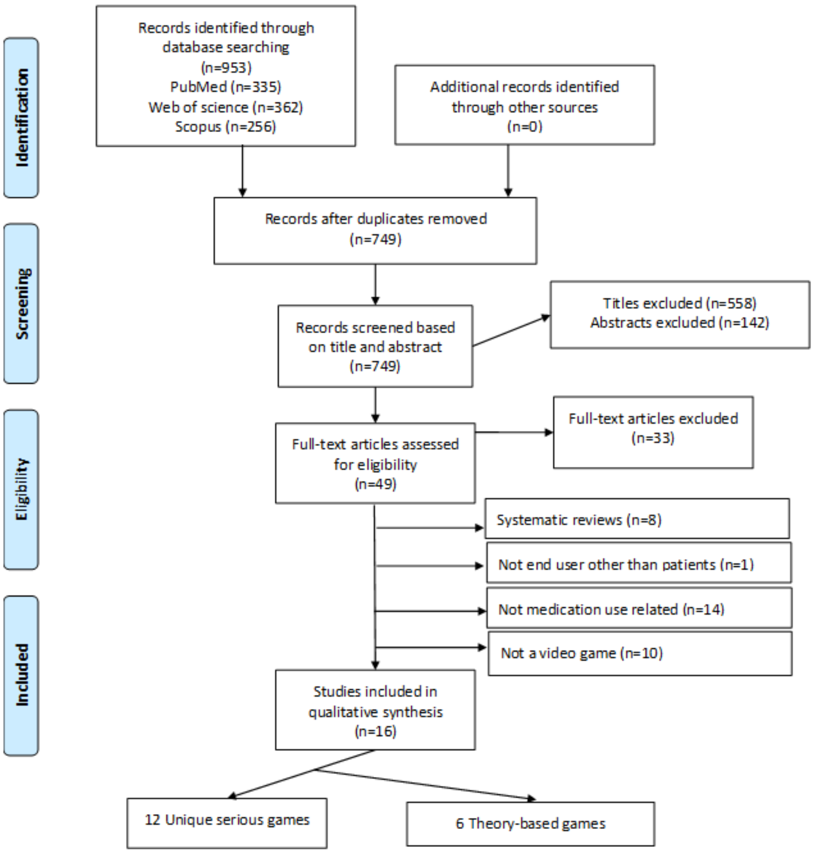
A standard data extraction form was used to collect study authors, article title, year published, journal title, study design, brief description of methods, primary outcome measures, and conclusions by all the authors for the articles included for full-text inclusions in the last step. References of the papers initially found were not included for evaluation.

Results

Literature Overview

A total of 953 records were obtained after searching PubMed, Web of Science, and Scopus. After removing duplicates, 749 articles with unique titles were identified for title reviews. After title review, 558 studies were removed, and another 152 studies were removed after abstract review for not meeting the inclusion criteria. Studies were removed if they did not include a serious game focusing on patients as end users and based on medication use, adherence, and safety. A comprehensive review of 49 full-text articles was conducted, 33 of which were excluded. Systematic reviews, serious games for end users other than patients, nonmedication-related games, and nonvideo games were excluded (see Figure 1). As a result, 16 articles were included in this systematic review. The results are presented below based on the following three specific aims of the paper: (1) serious games intended to educate patients about medication adherence, education, and safety; (2) types of theoretical frameworks used to develop serious games for medication use; and (3) sampling frames for evaluating serious games on medication use.

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram of the included studies.



A total of 16 articles on serious games published between 2003 and 2019 were found to incorporate medication use targeted toward patients. The 16 articles found focused on 12 unique serious games. Moreover, eight games were tested in adolescent populations, three games were tested in young adults, and one game was tested in adults only. In some cases, there were multiple articles focused on a single serious game. As shown in Multimedia Appendices 1 and 2, the included games could be grouped based on the disease state or education on a specific topic. All 12 games are described in Multimedia Appendices 1 and 2.

Intention of the Serious Game

Most of these articles studied the change in patients' knowledge about medications as an assessment of medication adherence. The following are examples of 8 games that assessed patients' understanding of medications for managing chronic and acute health conditions.

- Games for antiretroviral therapy (ART) and pre-exposure prophylaxis (PrEP) adherence: Viral Combat, Adherence Warrior, Epic Allies, and Battle Viro were developed to promote adherence to ART and PrEP [26-30]
- Game for cancer treatment medication adherence: Re-Mission [31]
- Game for diabetes medication education and adherence: L'Affaire Birmann [32,33]
- Game for asthma medication education: Wee Willie Wheezie [34]
- Games for microbiology and antibiotic education: Microbe Quest and e-Bug Junior and Senior [35-37]
- Game for prescription drug abuse education: CSI Web Adventures [38]
- Game for over-the-counter (OTC) medication safety: Alchemy Knights [39]

Types of Theoretical Frameworks Used to Develop Serious Games for Medication Use

Of the 16 studies, seven used a theoretical model or framework in the game design process. The theories used in each game are mentioned in Multimedia Appendix 1. In *Viral Combat*, the information, motivation, and behavior (IMB) theory was used to promote medication behavior change [26]. *Adherence Warrior*, another game for HIV adherence, was guided by the social cognitive theory. Social cognitive theory goals included increased player self-efficacy, knowledge of HIV treatment goals, and social support [27]. *Battle Viro* was the only HIV-related game incorporating educational modules and did not report a specific theoretical framework or model that guided game development. In *Epic Allies*, the IMB model framework was used to develop objectives of increased ART adherence and social support. In *Re-Mission*, a game for cancer medication adherence, the behavioral objectives were developed based on the social cognitive theory and social learning theory [31]. The social cognitive theory was used to measure patient's confidence in their ability to carry out adherence behaviors to reach a goal [31]. The social learning theory connects medication adherence to a social component such as a multiplayer serious game [31]. *L'Affaire Birman* was a serious game for type 1 diabetes education and did not use a theoretical framework. *Wee Willie Wheezie* had a single medication learning objective of proper inhaler use and used the precede-proceed model, which involves incorporating components such as predisposing, enabling, and reinforcing factors into game development [34]. One published study with an unnamed computer game used the pain and medication model to teach players of any age how to manage activities of daily living through balancing activity level with the quantity of medication taken postoperatively [40]. The theoretical framework used in development was a blend of the middle-range theory of chronic illness, adult learning theory, and the experiential learning theory. The middle-range theory of chronic illness involves reflection and decision making, such as choosing when to take pain medication [40]. The adult learning theory incorporates self-directed learning methods, which is a preferred learning method for adults [40]. The experiential learning theory involves learning through observation, abstract conceptualization, and experimentation [40]. *CSI Web Adventures* used the theory of reasoned action to display the negative consequences of abusing prescription drugs, such as opioids in two separate case studies [38].

Sampling Frames Primary Results

Viral Combat, *Adherence Warrior*, *Epic Allies*, and *Battle Viro* were developed to promote adherence to ART and PrEP [26-30]. The target audience was aged between 13 and 35 years in all HIV-focused games [8,27-30]. Each game used three to four modalities to achieve learning objectives, summarized in Multimedia Appendices 1 and 2.

Viral Combat, an iPhone gaming app published only through the game development phase, incorporated a *Smart Pill Bottle Cap* and text messages to patients aged 18 to 35 years to promote adherence to PrEP [26]. A *Smart Pill Bottle Cap* reports to the app when the medication bottle is opened [26]. A small trial of nine participants showed an 88% satisfaction toward the game, and 100% of the participants would recommend it to a friend [30].

Adherence Warrior, a mobile gaming app for patients aged 13 to 24 years, promoted adherence while maintaining player privacy. Text messages were sent to patients to promote ART adherence [27]. A mixed method study had 12 participants having rank level of agreement on a scale of 1 to 5, with 5 being strong agreement to game characteristics. The study reported a median score of 5 of having fun while playing (P=.03), and players preferred to play games about topics other than the immune system (P=.01) [27]. No statistical significance was found to support whether participants would play the game if it were available or if they would use the game to take HIV medications [27].

Battle Viro, an iPhone gaming app targeted to patients aged 14 to 26 years, incorporated a *Smart Pill Bottle Cap*, text messages, and educational modules. Learning outcomes were to improve ART adherence, increase social support, increase HIV- and ART-related knowledge, and visualize progress. In a randomized controlled trial of 61 participants starting with a detectable viral load, the experimental condition had 23% greater adherence (P=.05) compared with the control group and a 0.96 log greater decrease in viral load (P=.04) [8,30].

Epic Allies was the only HIV medication adherence mobile gaming app that did not incorporate an electronic pill bottle or text messages. The target age for this game was 16 to 29 years [28,29]. The distinguishing modality of *Epic Allies* was a dashboard displaying various lifestyle behaviors, such as smoking, medication adherence, and mood [28]. A sample size of 20 study participants through focus groups supported game acceptability [28,29].

Re-Mission focused on increasing oral chemotherapy adherence and strategizing the use of medications to treat the side effects of oral chemotherapy for people aged 12 to 29 years [31]. Players control a robot, *Roxxi*, with the goal of adhering to oral chemotherapy and combating negative effects through taking medications such as stool softeners and antibiotics [31]. A randomized control trial of 375 participants yielded no significant results for adherence but a 9.8% increase in Trimethoprim and Sulfamethoxazole adherence (*P*=.01) [31] and a significant increase in player's self-efficacy for medication adherence (*P*=.01) [31].

Two studies on one game specifically included a diabetic medication-centered learning objective [28,29]. Target ages in published studies ranged from 10 to 19 years [32,33]. *L'Affaire Birman* was a serious game targeted toward children living with type 1 diabetes [32]. Players used a strategic approach to adjust the game character's insulin based on lifestyle factors such as food intake, physical activity, and glucose levels. With no results or sample characteristics reported, the authors suggested that further testing is needed to assess the effectiveness in the clinical setting [32].

Wee Willie Wheezie, a 3-level computer-assisted instruction program targeted toward children aged 7 to 12 years, had a single medication learning objective of proper inhaler use [34]. The players chose the correct medication to avoid asthma symptoms, exacerbations, and hospital trips [34]. A randomized controlled trial of 148 participants found no significant improvement in player's asthma symptoms or quality of life parameters [34].

In an unnamed game, patients learned safe medication regimens by using the icons in the game to learn about the side effects of each medication. [40]. An evaluation study of 20 participants aged 24 to 67 years found an increase in knowledge on strategies to manage pain (*P*<.001) [40].

e-Bug Junior and Senior were multiple-module educational adventure computer games targeted toward students ranging in age from 9 to 12 years and 13 to 15 years, respectively [35,36]. Each game had one module teaching the purpose of antibiotics and the importance of taking the full course. An evaluation study of 129 students yielded 98% positive comments about the senior game and no efficacy results [35,36].

Microbe Quest was a mobile gaming app targeted to patients aged 9 to 12 years [37]. A single level of gameplay introduced the concept of antibiotic resistance as a consequence of not finishing a full course of antibiotics [37]. No statistically significant results in learning objective retention were found in the initial pilot study of 19 participants [37].

CSI Web Adventures simulated a prescription drug abuse crime scene and took players through the science of forensic analysis [38]. This computer game was targeted toward people aged 14 to 18 years. A sample of 179 players conveyed negative attitudes toward illegal crimes in the baseline and game testing phases [38]. CSI Web Adventures is reported to need more testing before significant results can contribute to specific opioid safety-related learning objectives [38].

Alchemy Knights, a serious game available on the Web, was geared toward ages 9 to 12 years. The game taught players about responsible OTC medication safety, drug-drug interactions, and the consequences of misusing medications [39]. A pilot study of nine participants showed 78% increased knowledge in medication safety from a pretest to posttest analysis [39]. Results will be used to improve the game for future use [39].

Discussion

Overview

This systematic review offers valuable additions to the current evidence-based literature by examining serious games for patients that incorporate medication adherence, education, and safety. Existing systematic reviews explore serious games for health focused on the management of specific disease states, such as HIV, diabetes, and asthma, and on the positive impact of serious game education in each respective disease state [19-24]. Although other reviews target broad topics such as health care gamification and serious games to educate health care workers [7,17,25], no reviews focus solely on examined medication use [7,15-17,19,20]. The identified serious games that incorporate the use of medications are mainly focused on improving adherence, whereas medication safety is not widely explored. In addition, there is a lack of research on the efficacy and usability of medication-focused serious games often because of small and nonrepresentative sample sizes, which limit the generalizability of existing studies. Very few serious games described how theoretical frameworks were incorporated during development, showing an area for improvement in literature [26,28,34]. This systematic review signifies the need for the creation of serious games focused on medication adherence, education, safety, testing of existing serious games for efficacy and effectiveness, an evidence-based theory-driven approach for serious game design, and large-scale testing with randomized samples to improve generalizability.

Medication Incorporation

Each serious game included in this review was analyzed for the extent and quality of medication-related topics. The included games had a medication-related learning objective incorporated into a gameplay feature. Of the 12 unique serious games included in this study, most did not have medication as a principal component. The sole content in *Re-Mission*, *Alchemy Knights*, and the unnamed pain management game were medication adherence, education, and safety, respectively [31,39,40]. ART and PrEP adherence was incorporated in *Viral Combat, Adherence Warrior, Epic Allies, and Battle Viro* through social support, text reminders, computerized pill bottles, and various point incentives [8,26-30]. *Microbe Quest, e-Bug, Wee Willie Wheezie, and CSI Web Adventures* included a single medication-related module [34-38]. Although medication is not extensively incorporated into serious games, this demonstrates a modality of patient education to be explored in the future.

Theoretical Frameworks

Validated social, behavioral, and game theories such as IMB theory, social cognitive theory, precede-proceed model, middle-range theory of chronic illness, adult learning theory, experiential learning theory, and the theory of reasoned action as included in this review are developed and defined iteratively over time. Using these theories for game development and testing can improve the effectiveness of these serious games [26,30]. On the evaluation of the 12 serious games identified in this study, six incorporated varying degrees of theoretical frameworks to support game development and testing. A total of three articles about two serious games extensively focused on IMB theory for game development [26,28,29]. The goal of the IMB model in *Epic Allies* and *Battle Vivo* was to change specific health-related behaviors such as medication adherence through a combination of health education, self-motivation, and gaining required skills [26,28,29]. Game mechanics in *Epic Allies* were designed to motivate ART adherence in young men who have sex with men and long-term game use [28,29]. Another article extensively described the use of the precede-proceed model in game design of *Wee Willie Wheezie* [34]. Two games mentioned the social cognitive theory, and one game mentioned the theory of reasoned action, but neither of them described any specific details about using and integrating the theory in game design and mechanics [8,27,30,38]. Future goals in *Alchemy Knights* indicate examining theoretical contributions for further game development [39]. Although most of the serious games involving theory in their design used small sample sizes for testing their efficacy and effectiveness, positive outcomes were still demonstrated by a few [26,28,38]. A common theme identified was a lack of statistical power to test the efficacy of theory outcomes because of the small sample size or result usability [8,26-30,34,39,40]. Future literature describing serious game development should incorporate more thorough descriptions of the theoretical frameworks used and larger sample sizes.

Medication Adherence, Education, and Safety

Of the 12 serious games included in this study, six focused on improving medication adherence [7,8,26-31,38,40], three targeted medication education [29,32], and three were aimed at providing medication safety [35-39]. Medication nonadherence is a prominent issue in health care, which leads to increased costs and comorbidities. By using innovative approaches to teach patients the value of adhering to medication, serious games can assist in improving medication therapy outcomes. Serious games educating users on medication misuse or promoting safe usage of medication were lacking in the literature. Although the authors recognize that there is a thin line between medication safety and education, there were many more games with education and adherence components when compared with medication safety components such as preventing inappropriate use [36-40]. Future serious games with medication use as a component should incorporate learning objectives targeting medication safety principles to prevent adverse drug events.

Sampling Frames

This study recognizes that the majority of serious games included in this study were tested for usability and functionality with very small sample sizes. Only five of the included studies had more than 100 participants [29,31,34,38]. These small sample sizes limit the external validity of these studies, thus reducing the generalizability of the results to larger populations. In the future, the effectiveness of these serious games must be assessed using larger sample sizes to investigate their impact on patient’s knowledge and understanding about medication adherence, education, and safety.

Regarding geographical distribution of samples used in the studies, only one study included patients from outside of a single state [31], whereas other articles used convenient samples from a single clinic, city, or state [8,26,27,29,30,32,34-38]. By limiting the participants to a single site, geographical location or a specific age group, the external validity of the results from these games is again compromised. Of the 12 serious games, eight were tested in adolescents, three were tested in young adults, and one was tested in adults. Although adolescents benefit from serious games, adults could also benefit from serious games and should be a future area of exploration in serious game usability studies. In the future, more studies with randomized and diverse populations could increase the statistical power of these results.

The published literature on medication-based serious games has a strong focus on game design, mechanics, and methodologies rather than the effectiveness of the game. Of the included articles, seven focused on game design and the plans for future game development without elaboration on outcomes and game efficacy [8,27,29,30,33-36]. A total of four studies focused on the intended outcomes of the games and whether they were met [26,31,37]. The common method of evaluation was surveys on gameplayers’ satisfaction while playing but not the information that they sustained and retained from the games. Quantifying whether learning objectives were met is necessary to determine the success of serious games for future studies. Thus, future serious game design development should include plans for rigorous testing of efficacy.

Limitations

The authors recognize key limitations of this study. First, only 3 databases were used for the literature search. Although the extent of duplicates supported a thorough search, there is a chance that there are relevant papers that were not included. Second, only papers written in English were included. This may have excluded papers from non-English–speaking countries. Finally, small sample sizes were used to test most games included in this study. None of the literature discussed the sustainability of the games post study, and most of the included games did not have long-standing follow-up data on their participants.

Conclusions

There have been limited studies on serious games for health that incorporate medication use. The findings from these studies focus on developing and testing serious games that teach patients about medication use and safety. Most of these studies do not apply a theoretical framework in the design and assessment of these games. The development of serious games for patient medication use, education, and adherence should incorporate evidence-based and theory-driven methods to ensure maximum retention of the learning objectives by study participants and game players. More diverse, randomized studies with long-term data collection need to be conducted to demonstrate the effectiveness of serious games in this area. Serious games have the potential to reduce patients' knowledge gaps and address misconceptions, which may lead to improved medication adherence and reduced errors. This review shows that there has been an increased interest in the application of serious games to improve medication use outcomes, and it is expected that this review will help advance the effectiveness of game development in the future.

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Conflicts of Interest

None declared.

Multimedia Appendix 1
Table 1. Inclusion of medication-focused serious games.
[DOCX File , 18 KB - games_v8i2e16096_app1.docx]

Multimedia Appendix 2
Table 2. Summary of learning objectives and outcomes of serious games.
[DOCX File , 18 KB - games_v8i2e16096_app2.docx]

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Abbreviations

ART: antiretroviral therapy
IMB: information, motivation, and behavior
NIH: National Institutes of Health
OTC: over-the-counter
PrEP: pre-exposure prophylaxis
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
UW: University of Wisconsin

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Original Paper

Experiences of Gamified and Automated Virtual Reality Exposure Therapy for Spider Phobia: Qualitative Study

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Abstract

Background: Virtual reality exposure therapy is an efficacious treatment of anxiety disorders, and recent research suggests that such treatments can be automated, relying on gamification elements instead of a real-life therapist directing treatment. Such automated, gamified treatments could be disseminated without restrictions, helping to close the treatment gap for anxiety disorders. Despite initial findings suggesting high efficacy, very is little is known about how users experience this type of intervention.

Objective: The aim of this study was to examine user experiences of automated, gamified virtual reality exposure therapy using in-depth qualitative methods.

Methods: Seven participants were recruited from a parallel clinical trial comparing automated, gamified virtual reality exposure therapy for spider phobia against an in vivo exposure equivalent. Participants received the same virtual reality treatment as in the trial and completed a semistructured interview afterward. The transcribed material was analyzed using thematic analysis.

Results: Many of the uncovered themes pertained directly or indirectly to a sense of presence in the virtual environment, both positive and negative. The automated format was perceived as natural and the gamification elements appear to have been successful in framing the experience not as psychotherapy devoid of a therapist but rather as a serious game with a psychotherapeutic goal.

Conclusions: Automated, gamified virtual reality exposure therapy appears to be an appealing treatment modality and to work by the intended mechanisms. Findings from the current study may guide the next generation of interventions and inform dissemination efforts and future qualitative research into user experiences.

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KEYWORDS

virtual reality; gamification; serious game; exposure therapy; phobia; user experience

Introduction

Virtual reality (VR) refers to technology that creates an immersive experience of being present in a virtual, computer-generated world. Today, this is typically achieved through the use of a head-mounted display (HMD) with stereoscopic screens that withhold the outside world and allow the user to look around the virtual world by measuring head rotation and adapting the visual presentation accordingly [1]. Until recently, VR was an expensive, inaccessible, cumbersome technology with poor graphical quality that required specialized skills to operate [2], yet innovative clinical applications emerged nevertheless in the 1990s [3]. Over a dozen high-quality clinical trials have since supported the efficacy of VR exposure therapy

(VRET) for the treatment of anxiety disorders [4-6], in which phobic stimuli are replaced with virtual equivalents to perform otherwise typical exposure therapy (ie, graded, systematic exposure under controlled conditions until the fear response habituates or inhibitory learning occurs) [7]. Importantly, this treatment works across age groups [8], the fear reduction in VR generalizes to real-world equivalent stimuli [9], there are low rates of deterioration [10], and clinicians have positive attitudes toward using the technology for therapeutic purposes [11,12].

The recent advent of consumer VR technology presents a paradigm shift in the design and dissemination potential of VRET interventions [13]. In particular, recent research has explored whether this type of intervention can be automated (ie, delivered without any real-life therapist and relying instead on gamification elements). Gamification is commonly defined as the application of traditional game elements, originally designed for enjoyment, to other contexts [14]. Common gamification elements include tasks relying on game mechanics, and reinforcement of progress and achievements through points and badges. When used for an explicit primary purpose other than enjoyment, the term serious game applies [15]. A coherent combination of gamification elements such as onboarding, level design, narrative building, performance feedback, and avatar assistance is inherently well suited to replace many of the tasks otherwise performed by a real-life therapist, meaning that a complete, self-contained serious game can be designed to be played and completed without a therapist directing the intervention, while still containing evidence-based treatment components [16]. To our knowledge, only three randomized clinical trials of automated VRET interventions have been published to date: two for fear of heights [17,18] and one for spider phobia [19]. Although all three studies reported large effect sizes in terms of symptom reduction, none reported on any user experiences beyond providing quotes from four participants on treatment effects [17], system usability ratings and cybersickness scores [18], and common negative effects [19]. A recent single-subject replication trial of the same VRET intervention for spider phobia reported descriptive statistics on app engagement and use, and additionally found no associations (eg, between cybersickness scores and intervention outcomes), although these correlational analyses had low power [20].

Automated, gamified VRET apps constitute a novel merger of gaming and technology with classic psychotherapy, and user experiences will likely be shaped by both technology-specific and therapeutic aspects. Design considerations for such interventions should be informed by a clear therapeutic rationale and preclinical research [13], while also taking user experiences into account so that the interventions are not only efficacious but also appealing. This is particularly relevant for consumer-targeted VRET apps intended for release on ordinary digital marketplaces, which will realistically compete for user time and interest with other apps (eg, pure games). As an example, a first-generation consumer-targeted VR relaxation app had a low degree of recurrent users despite being downloaded over 40,000 times (even in the infancy of consumer VR) and enjoying high ratings on the digital marketplace [21]. This reveals that although the intervention was well-received by a subset of users, most users did not find it appealing enough to use it multiple times. Careful mapping of user experiences may inform design decisions that avoid such outcomes.

Notwithstanding the demonstrated efficacy of VRET and other types of VR interventions for health, both in the automated and traditional format, very little is known about how users experience these interventions. Qualitative research on nongamified VRET has uncovered themes pertaining to the user's sense of presence in the virtual environment, along with factors that break presence [22]. Congruently, previous qualitative research in adjacent fields has revealed that VR allows users to *experience* rather simply perceive different situations [23], and that VR technology has an appealing allure in itself, being exciting, novel, and enjoyable through the inherent feature of creating a sense of presence [24]. To attain a first glimpse into user experiences of undergoing automated, gamified VRET to guide the development of future iterations and quantitative research, we conducted a pilot explorative qualitative interview study in parallel with a randomized controlled noninferiority trial comparing this novel treatment approach to traditional in vivo exposure therapy for spider phobia [19,25].

Methods

Trial Design, Participants, and Procedure

The clinical trial (2015/472-31) and the parallel interview study (2015/1695-32) were approved by the Stockholm Regional Ethical Review Board.

Participants recruited for the interview study had completed the screening battery for the parallel clinical trial [19,25] but were not among the first 100 participants to be scheduled for and complete the on-site pretreatment assessment. Once the clinical trial had reached its recruitment goal, remaining participants were invited to join a reserve list for future similar studies. Ten participants expressed interest in joining a qualitative study entailing the same assessment procedure (before and after treatment), receiving VRET, and completing a face-to-face interview in conjunction with the posttreatment assessment. Among this group, one participant dropped out before the pretreatment assessment, one participant dropped out before the treatment session, and one participant dropped out before the posttreatment assessment, leaving a final sample of 7 participants.

Sample size considerations for qualitative studies is an ongoing topic of debate with little consensus across fields and great variation in the extant literature [26]. The sample size for the current study was upper-bounded by the availability of participants as determined by the recruitment to the parallel clinical trial, and generalization was a priority. The final sample size was deemed to be acceptable owing to the pilot and explorative nature of the study, with an explicit aim of informing subsequent research and a relatively homogenous sample undergoing a fully standardized intervention. Given the former consideration, a lower number of theme instances was deemed to be sufficient, and given the latter considerations, a high sample theme prevalence was to be expected. This meant that the final sample size of 7 was within the realm of acceptability according to guidelines [27], in addition to being in accordance with the minimum acceptable sample size suggested by meta-analyses of published qualitative studies in the field of psychology [26]. The final sample comprised 86% women with a mean age of 36.29 (SD 13.38) years, similar to the demographics of the VRET arm in the clinical trial [19].

Participants completed the same assessment procedure and received the same VRET intervention as in the clinical trial. All three parts took place on site at Stockholm University. Approximately 1 week prior to treatment, participants completed the pretreatment assessment consisting of a standardized behavioral approach test (BAT) [28], a diagnostic interview, and self-rating scales. The BAT featured a real-life, medium-sized spider (approximately 2 cm in diameter including the legs); only harmless varieties common to Sweden (such as *Tegenaria* and Araneidae) were used. The stated goal of the BAT was to enter a room, approach the spider contained in a transparent plastic container, pick it up, and hold it for 20 seconds. Participants were rated on a standardized scale (0-12) depending on how close they came to achieving this objective (see [19] and [29] for more details). The self-rating scale battery included the Fear of Spiders Questionnaire (FSQ) [30], which is an 18-item scale covering different spider phobia symptoms based on a 7-point response format with a theoretical score range of 18-126.

Treatment took place in a single 3-hour session (see below). Approximately 1 week later, participants completed the combined interview and posttreatment assessment (BAT and self-rating scales). Although the exact durations of interviews were not recorded, 15-30 minutes was allocated to the interview part of the posttreatment assessment. All interviews were conducted in Swedish (all participants spoke fluent Swedish, as per the inclusion criteria of the parallel trial) according to a semistructured interview guide comprising the following seven topics: treatment expectations, use of hardware and software, the virtual environment, the virtual therapist and spider expert, gamification elements, exposure elements, and satisfaction and progress. The audio-recorded interviews were conducted and transcribed verbatim by one author (AJ) who is a native Swedish speaker.

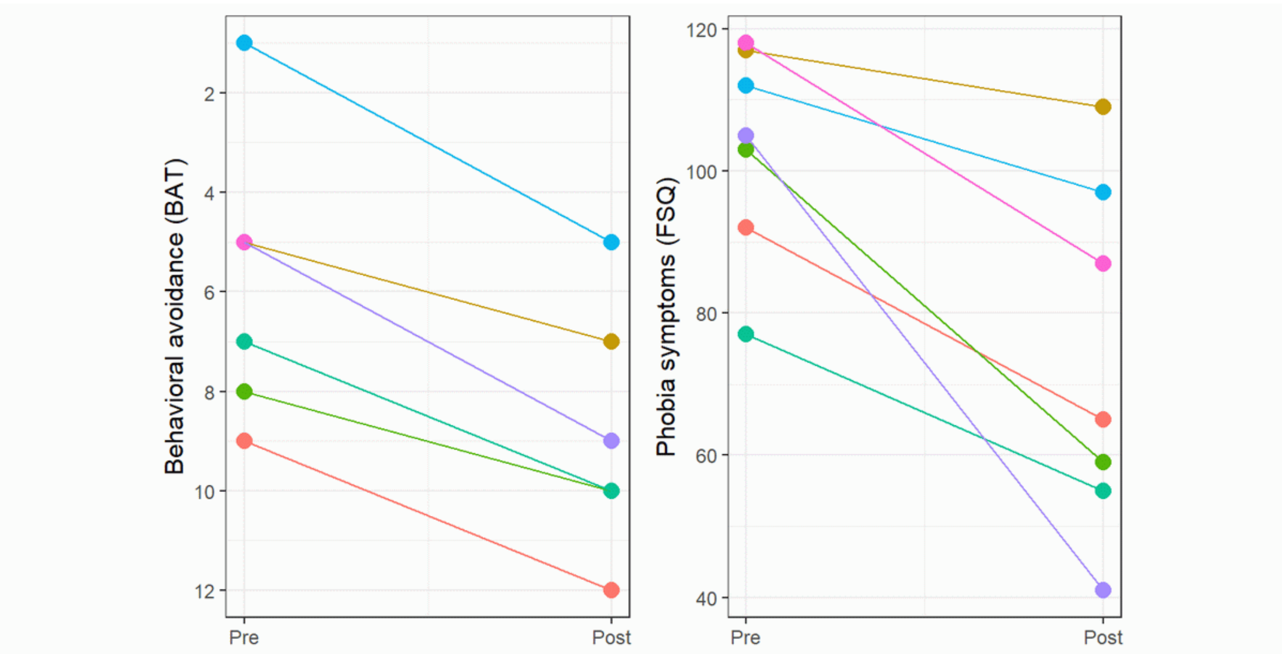
Participants achieved significantly higher BAT scores (reduced avoidance, t_5=–8.22, P<.001) and reported significantly lower FSQ scores posttreatment (t_6=4.23, P=.006), similar to the results of the VRET arm in the clinical trial. Table 1 compares the pre and posttest values in the BAT and FSQ between the present study and clinical trial, and Figure 1 shows a spaghetti plot of the changes for individual participants.

Table 1. Treatment outcomes in the present study and clinical triala.

Time	Behavioral Approach Test, mean (SD)		Fear of Spiders Questionnaire, mean (SD)	
	Qualitative study	Clinical trial	Qualitative study	Clinical trial
Pretest	5.71 (2.63)	4.76 (2.71)	103.43 (14.73)	95.82 (15.26)
Posttest	8.83 (2.48)	8.50 (2.29)	73.29 (24.75)	70.35 (22.45)

[a]Data are from participants in the virtual reality exposure therapy arm in the clinical trial [19].

Figure 1. Spaghetti plots of individual participant treatment outcomes pre and post treatment. Different colors denote different individuals. Left panel: scores on the behavioral approach test (BAT) with a real spider (a higher score indicates less avoidance). The Y-axis is flipped for consistency. Right panel: scores on self-rated Fear of Spiders Questionnaire (FSQ) measuring the fear of spider symptoms (a lower score indicates fewer symptoms).



Treatment

The Itsy app is an automated VRET intervention designed as a serious game around classical exposure therapy elements [31]. The intervention starts with a psychoeducational introduction through a voiceover virtual therapist that conveys a cognitive behavioral conceptualization of spider phobia and provides a treatment rationale for exposure therapy. This psychoeducation takes place in a virtual therapist office with a projector for display purposes [13]. Once completed, the user progresses through 8 levels of exposure tasks, each with 3 sublevels: a simple gaze task (keep focusing on the moving spider to gain points), a game (eg, keep a moving spider safe by stopping objects from hitting it), and “boss” level (keep focusing on approaching the spider or it will turn away). The spider stimuli are increasingly realistic and frightening when progressing across the levels, beginning with a cartoon-looking, smiling spider, and ending with a realistic Black Widow spider. Spider movement animations were designed to be realistic and dynamic (ie, interactive to user behavior and not scripted). All sublevels featured gamification elements along with an overarching gamified structure. Table 2 summarizes the gamification aspects grouped according to a definitional framework derived from a systematic review of the extant gamification literature [14]. At the beginning and end of each sublevel, the user was prompted to rate subjective units of distress using a 0-100 scale. See Figure 2 for representative app screenshots. In addition to the virtual therapist, a voiceover spider expert was also included who presented facts about spiders (eg, descriptions of different spider species along with their biology and role in the ecosystem).

Table 2. Gamification elements included in the intervention.

Gamification element	Description
Dual-purpose game mechanics	All games designed to be both enjoyable and therapeutic, requiring the user to keep their gaze on a moving spider, with or without additional game mechanics. No included first-person movement, to both evoke common fear of invasion of private space by the spider and to avoid cybersickness.
Speed	Moving spider stimuli to evoke a greater fear response and prevent virtual reality-specific safety behavior of closing one’s eyes.
Goals	Clear goals for completion of each sublevel, conveyed verbally or visually.
Performance feedback	Scores displayed at all times and users could replay levels to achieve a higher score.
Badges and achievements	Visual summary of levels completed.
Dual-purpose narrative	Many sublevel games presented with a short narrative on task background and goal.
Points	Scoring key to game mechanic in gaze task and “boss” type sublevels, requiring a certain score to complete.
Levels	Familiar level design with levels and sublevels.
Increasing difficulty	Increasing spider realism with each level.
Onboarding/psychoeducation	First part of game features traditional cognitive behavioral therapy psychoeducation on phobia development and maintenance, and rationale for exposure.
Virtual helper	Voiceover virtual therapist, also presented as hologram avatar in the virtual therapist room, introduced at beginning of game and guiding the user throughout, giving instructions, encouraging progress and achievements, and summarizing key therapeutic points.

Figure 2. Screenshots from the virtual reality exposure therapy (VRET) app. (A) Example of a spider featured in an early, gaze-based level. (B) Example of a gamified exposure task (preventing the spider from being washed off the wall by moving the umbrella using gaze focused on the moving spider). (C) Example of realistic spider in a subsequent, boss-type level. (D) Example of a realistic spider used in higher levels.

The Itsy app was designed for and operated on a Samsung (Seoul, Republic of Korea) smartphone (Note 4 or Galaxy S6) together with a first-generation Samsung Gear VR headset (ie, mobile VR) and inexpensive headphones. At the time, no hand controllers were available for the Gear VR platform; users interacted with the virtual environment via the headset touchpad and a gaze-directed crosshair. Users could pause the app at any time using a physical button on the headset. While automated, treatment was delivered with a "technician" in the room to assist in case of technical difficulties or a severe emotional reaction, as in the parallel noninferiority trial. At the time of data collection, the occurrence of severe emotional reactions was unknown and although not systematically recorded in the current study, only 10% of VRET participants in the parallel clinical trial were provided with qualified support requiring at least some expertise in clinical psychology (eg, discussing and coping with catastrophic beliefs) [19]. The duration of app use and rates of full completion were not systematically recorded in the current study; however, in the subsequent replication trial, all but one participant (96%) completed the full intervention in the same allocated time as in the current study.

Qualitative Analysis

Inductive thematic analysis was used to explore the transcribed interviews in accordance with established guidelines [32]. This method was selected since no tailored theoretical framework exists concerning users' experiences of undergoing automated, gamified VRET for specific phobia. The material was analyzed by one author (AR), who is a native Swedish speaker and a clinical psychologist and researcher with extensive experience of cognitive behavior therapy, internet-based psychological treatments, and qualitative studies, but not of the VR field. AR was not involved in the parallel clinical trial from which the participants were recruited, nor has any financial or other interests in the equipment or software used. No dedicated software for thematic analysis was used.

AR first familiarized himself with the material by repeatedly reading and exploring its content, followed by coding recurrent ideas put forward by the participants. In this case, the coding process can be considered selective [32], as the main purpose of the current study was to explore the expectations, experiences, and outcomes of participants undergoing treatment. The codes can be considered the building block of the analysis: examples such as "feeling unreal," "animated," "pretending," and "no tactile stimulation" reflected the semantic or explicit meaning of the material as no interpretative framework was being used. The codes were then examined consecutively to find possible themes and subthemes, which were further reviewed and refined by revisiting and reexamining the material numerous times, such as "Expectations," "Doubts," and "Lack of expectations."

Results

Thematic Structure

The inductive thematic analysis resulted in 7 themes and 8 subthemes, which are presented in Table 3, along with the covered codes. Representative quotes on each theme are provided below. The quotes were translated into English from the original Swedish by the researcher (AR) that conducted the thematic analysis; validity of these translations was assessed by independent backtranslation into Swedish by another author (PL) and differences were resolved collectively.

Table 3. Themes and subthemes from qualitative analysis.

Themes and subthemes	Codes
Expectations	
Doubtful	Feeling unreal, cartoonish, make-believe, no tactile stimulation, simulated, unreasonable, short duration, too simple, level of fear, duration of phobia, routines, being different, lack of expectations, avoidance.
Hopeful	Feeling safe, easier than the real thing, less afraid, research study, cognitive behavior therapy, providing some relief.
Becoming absorbed	Surprised, engaged, better than expected, forgetting reality, forgetting it is treatment, real movements, realistic, well-done, anxious, scared, crying, scary, reacting, trying to hide, trying to avoid, being focused.
Good enough	Safer than the real thing, good that not too realistic, control.
Simplicity	Thought-through, sympathetic/empathetic, novice, pedagogical, focus, undramatic, gamification, tasks, increasingly more difficult, interaction, generational issue, being a gamer.
Psychoeducation	
Understanding your fears	Calming voice, confronting your fear, subjective units of discomfort, informative, normalizing, fears, expert, assumptions, like school, learning about phobias.
Getting worse	Trying to avoid, negative association, increasing your fear.
Problems and glitches	
Technical issues	Visual perspectives, acuity, lack of details, menus, not real enough, getting stuck, pauses, wrong sequence, stopped working, overheated, battery issues, clumsy, computer errors, restricted movements.
Human issues	Becoming nauseous, difficult exercises, difficult understanding, panicky, time constraints, frustration, contacts and glasses, overwhelmed, without notice, without warning.
Outcomes	
Benefits	Less anxious, less attentive to fears, continued exposure, proud, applications in real life, less worried, approaching spiders, improved, recommending treatment to others, increased knowledge, confident, quick response, not the whole world, seeing things differently, daring, significant others.
Obstacles	Expensive equipment, more information needed, more exercise needed, doing it again, still scared, wrong season.

Expectations

Many participants were doubtful that automated VRET would actually work for their specific phobia and expressed concerns that the treatment did not involve real spiders or any sensory stimuli except for visual representations. Ideas about VR feeling too unreal and cartoonish were also mentioned, and that the treatment might be perceived as make-believe or simulated. Others conveyed skepticism toward what was seen as an intervention that was overly simplistic or too short in duration for something they had been struggling with for years and had become part of their daily routines. Some participants were slightly more optimistic, but believed their fear to be different or too intense in order for VRET to work; others lacked expectations altogether or tried not to think about it so that they would not become fearful.

> *I think I had some, I doubted how it would work since this was something that you know, I've only tried VR a couple of times before and I didn't know how realistic it would feel.* [Participant #1]

Apart from the participants who had some doubts about whether VR would work for them, others were much more positive toward the treatment or believed it would be effective, despite some initial doubts. These participants highlighted the fact that a virtual environment would feel safer than engaging with spiders in real life, making it easier to take the steps necessary to manage their fears, or at least providing some relief. Others pointed out that they were part of a research study that was based on cognitive behavior therapy, which made them more confident that the VR intervention could work.

> *I had quite high expectations, since it was research and because it involved cognitive therapy which I've got great experiences of. So they were quite high.* [Participant #4]

Becoming Absorbed

Once engaged with treatment, most of the participants were surprised by their experiences of the virtual environment. They expressed being absorbed, that it exceeded their expectations, and that they almost forgot that they were seeing things through an HMD. More specifically, several participants described how real the spiders felt to them, especially how the movements of their legs were accurate and made them scared and anxious. A few participants even talked about jumping out of the chair, trying to hide, or crying, while others had a hard time letting the spiders out of their sight because of their fear.

> *Ehm, it wasn't real spiders, you know, but at the same time, it felt very scary because they, it's similar to how they behave in real life.* [Participant #7]

Good Enough

Not all participants were astonished by the virtual environment, complaining about the graphics and stating that it did not seem real. However, they still contended that it worked and was "good enough." Moreover, a few participants said that it was better to use something that is a bit flawed and "sketchy" as it felt safer than exposing themselves to the real object of their fear. One participant even mentioned that it helped her feel in control, thereby allowing her to go through with all of the steps in treatment.

> *It wasn't bad, it was okay, you know. I mean, it could be improved. But it was, basically, good enough for its purpose.* [Participant #3]

Simplicity

One important aspect raised by many of the participants was that the treatment felt simple, well thought out, and pedagogical. In particular, the outline was referred to as easy to grasp even for someone who had no prior experience of cognitive behavior therapy or had never previously used VR. In particular, some participants commented on the tasks in the game becoming increasingly more difficult, that it felt undramatic, and that it even made you feel sympathetic or empathetic toward the spiders. Some liked the fact that the treatment was framed as a game, making you more willing to focus and interact with the virtual environment. One participant noted that this type of outline could be particularly attractive to a generation of gamers who are accustomed to video and computer games.

> *Ehm, I thought it was nice except for when things crashed, but it was simple enough so that you would not just focus on the game but on the interaction with the spider, you know. Yeah, I thought it was great, you know, they increased the levels great, you know.* [Participant #1]

Psychoeducation

One feature of the treatment involved receiving psychoeducation from a voiceover therapist about specific phobia and managing anxiety through exposure. A male voice acted as a virtual therapist while a female voice acted as an expert who provided more general information about spiders. Some participants said that they enjoyed this support as it made them understand their fears better. In particular, they emphasized the calming nature of the virtual therapist and that the psychoeducation was informative and normalizing. A few participants mentioned that they liked exploring their beliefs about spiders and testing them out in VR, while others felt helped by labeling their anxiety level using subjective units of discomfort and rating whether their anxiety level increased or decreased during treatment, both of which were instructions provided from the voiceover therapist. One participant described the support as similar to being in school again, but learning about your worst fears and how to deal with them.

> *Yeah, and you also got to know a lot about spiders, that was really good, nice and calming voice that talked about spiders. That felt really great. So she could have talked some more.* [Participant #2]

However, not all participants experienced the voiceover therapist in the same way. Some felt annoyed by the voices and tried to focus on what was in front of them instead. Others started experiencing the female voice (the spider expert) negatively as the information she provided covered topics they were fearful of. To some extent, hearing about their worst fears made the anxiety worse.

> *No, for the most part I didn't listen, I wasn't interested in knowing, and then during level six, I think, I just felt that it was annoying that she kept going on, because I was really afraid, and got even more afraid when she started talking about 3000 babies, and I thought, I don't want to listen to that to be honest. It all just became too much.* [Participant #5]

Problems and Glitches

Some problems were encountered during treatment, with several participants complaining about technical issues that either interfered with their engagement in the virtual environment or put everything to a halt. Some of these issues were related to the milieu they were in, such as visual perspectives or the visual acuity being off-putting, or that the details were all wrong and did not feel real enough. Others complained about menus in the game not working, that they got stuck during one phase or another, or that the sequence of tasks did not seem correct, such as when one level induced less fear than those they had already passed. Most participants also brought up the fact that the HMD stopped working completely, overheated, had battery problems, or that the software crashed altogether, which paused treatment for some time. Moreover, a few participants were frustrated by the equipment, which they described as being clumsy and restricting their movements.

> *Yes, that's the thing, I had a stroke of bad luck, it crashed on me and the therapist said that this hadn't happened before, not when he'd been using it, yeah, it was a bit problematic, it asked for some battery and then it just, it stopped and froze sometimes.* [Participant #4]

However, other difficulties were related to human issues, or that certain aspects of the treatment created problems for some participants. One of the most recurrent complaints was related to becoming nauseous after being in the virtual environment for an extended period of time, which meant that it was necessary to take a break. Others brought up aspects such as not being able to see things clearly because they were unable to wear their glasses in the HMD or that their contact lenses interfered with specific visual elements. A few participants also felt overwhelmed and panicky by some components in treatment, such as when spiders emerged in the game without notice or warnings. In addition, several participants had trouble understanding certain parts of the treatment, including how to rate your anxiety level or what to do in some levels of the game. One participant also complained about the length of the treatment, referring to time constraints in her personal life and feeling frustrated about the duration of several exercises she needed to complete in order to pass to the next level:

> *No, I just felt stupid when I was supposed to help one of the spiders from being hit by a ball, I sat there for ages, I was just like, I don't understand!* [Participant #6]

Outcomes

Overall, participants were able to describe a number of benefits from undergoing the treatment, ranging from being less anxious, worried, and attentive to their fears to continuing applying the lessons they had learned such as using exposure and to approach spiders in everyday life. These participants described themselves as improved and more confident about managing difficult situations, as well as knowing more about what their fears were and how to deal with an episode of anxiety. Some participants also talked about seeing things differently, such as when referring to their own responses as normal and that it would not be the end of the world if they became anxious when seeing a spider. A few participants even brought up the fact that their significant others such as a partner had noticed a change and were praising them for being more daring in situations they previously would have avoided altogether.

> *I believe it's better, I'm still no friend of spiders, but it's like when I went over to visit my sister recently, there was a spider there, which I looked at, but it was dead and just lied there. I didn't remove it immediately, I just let it be.* [Participant #7]

However, not all participants were quite so content with their outcomes. Some mentioned needing further treatment and wanted to have another session with VR. These participants argued that they needed further exercise and more information about how to deal with their fears, referring to several episodes in their daily life when they became overwhelmed and cried when seeing a spider. Continued practice also proved to be difficult for some participants, as a change in seasons from summer to winter made it impossible to find spiders where they lived. One participant was also skeptical about the dissemination of VRET to a wider audience, highlighting the fact that the hefty price tag of an HMD would deter a lot of people from using this type of treatment by themselves.

> *But I cry and scream, oh man, it's so bad, it's really awful to feel this way. Going up in the middle of the night, I have to turn on the lights everywhere so that I don't miss a spider. It's difficult, and you also feel stupid, because I know that they're not dangerous.* [Participant #2]

Discussion

Principal Findings

To our knowledge, this is the first study to use qualitative methods to examine user experiences of undergoing automated, gamified VRET. Using inductive thematic analysis, we recovered several extant topics and open research questions in the field of clinical VR research, and also uncovered novel themes that may guide future quantitative research into the design of VRET interventions and the moderators and mediators of successful outcomes.

Several distilled themes, subthemes, and codes were related directly or indirectly to the sense of presence in the virtual environment [33]. Overall, the app appears to have evoked a strong sense of presence, in some cases to the surprise of the user. Meta-analytic research has confirmed a robust but relatively weak association between self-rated distress and sense of presence during exposure [34]; however, the precise nature of the association, and in particular the direction of causality [35], remains poorly understood. A smaller, single-subject replication trial on the same VRET intervention featured in the current study found no correlation between intervention outcomes and presence rating [20]. Presence is a potential moderator or mediator of intervention effects in VR for mental health. In VR relaxation [21] and VR pain management [36], presence is likely a mediator of intervention effects due to the inherent correlation with distraction from the outside and inside world, the mechanism through which the intervention is hypothesized to work. In VRET, presence is likely a moderator of intervention effects: an adequate sense of presence could arguably be considered a prerequisite for evoking a fear response that can then be attenuated through the same mechanisms as in traditional exposure therapy [37]. Congruently, reported correlation coefficients between presence and pain are typically of stronger magnitude than those reported between presence and distress during VRET [34,38,39]. However, distress in itself has been found to increase presence in VRET [40]. More psychometric research is needed to better separate distress and presence during VR exposure as two separate constructs, which would facilitate in-depth experimental research on how sense of presence moderates experiences during exposure and subsequent outcomes. Using behavioral measures of presence [41] in future research, as opposed to the typical self-reports, may also help to resolve this elusive question.

Further related to the issue of presence, several participants mentioned how realistically the spider locomotion was recreated in the app and how this increased distress. Locomotion-related aspects do indeed appear to be the primary fear-inducing characteristics of spiders [42], revealing the importance of carefully surveying and capturing the fear-relevant aspects of phobic stimuli when developing VRET interventions in order to evoke a strong fear response and sense of presence. Further, several distilled themes and codes concerned threats to presence. Replicating prior qualitative research on VRET [22], technical problems emerged as a prominent theme. In the subsequent replication trial, participants reported comparatively few instances of severe technical issues (sample average app restarts 0.3, SD 0.56, due to overheating for example) [20], although instances of minor technical issues remain unknown. Research on this aspect is difficult due to individual differences in thresholds: even though technical issues could be detected and logged automatically, such issues may be perceived very differently by different users. Some of the issues raised in the current study are generic to the VR field (eg, glitches, bugs, and other software issues), whereas others appeared to be specific to the mobile platform type or even the specific device model used. Compared to tethered VR platforms, mobile VR devices are computationally limited, resulting in lower graphical quality (eg, codes "lack of detail" and "not real enough"). Mobile VR devices also require recharging and are significantly more prone to overheating. It should be noted that mobile VR devices that can accommodate glasses, have higher-quality graphics, and with better battery and heat dissemination capacities have been released since the time of data collection for the current study. Thus, the presentation of this theme and subtheme will likely change over time.

Technical problems are also indirectly related to sense of presence, which in VRET research has typically been measured as a numeric construct at specific time points, with the implicit assumption that the underlying experience can be adequately captured by a measure averaged across some duration. However, it is also possible that measurements at a higher temporal resolution would reveal considerable fluctuations within a distressing task, perhaps even appearing as a near-binary variable since presence is easy to break rapidly, combined with a rapid (new) fear response that is evoked by even minor variations in engagement or stimulus behavior (eg, a still spider suddenly moving). By contrast, technical problems such as overheating and obvious glitches will likely immediately break presence and two occurrences can be sufficient to condition the user to expect more, thereby also attenuating presence in between occurrences. Preventing such issues should be a development priority; however, as evident by the large effect sizes observed despite their occurrence, it need not be catastrophic for outcomes (at least on a group level). Another possible and likely source of rapidly decreasing presence is deliberate safety behaviors. Subtle safety behaviors are common with in vivo exposure therapy [43] and are likely to also occur in VRET, although, to our knowledge, this has not been studied systematically. Deliberately decreasing one's sense of presence (eg, by focusing on glitches or leaking light) would likely function as a potent, VR-unique safety behavior. Thus, from measurement error alone—distress and presence not being fully disentangled measurements—rapid fluctuations in presence during an exposure task are likely to occur. Future research should attempt to measure presence at a higher temporal resolution, combined with objective measures of technical issues (such as glitches) and safety behaviors (eg, gaze directed away from the phobic stimulus), and statistically model possible causal scenarios.

With respect to VR-unique safety behaviors, participants in the current study mentioned several advantages of VRET, some of which are directly related to what would otherwise be considered an issue of low sense of presence; for example, codes like "feeling safe," "easier than the real thing," and "less afraid" reveal that a subset of users were not fully immersed, but that this was not necessarily detrimental to the therapeutic process. Recent empirical research has challenged the long-held assumption within the exposure therapy field that safety behaviors are always detrimental to treatment [44,45]. By inherent design, gamified VRET may be an appealing compromise that offers the user full control in what is expected to be a less distressing experience. Indeed, some research suggests that individuals with phobias show a preference for VRET over in vivo exposure therapy when given a choice [46,47], although it is uncertain to what degree this functions as an avoidance behavior. Future research should examine the role of pretreatment preferences and the occurrence of VR-specific safety behaviors, along with the correlations with outcomes.

As another aspect related to threats to presence, participants in the current study discussed the lack of tactile stimulation (exposure) as a source of skepticism toward the treatment. In an in vivo exposure scenario, touching and holding a spider are among the final steps of treatment [48], a therapeutic ingredient that could not be mimicked in the VRET intervention examined (limited by the consumer technology available at the time), which could partially explain the superiority of in vivo exposure in the clinical trial [19]. Although early research suggested that tactile augmentation of VRET increases the sense of presence, perceived realism, and led to better treatment outcomes [49], subsequent research has failed to replicate these findings [50], leaving an open question to be examined in future research. Of note, since all modern VR platforms feature hand controllers, or even camera-based mapping of actual hand movements, it is now possible to have users experience having virtual hands synchronized to actual hand movements. Future research should examine whether relying on phenomena akin to the Rubber Hand Illusion [51] (eg, seeing a virtual spider crawling up one's virtual arm) has similar augmenting effects as tactile stimulation (if any) while being logistically easier to deploy until consumer VR hardware platforms integrate tactile stimulation.

Surprisingly, the specific lack of a real-life therapist did not emerge as a theme or even subtheme, and few individual codes were directly associated with the virtual therapist, indicating that the automated format per se did not stand out as a prominent topic. Although we cannot rule out the possibility that this was due to the pilot nature of the study (no study on automated VRET had been published at the time), an inadequate level of detail in the semistructured interview guide (which did however explicitly cover the virtual therapist), or interviewer decisions during the interview, another plausible interpretation is that the automated format was simply perceived as natural and that the gamification elements were successful in framing the experience not as psychotherapy devoid of a therapist but rather as a serious game with a psychotherapeutic goal. Codes such as "forgetting it is treatment," "well done," "pedagogical," "tasks," and "increasingly more difficult" indicate that the intervention succeeded in blending classic exposure therapy elements (such as psychoeducation and progression along a fear hierarchy) with gamified elements. These qualitative findings thus complement previous quantitative research revealing the high efficacy of automated VRET [17-19] in showing that these interventions are also perceived as appealing. Interestingly, all three studies on automated VRET [17-19] have included a virtual therapist in some format. Recent research has shown that users can develop a relationship similar to a working alliance with either the VR intervention itself [52] or a VR therapist [53]. Participants in this study reported appreciating the calming voice of the virtual therapist, and indicated that it helped them understand their fears better. However, it remains unknown whether the alliance to a virtual therapist has a direct causal role or simply functions as a reminder of the therapeutic context of the serious game. Although initial research has revealed a correlation between alliance and outcomes [53], future randomized controlled trials must experimentally manipulate the availability and format of the virtual therapist to obtain firm conclusions about the therapist's causal role in automated, gamified VRET outcomes.

Strengths and Limitations

The current study has both methodological strengths and limitations that should be recognized. First, participants responded to open-ended questions during an interview that was conducted by someone not directly involved in the provision of their treatment. This may have helped them to express their opinions more freely, while also providing more detailed and vivid information than relying solely on survey questions. Nevertheless, given that participants were recruited from those seeking participation in a clinical trial, some participants might have been reluctant to provide more negative views of their experiences due to social desirability effects. Second, providing a transparent and step-by-step description of the analytic process increases the credibility of the results; that is, to what extent any conclusions and inferences made from the interview material seem trustworthy and whether the procedures involved can be replicated. However, the current study did not include a second, independent coding of the material, entailing that the reliability of the uncovered themes is unknown. Third, this pilot study featured a relatively small sample size of 7 participants, which, although justified conceptually and in line with minimum sample sizes in the greater extant literature [26], imposes limitations as to interpretation of the findings. Influential empirical research on theme saturation suggests that although theme fundamentals emerge by 6 interviews, saturation occurs after twice that amount [54]. For this reason, we believe that although this pilot qualitative study is a first explorative attempt to map user experiences of VRET resulting in a preliminary set of themes and subthemes, it is not unlikely that other, low-prevalence themes were not uncovered and that the material may not have been thematically saturated. Therefore, future qualitative work should further explore the themes uncovered in a larger and more diverse sample. In addition, some objective measures describing similarity of experiences such as the exact intervention duration, progress (ie, levels completed), experienced difficulty, and interactions with the technician were not systematically recorded in the current study; however, the intervention itself and format of delivery were highly standardized, which should increase similarity of experiences. Fourth, the issue of transferability in qualitative research is also an important consideration, referring to the extent to which the findings are applicable to another setting or circumstance [55]. Similar studies on participants undergoing other automated, gamified VRET interventions should be conducted to confirm that the themes that emerged in the current study hold true to the larger field of automated, gamified VRET. This includes experiences related to undergoing VRET in complete solitude [20], both in clinical and home settings. The physical presence of a technician during the automated treatment in the current study may have had an impact on user experiences, although none of the uncovered themes beyond technical difficulties directly alluded to an aspect related to the role of the technician. This of course does not exclude the possibility that novel themes could be uncovered from users undergoing VRET in complete solitude.

Conclusions

Gamified, automated VRET appears to be perceived as an attractive treatment modality by users, despite the inherent distressing nature of exposure therapy. The gamification elements appear to have been successful in framing the experience not as psychotherapy devoid of a therapist but rather as a serious game with a psychotherapeutic goal. A high sense of presence, as well as threats thereto, were discussed as both beneficial and detrimental to usage. Future quantitative and qualitative research is needed to further examine these topics and associations with outcomes, as to inform the next generation of automated VRET apps and achieve a positive public mental health impact.

Conflicts of Interest

WH is the founder of the private company (Mimerse AB) that developed the Itsy app used in this study, which was subsequently released as a commercial app on a VR digital marketplace but does not generate revenue for Mimerse AB. WH was not involved in data collection, analysis, or any decision related to publication of this article. PL has received consulting fees from Mimerse AB but has no financial stake in the company, and was not responsible for analysis. The other authors declare that they have no competing interests.

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Abbreviations

BAT: behavioral approach test
FSQ: Fear of Spiders Questionnaire
HMD: head-mounted display
VR: virtual reality
VRET: virtual reality exposure therapy

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Original Paper

Development and Feasibility Testing of a Video Game to Reduce High-Risk Heterosexual Behavior in Spanish-Speaking Latinx Adolescents: Mixed Methods Study

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Abstract

Background: Similar to broader health disparities, Latinx adolescents have higher rates of high-risk sexual behavior resulting in pregnancy rates that are 2 times higher and sexually transmitted infection rates that are 5 to 8 times higher than non-Hispanic, white adolescents. Novel approaches are needed to reduce high-risk sexual behavior among Spanish-speaking Latinx adolescents who represent the fastest-growing group of US immigrants.

Objective: This study aimed to partner with Spanish-speaking Latinx adolescents in a participatory design process to develop and test a Spanish-language video game intervention to decrease high-risk heterosexual behavior.

Methods: This is an iterative, two-phase, mixed methods study. In phase 1, we conducted focus groups with Spanish-speaking Latinx adolescents to elicit feedback on the content and format of an existing English-language video game. Feedback was then incorporated into an expanded and culturally adapted Spanish-language video game. In phase 2, we pilot tested the feasibility, acceptability, and preliminary efficacy of the new Spanish-language video game intervention by measuring known antecedents to sexual behavior (intentions, self-efficacy, risk perception, and knowledge) assessed at enrollment and 12-week follow-up. We applied a thematic analysis to examine focus group feedback and a bivariate analysis to analyze pre- and postquantitative data.

Results: In phase 1, 15 Spanish-speaking Latinx adolescents provided feedback for further video game development. A Spanish-language video game was then produced and tested in phase 2. We recruited and enrolled 24 Spanish-speaking Latinx adolescents aged 15 to 17 years. Participants played the video game for an average of 4.2 hours during monitored sessions. Pilot testing demonstrated feasibility and acceptability; 65% (3/20) of participants stated that they would play it again, and 65% (3/20) said they would recommend it to friends. Condom-specific knowledge did significantly increase between baseline and follow-up (*P*=.007). Other variables of sexual behavior antecedents did not differ significantly between baseline and 12-week follow-up.

Conclusions: An iterative participatory design process in partnership with Spanish-speaking adolescents produced an innovative and acceptable Spanish-language video game intervention aimed at decreasing high-risk sexual behavior in adolescents. Pilot testing demonstrated preliminary feasibility and yielded essential information for further video game development.

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KEYWORDS

adolescent; Latino; Latina; sexual activity; video game

Introduction

Background

Adolescents are susceptible to high-risk sexual behaviors, such as having vaginal intercourse without a condom, multiple sexual partners, and intercourse under the influence of drugs and alcohol. Such behaviors expose individuals to an increased risk of sexually transmitted infections (STIs) and unintended pregnancy [1]. However, not all adolescents are at the same risk for these behaviors and consequences. Health disparities account for marked variations in rates of STIs and unintended pregnancy among different subgroups of teenagers. Latinx adolescents are a high-risk population for STIs and unintended pregnancy. Chlamydia rates for Latina adolescents are 17.8 per 1000 adolescents compared with 14.3 per 1000 white female adolescents [2]. Latino adolescents also have higher rates of chlamydia compared with white male adolescents, 41.4 versus 26.6 per 1000, respectively [2]. Although the pregnancy rate among Latina adolescents is lower than the pregnancy rate in non-Latina black adolescents, it is significantly higher than the pregnancy rate in non-Latina white adolescents; there are 61 pregnancies per 1000 Latina teens, 76 pregnancies per 1000 black teens, and 30 pregnancies per 1000 non-Latina white teens [3].

Understanding the experiences of the US Latinx adolescent community is vital, given that Latinx adolescents currently contribute to the fastest-growing group of immigrants in the United States [4]. According to the 2010 US Census, Hispanics comprise 16.3% of the population [4]. Of note, the terms *Latino* and *Hispanic* are often used interchangeably. The US Census defines “Hispanic or Latino as a person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin regardless of race” [5]. Neither of these terms include the current language spoken, and over 50% of Hispanic adults do not have a preference for being identified as either Latino or Hispanic [6]. In this paper, we used Latino to refer to our target population. For references to population data, such as the US Census, we used the term that was used in the survey. Between 2000 and 2010, the Hispanic population grew by 43%, of which 23% are aged 17 years or younger—a 39% increase over the last decade [4]. Millennial age and younger Latinx adolescents are increasingly more proficient in English; however, 90% still speak Spanish as their primary language at home [7]. Given these demographic changes, it is increasingly important to consider language preference and cultural context when designing health interventions for Latinx adolescents.

Existing public health efforts to decrease high-risk sexual behavior among adolescents are informed by an epidemiologic and cultural understanding of risk factors. Conventional interventions are often delivered within school-based curricula or self-directed learning modules. Recently, there has been a pressing need to diversify approaches aimed at decreasing adolescent high-risk sexual behavior and a call for creative solutions [8,9]. Technology in the form of video games provides an ideal avenue to reach teens: according to the Centers for Disease Control and Prevention (CDC) Youth Risk Behavior Surveillance survey, 41.7% of high school students reported playing a video game, computer game, or using the computer for nonschool purposes for 3 or more hours per day [10]. About 50% of youths reported playing video games daily [11]. The emerging science of serious games, defined as video games for purposes other than just entertainment, holds a special potential to promote healthy behaviors among teenagers [11,12]. Through interactive simulations, serious games offer adolescents the opportunity to practice decision making (eg, whether to use a condom) and experience consequences (eg, positive pregnancy test) in safe, virtual learning environments. A recent randomized controlled trial in young (mean age 12.9 years), minority adolescents showed that an interactive serious video game led to improved sexual knowledge and sexual health attitudes [13]. Similarly, a pilot study to create and test an English-language video game among black and Latinx adolescents to target known antecedents of high-risk sexual behavior showed improvements in sexual knowledge, self-efficacy, and risk perception [14]. Latinx participants in the English-language pilot study suggested developing an expanded and culturally adapted Spanish-language video game to meet the needs of the growing Spanish-speaking Latinx population in the United States [14], which formed the basis for this study.

Objectives

We designed a 2-phase pilot study in direct partnership with Spanish-speaking Latinx adolescents. In phase 1, we conducted focus groups with Spanish-speaking Latinx adolescents to elicit feedback on the existing English-language video game [14] and employed a participatory design to develop an expanded and adapted Spanish-language video game aimed at addressing high-risk heterosexual behavior to include content that was culturally relevant and responsive to Latinx teens. In phase 2, we pilot tested the feasibility and acceptability of the new Spanish-language video game intervention among Spanish-speaking Latinx adolescents aged 15 to 17 years. We also evaluated the video game’s preliminary efficacy by examining antecedents to and actual high-risk sexual behaviors among Spanish-speaking Latinx adolescents. This paper aimed to describe the development and feasibility testing of this video game to reduce high-risk heterosexual behavior in Spanish-speaking Latinx adolescents.

Methods

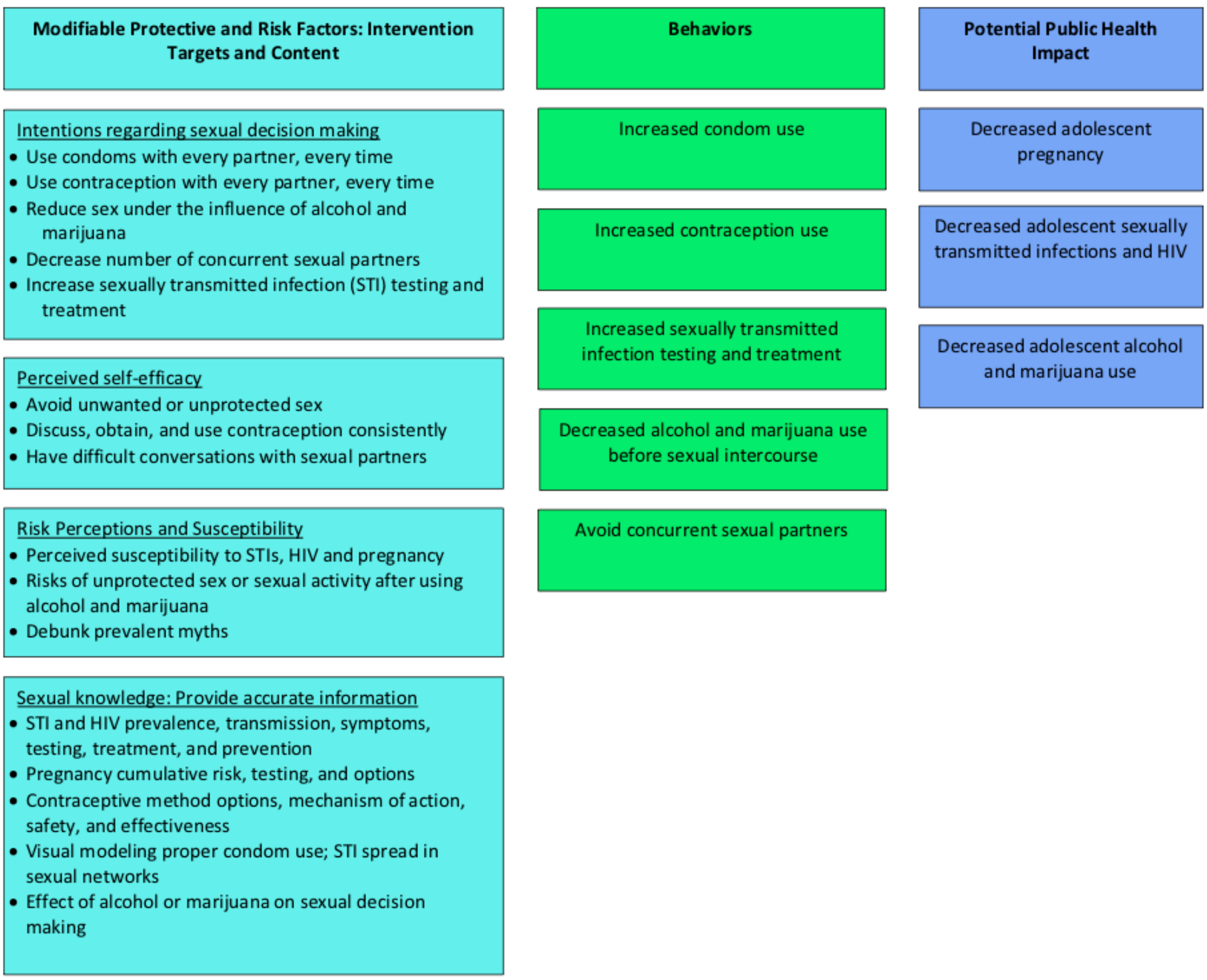
Study Design

We conducted a pilot study with a mixed methods design that built on an existing English-language video game prototype utilizing a theory-driven framework (Figure 1) to target known antecedents of adolescent sexual behavior. This framework [15-17] triangulates strategic components of 3 theoretical models to effect behavior change by targeting modifiable protective and risk factors associated with adolescent sexual risk-taking behavior, including improving intentions regarding sexual decision making, perceived self-efficacy, risk perception and susceptibility, and sexual knowledge [15-38]. The Theory of Planned Behavior posits that an individual’s *intention* to engage in a specific behavior predicts that behavior. The Health Belief Model stresses the importance of individuals’ *self-efficacy* to accomplish a given behavior, *perceptions of susceptibility* to a given health problem, and *knowledge* of and beliefs in the effectiveness of an intervention. The Social Cognitive Theory proposes that knowledge is insufficient to change behavior and emphasizes that observational learning, such as seeing modeled behavior and its consequences or, more importantly, providing individuals with the opportunity to practice skills (as can occur in video game simulation), may enhance behavioral change. An adolescent brain development theory, namely emotional and social self-efficacy [25] and impulsivity (sensation seeking, negative urgency, positive urgency, lack of premeditation, and lack of perseverance) [30], was also incorporated into our design. This theoretical foundation and its key intervention targets, which have been shown to improve black and Latinx adolescent sexual risk-taking behavior (eg, increased STI testing and treatment) [17-38], informed the video game intervention framework and content (Textbox 1).

The existing English-language video game previously was developed and tested with black or Latinx adolescents aged 15 to 17 years, who suggested that the video game setting be a party scene populated by avatars (ie, a digital representation of a person playing the game) [14]. The player then makes decisions for multiple avatars (eg, the Hand of God viewpoint) that simulates decision making in real-life scenarios regarding alcohol or marijuana use, sexual activity, and use of condoms and/or other contraception. Finally, the video game modeled short- and long-term consequences of decisions regarding sexual behavior, such as STI acquisition and pregnancy [14].

This study was conducted in 2 phases: a formative phase (phase 1) and a testing phase (phase 2). During phase 1, we conducted focus groups with Spanish-speaking (English-proficient) Latinx adolescents to modify and shape the existing English-language video game with maximum input from our target audience. Then the video game was adapted and modified in response to participants' feedback and suggestions. In phase 2, we evaluated the following aspects of feasibility and acceptability of the gameplay experience: usability, engagement, satisfaction, game completion, and preliminary efficacy.

Figure 1. Focused logic model.



Textbox 1. Description of framework and content of Colegio del Sexperto (Sexpert High School), a video game intervention to reduce high-risk sexual behavior in Spanish-speaking Latinx adolescents.

- Type of video game: role-playing, simulation, educational
- Player's objective: Become a sex expert (sexpert). Unlock information and answer trivia to gain points, accumulate avatars, and reach higher video game levels
- Video game design:
  - *Party*
    1. Game starts at a party where player controls multiple avatars (digital representations of partygoers), conversing, making decisions
    2. Player guided to unlock key information about sex and answer trivia questions, both of which earn points
    3. Player makes decisions for avatars regarding alcohol/marijuana use, sex, using a condom and/or effective contraception
    4. If player uses alcohol or marijuana, a condom and/or effective contraception may not be available
  - *Party results*
    1. For every avatar that was sexually active, player spins a wheel to view the consequences of decisions, including possible pregnancy (based on the use of alcohol, marijuana, condom, or other contraception use)
    2. Player is presented with a choice to go to a clinic for sexually transmitted infection (STI) testing and/or to discuss and choose contraception
    3. After receiving test results, the player is led to a conversation with a sexual partner to discuss results and any concerns
  - *Advancement*
    1. Advance to next level, gain more avatars, have options to get STI testing, and obtain condoms and/or contraception before the next party
    2. Presented with new scenarios and choices at the next level, as mentioned earlier
- Video game content: Known antecedents to sexual behavior including intentions, self-efficacy, risk perceptions and susceptibility, and knowledge
- Components targeting behavior change:
  - Skill building via simulations of difficult discussions about sex and decision making in scenarios like real life
  - Modeling short- and long-term consequences of decisions (eg, contraception use and STI testing and treatment)
  - Incentivization by earning points within the video game
- Transferrable skills:
  - Communication: discuss whether to have sex, sex refusal, contraception negotiation, and HIV/STIs and pregnancy testing and results
  - Evaluating risk: how the use of alcohol and marijuana can influence sexual risk taking
  - Decision making: communication, take pregnancy tests, STI testing and treatment, and condoms and contraception
  - Problem solving: where and how to obtain pregnancy tests, STI testing and treatment, and condoms and contraception

Recruitment

We partnered with a racially, ethnically, and socioeconomically diverse public high school in New Haven, Connecticut. Participants were recruited through flyers at the school and during presentations in English as a second language classes. Enrollment criteria for both phases included female or male adolescents who identified as Latino or Hispanic, aged 15 to 17 years, fluent in Spanish, and proficient in English. There were no enrollment criteria related to prior sexual experience. In phase 1, only nonidentifying demographic information was collected. Parents were notified of their adolescents' desire to participate in the study and were given the chance to decline participation on behalf of their children. Verbal assent from adolescents was required for participation. In phase 2, potentially identifying demographic information was collected, and both parental and adolescent written consent was required for participation. The study protocol was approved by the Yale University Human Investigation Committee and was granted a certificate of confidentiality from the Department of Health and Human Services to guarantee the protection of participants' privacy.

Formative Phase—Phase 1

Bilingual moderators trained in conducting focus groups facilitated all phase 1 focus group sessions, which lasted approximately 75 min each. Focus groups were conducted separately by those of self-identified same gender to maximize comfort, minimize self-consciousness, and encourage open discussion [39]. First, participants spent 30 min playing the English version of the video game on individual tablets; this was followed by a group discussion until thematic saturation was reached across multiple focus groups. We used a semistructured interview guide comprising open-ended questions to lead the discussion. Questions explored adolescents' attitudes and perceived social norms regarding drug and alcohol use, sexuality, monogamy, fidelity, pregnancy, contraception, and abortion, and also attitudes toward and experiences with romantic relationships, decision making with respect to sex initiation, drug and alcohol use separate from or concomitant with sexual encounters, use of contraception and/or STI protection, and the issue of who has control in romantic relationships and why [1,19,34]. We also assessed participants' interest in playing a video game designed to improve knowledge about the implications of sexual behavior and drug use and to simulate and practice decision making in a virtual setting and explored culturally relevant content and video game features that would be responsive to Latinx teens. We audio-recorded interviews that were translated and transcribed by native Spanish speakers. We analyzed transcripts using a thematic analysis to identify key themes and specific domains of impact [40,41].

Testing Phase—Phase 2

Adolescents participating in phase 2 played the video game weekly at monitored 1-hour sessions for a total of 6 weeks. Video gameplay was done individually on personal tablets. Participants were encouraged not to talk or interact during video gameplay time and were monitored to ensure individual, independent gameplay. Tablet devices were numbered, and participants were given the same tablet each time they played. Self-administered, paper survey assessments were given at 3 time points: upon phase 2 enrollment, immediately after the last gameplay session, and at 12-week follow-up. We collected baseline demographic information at the time of enrollment. Given the short time frame of the study period and small sample size of the pilot study, preliminary efficacy of the video game was assessed with variables known to be antecedents of high-risk sexual behavior including intentions, self-efficacy, risk perceptions, and sexual knowledge. These were assessed at the time of phase 2 enrollment, immediately after the last gameplay session, and at 12-week follow-up. We also collected data on actual sexual behaviors such as frequency of intercourse, condom use, contraception use, number of partners, intercourse under the use of drugs and alcohol, and diagnoses of STIs and pregnancy at enrollment and follow-up. Survey questions came from validated tools, including the CDC Youth Risk Behavior Surveillance, the safer sex intention scale, and self-efficacy for negotiating condom use [42-44].

Video game acceptability and feasibility were assessed with qualitative and quantitative data. Qualitative feedback was collected during focus groups after the completion of gameplay. A total of 4 focus groups were conducted by the same bilingual moderators as in phase 1 and were audio-recorded, translated, transcribed, and analyzed using a thematic analysis to identify key concepts. Quantitative data on gameplay acceptability and feasibility, including how long each participant played for, maximum game level reached, and the number of sessions attended were collected as part of the survey following the completion of gameplay. Additional quantitative survey data were collected following the completion of gameplay and 12 weeks after exposure to the video game to assess video game visual acceptability, like/dislike of the video game, connection to the avatars, frustrations with the video game, and desire to play the video game again or recommend to friends.

Statistical Analysis

We assessed demographics and participant characteristics using descriptive statistics. The preliminary efficacy of the video game was assessed by examining mean summary scores for intentions, self-efficacy, risk perception, and knowledge. Individual questions were measured using 5-point Likert scales where 4=I strongly agree, 3=I agree, 2=I am not sure, 1=I disagree, and 0=I strongly disagree. The statements were worded in the affirmative. For example, "If I have sex without contraception (something to prevent pregnancy), I would probably get pregnant (or get someone pregnant)." Higher scores indicated an improvement in the respective categories; 1 question was reverse coded. Mean summary scores were calculated for the variables measuring the preliminary efficacy of the video game within the following categories: intentions, self-efficacy, risk perception, and knowledge. Mean summary scores for intention (0-64), self-efficacy (0-44), and risk perception (0-44) were cumulative, based on Likert values 0 to 4 for individual questions. Mean knowledge scores (0%-100%) were calculated as the percentage correct. We calculated the Cronbach α for each scale to examine internal consistency. Cronbach α scores ranged from .70 to .80, demonstrating good overall reliability. Knowledge questions were asked with *true/false/not sure* answers, and the total percentage correct was reported. Baseline and 12-week follow-up assessment scores were compared with a Student *t* test, and *P* values were calculated.

Results

Formative Phase—Phase 1

A total of 15 Spanish-speaking Latinx adolescents participated in 4 phase 1 focus groups, each consisting of 4 to 6 participants. Out of 15 participants, 7 (47%) were female, and 12 (80%) participants were born outside of the continental US. After 30 min of gameplay, participants overwhelmingly liked the premise of the video game, including the process of simulated decision making using avatars, virtually experiencing consequences of those decisions, getting feedback on the decisions, having opportunities for *do-overs*, and the chance to answer trivia questions, which allowed them to test their knowledge and gain new information. Participants recommended modifying the existing video game, as opposed to developing a new game. Key suggestions to generally improve the English-language video game included adding content to increase gameplay time, decreasing the length and overall amount of text, adding more animation to avatars, and increasing the number of video game background settings (eg, party and bedroom). One major Latinx-specific theme that emerged and that teens recommended to be incorporated into the video game was the importance of involving family members and close friends in the decision-making process around dating, sex, contraception, and pregnancy. This underlines the importance of *familismo*, the loyalty that Latinx individuals often feel toward extended family over personal needs that is present in Latinx culture [44]. Participants suggested modeling difficult conversations with parents in the video game to meet their needs of family engagement in their decision-making processes; participants wanted to simulate both positive and negative conversations to have these skills to use in their real lives. Additional Latinx-specific themes that emerged included the need to address perceptions of *fatalismo*, the belief that individuals cannot control when or if pregnancy occurs (even if contraception is used) because it is part of their destiny regarding pregnancy [45], and the incorporation of more opportunities to navigate decisions regarding long-term (novio and novia) and casual relationships. These themes were incorporated into the next iteration of the video game prototype, which was also translated into Spanish by bilingual speakers, including native Spanish speakers.

Testing Phase—Phase 2

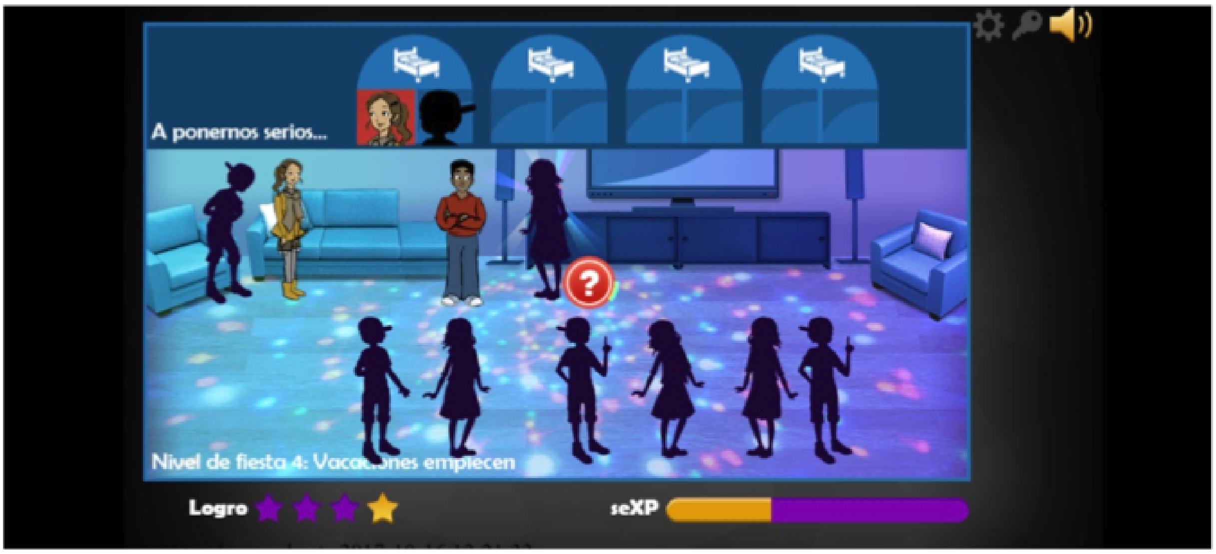
The Intervention

We named our Spanish-language video game *Colegio del Sexperto*, which means Sexpert High School. The goal of the 12-level video game is to become a sex expert (sexpert), which players do by working through multiple simulated scenarios to practice decision making around sexual behavior and experience consequences of those decisions, all while accumulating knowledge (Textbox 1). We identified 9 thematic learning objectives of the video game that decision-making scenarios and trivia questions incorporated: spread of STIs in sexual networks; STIs and HIV risk, testing, and treatment; cumulative risk of pregnancy with unprotected sex; contraception; possible consequences of pregnancy; effects of alcohol and drug use; partner communication regarding STIs; partner communication regarding contraception; and partner communication regarding pregnancy [18,19]. The learning objectives were spread out across 12 levels to facilitate players' decision-making simulation and knowledge accumulation in a step-wise fashion with the goal of not having players stay on each level for too long. Players *win* the video game when they complete all 12 levels.

Through a *Hand of God* view, players guide multiple male and female avatars through a house party (Figure 2). Each level begins with a new party and an additional avatar. At the party, the player-guided avatar interacts with computer-guided avatars. The computer-guided avatars offer alcohol, marijuana, and the opportunity to *hook-up*. Player-guided avatars can advance from the dance floor at the party to the bedroom for the *hook-up*, while making decisions for their avatars about whether to use alcohol or marijuana, engage in sexual activity at a party, and use condoms and/or contraception. Players then follow their avatars as they experience the outcomes (eg, pregnancy and STIs) of those decisions. Upon completion of each level, players have simulated conversations in which they disclose STI and/or pregnancy test results to sexual partners, friends, and family members. They are given opportunities to seek (or decline) treatment for STIs and to obtain condoms and other forms of contraception before starting the next party.

Player-guided avatars also answer trivia questions that address the main thematic learning objectives of the video game (eg, risks of STIs, effects of drugs and alcohol on sexual behavior, and partner communication). Players gain points by answering trivia questions correctly, and a minimum of trivia questions must be answered correctly to obtain enough points to advance to the next level.

Figure 2. Screenshot from Colegio del Sexperto (Sexpert High School) video game illustrating avatars interacting and trivia questions.



Participant Characteristics

In phase 2, we recruited and enrolled 24 Spanish-speaking Latinx adolescents. The average age of participants was 15.8 years (range 15-17), and there were equal numbers of male and female participants (Table 1). Out of 24 participants, 14 (59%) were born in Puerto Rico; the remaining reported being born outside of the United States. Out of 23 participants, 14 (61%) reported living in continental United States for 1 to 5 years, 87% (21/24) participants reported speaking only or mostly Spanish at home, and 58% (14/24) participants reported speaking only or mostly Spanish with friends. At baseline, 7 out of 24 (29%) participants reported any prior sexual experience, and within this group, all reported using only condoms or no method of contraception at the time of last intercourse. Only 1 participant reported the use of drugs or alcohol at the time of last intercourse (Table 1).

Table 1. Phase 2 baseline characteristics (N=24).

Characteristic	Values
Age (years), mean (range)	15.8 (15-17)
Sex/gender, n (%)	
Female	12 (50)
Male	12 (50)
Race, n (%)	
American Indian or Native Alaskan	4 (19)
Black or African American	0 (0)
Native Hawaiian or other Pacific Islander	1 (5)
White	3 (14)
Other	13 (62)
Country of birth, n (%)	
United States	0 (0)
Mexico	2 (8)
Puerto Rico	14 (58)
Dominican Republic	4 (17)
Other	4 (17)
Time in the United States (years), n (%)	
<1	7 (30)
1-5	14 (61)
5-10	2 (9)
Language spoken at home, n (%)	
Only or mostly Spanish	21 (86)
Spanish and English	3 (13)
Only or mostly English	0 (0)
Language spoken with friends, n (%)	
Only or mostly Spanish	14 (58)
Spanish and English	9 (38)
Only or mostly English	1 (4)
Self-reported behaviors at baseline[a]	
Ever had sexual intercourse, n (%)	7 (29)
Mean age of first intercourse (SD)[b]	14.6 (1)
≥2 lifetime sexual partners[b], n (%)	3 (43)
Contraception used at last sexual intercourse[a], n (%)	
Only condoms[b]	5 (71)
No method[b]	2 (29)
Use of alcohol or drugs at last sexual intercourse[a], n (%)	1 (14)

[a]On the basis of questions used in the Centers for Disease Control and Prevention, Youth Risk Behavior Surveillance.

[b]Percentage out of only sexually active participants (n=7).

Gameplay Experience

On average, participants played 4.2 hours of the video game over the 6-week time period. Out of 24 participants, 14 (58%) reached level 5, and 2 (8%) participants successfully completed all 12 levels of the video game. At the 12-week follow-up, 65% (13/20) participants reported that they enjoyed playing the video game, would play it again, and would tell their friends to play the video game (see the table in Multimedia Appendix 1). Out of 20 participants, 16 (80%) participants felt responsible for the choices they made in the video game, 15 (75%) participants liked the way it looked, and 14 (70%) participants found the video game challenging; 8 (40%) participants felt frustrated playing the video game. When asked to elaborate on these frustrations in focus groups, participants reported that the video game was repetitive, had too many levels, and was unnecessarily challenging (eg, losing avatars without knowing why or getting stuck on a given level). Nevertheless, they reported that they liked playing the video game and described it as an improvement over school-based sex education classes. Suggestions for future iterations of the video game included adding more avatars, diversifying the information encountered in each level, providing in-game clues for how to advance to the next level, condensing the number of levels, and further improving animation of the avatars.

Impact of the Video Game on Intentions, Self-Efficacy, Risk Perception, Knowledge, and Sexual Behavior

Mean summary scores for intentions, self-efficacy, risk perception, and knowledge did not change significantly between baseline and 12-week follow-up assessments (Table 2). However, mean summary knowledge scores did increase from 27% correct to 33% correct (*P*=.12). On the basis of the finding that most players (14/24, 58%) did not get past level 5 of the video game, we explored how content was distributed throughout the video game. An in-depth review revealed that condom-specific information, although a central focus of the video game overall, was heavily represented in the first 3 levels of the video game, and 92% (22/24) participants played through the levels in which condom-specific information was addressed. Therefore, we performed a subanalysis of condom-specific questions. The mean summary scores for condom-specific measures were compared between baseline and 12-week follow-up. Condom-specific knowledge scores significantly increased from 29.6% to 47.4% correct (*P*=.007, Table 3). Condom-specific intentions, self-efficacy, and risk perception did not significantly change. At the 12-week follow-up survey, 45% (9/20) of participants reported being sexually active compared with 29% (7/29) at enrollment; however, this was not significant, and data were not shown here. Of the sexually active participants at 12-week follow-up, 80% (4/5) reported condom use at the time of last intercourse compared with 71% (5/7) at baseline, again not a significant difference. Among those individuals who were sexually active at the 12-week follow-up (n=7), all reported not using alcohol or drugs at the time of last intercourse.

Table 2. Participant summary scores for key intervention targets before video game intervention and at 12-week follow-up.

Mean outcome summary scores[a]	Baseline, mean (SD)	12-week follow-up, mean (SD)	*P* value (baseline to follow-up)
Intention score (0-64)[b]	42.68 (8.03)	42.95 (7.94)	.75
Self-efficacy score (0-44)[c]	31.39 (5.57)	32.55 (7.18)	.42
Risk (misperception) score (0-44)[d]	29.38 (5.28)	26.65 (6.62)	.14
Knowledge score (0%-100%)[e]	26.71 (11.25)	32.77 (14.82)	.12

[a]Higher scores indicate improved intentions, self-efficacy, and risk perceptions as measured using a 5-point Likert scale where 4=I strongly agree, 3=I agree, 2=I am not sure, 1=I disagree, and 0=I strongly disagree. The statements are worded in the affirmative. For example, "If I have sex without contraception (something to prevent pregnancy), I would probably get pregnant (or get someone pregnant)."

[b]16 questions; Cronbach α=.80; n=18 [19,35].

[c]11 questions; Cronbach α=.73; n=19 [19,46,47].

[d]11 questions; Cronbach α=.70; n=19 [18,19].

[e]35 questions; percent correct out of 35 questions; n=14 [1,35,48].

Table 3. Condom-specific questions—summary scores before and at 12-week follow-up.

Mean outcome summary scores[a]	Baseline, mean (SD)	12-week follow-up, mean (SD)	*P* value baseline to follow-up
Intention score (0-16)[b]	11.96 (2.26)	11.50 (3.46)	.73
Self-efficacy score (0-36)[c]	25.96 (4.93)	26.80 (5.85)	.5
Risk perception score (0-4)[d]	2.04 (1.27)	2.00 (1.84)	.72
Summary knowledge score (0%-100%)[e]	29.55 (19.11)	47.37 (22.27)	.007[f]

[a]Higher scores indicate improved intentions, self-efficacy, and risk perceptions as measured using a 5-point Likert scale where 4=I strongly agree, 3=I agree, 2=I am not sure, 1=I disagree, and 0=I strongly disagree. The statements are worded in the affirmative. For example, "If I have sex without contraception (something to prevent pregnancy), I would probably get pregnant (or get someone pregnant)."

[b]4 questions (n=18).

[c]9 questions (n=19).

[d]2 questions (n=19).

[e]8 questions, percent correct out of 8 questions (n=14).

[f]Statistically significant result.

Discussion

Principal Findings

We successfully partnered with Spanish-speaking Latinx adolescents to further develop and adapt an existing English-language video game intervention designed to decrease high-risk heterosexual behavior and adapted it to meet the specific needs of Spanish-speaking Latinx adolescents. Following a participatory, iterative video game design and development process with our target audience, our pilot testing of *Colegio del Sexperto* exhibited feasibility, including the production of a useable Spanish-language video game that included culturally relevant and responsive content. This pilot testing also demonstrated high acceptability: study participants liked the video game and reported feeling invested in the decisions they made during gameplay. Pilot testing also produced thoughtful feedback and detailed suggestions for ways to improve future iterations of the video game, including improving avatar animation, adding more avatars and content, condensing the number of levels, and improving game flow. Our pilot study meets Bowen et al [49] proposed criteria for a successful feasibility study.

We observed improved overall knowledge and significantly increased condom-specific knowledge after exposure to the video game. Although we did not find a significant improvement in intentions, self-efficacy, and risk perception, a larger sample size specifically powered to detect such differences might reveal them. In addition, only 29% (7/24) of participants reported any previous sexual experience at baseline (compared with 48.6% of Hispanic high school students nationwide) [1]. Testing intentions, self-efficacy, and risk perception among a group of sexually active adolescents might yield different results.

Our findings support a growing body of evidence showing that serious games or video games designed for health-related topics have the potential to influence sexual health and behaviors, [50,51] and that there is a need for more culturally specific games to increase engagement and efficacy of such interventions [52]. Video games and mobile health interventions have the ability to cross language and cultural barriers [50,53,54], which makes them especially useful for reaching Spanish-speaking Latinx adolescent populations. The video game developed in this pilot study met adolescents where they are today—playing video games. Moreover, our work adds to the body of emerging research, demonstrating that serious games can be used for purposes other than entertainment [50-52]. Additionally, video games are multi-component and can incorporate strategies to improve modifiable behaviors. This modality can capitalize on experiential learning by offering opportunities to demonstrate social norms, practice self-efficacy skills, visually model risk and risk prevention, and allow adolescents to experiment with and experience consequences of high-risk behaviors in a risk-free virtual world [11,13,14,51,55-58].

Limitations

As is the nature of a pilot study, our study is limited by its small sample size, lack of control group, and relatively short follow-up interval. Recruitment criteria did not include prior sexual experience; this allowed for a larger recruitment pool but potentially limited our ability to reach an audience that might benefit most from a video game–based intervention. Although our study did include a certificate of confidentiality to guarantee the protection of privacy, the contemporary political climate's anti-immigrant rhetoric may have contributed to distrust among our target audience of Spanish-speaking Latinx adolescents, which likely hindered the study recruitment and participant retention. Teachers who assisted with participant recruitment noted that some otherwise eligible adolescents expressed hesitancy in joining a research study because they or their family members were undocumented immigrants. Similarly, we had difficulty maintaining ongoing contact with our participants because of the reluctance to share contact information and conflicts between our testing period and the school holiday schedule. As a result, only a small number of participants ultimately completed the immediate postgameplay survey, which limited our ability to compare scores between time points and our analysis of preliminary efficacy. Consistent assurance of anonymity is crucial as are alternative ways of contacting participants (such as adolescent-friendly apps, such as Snapchat or Twitter). Future studies should take special care to create strong partnerships with community members to garner trust and acceptance, especially when working with vulnerable populations. Finally, opportunities exist to improve the mechanics of the video game to decrease the number of levels and make it less challenging, which could increase exposure to the game content. Larger clinical trials are needed to test the intervention against a control group before promoting this intervention on a larger scale.

Conclusions

Through an iterative intervention design in partnership with our target audience, we developed an innovative and usable Spanish-language video game aimed at decreasing high-risk heterosexual behavior in Latinx adolescents. Findings from this pilot study support the growing body of evidence that serious video games may be used to both increase knowledge and modify behaviors. Our study addresses current gaps in research on culturally sensitive games for health [52]. Pilot testing yielded valuable information and feedback that will aid in future video game development. The next steps include incorporating participants' specific suggestions into the next video game iteration and testing it in larger studies to adequately examine whether the intervention can decrease high-risk heterosexual behaviors among Latinx adolescents.

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Conflicts of Interest

NLS receives honoraria from Merck for Nexplanon Training as well as from Medicines360 for being on their Independent Data Monitoring Committee.

Multimedia Appendix 1
Reports of gameplay experience assessed at 12-week follow-up (N=20).
[DOCX File , 13 KB - games_v8i2e17295_app1.docx]

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Abbreviations

CDC: Centers for Disease Control and Prevention
STI: sexually transmitted infection

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Viewpoint

Can Social Communication Skills for Children Diagnosed With Autism Spectrum Disorder Rehearsed Inside the Video Game Environment of Minecraft Generalize to the Real World?

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Abstract

In this paper, we outline opportunities within the video game environment for building skills applicable to real-world issues faced by some children. The game Minecraft is extremely popular and of particular interest to children diagnosed with autism spectrum disorder. Although the game has been used by support communities to facilitate the social interaction of children and peer support for their parents, little has been done to examine how social skills developed within the game environment generalize to the real world. Social Craft aims to establish a framework in which key social communication skills would be rehearsed in-game with a view to facilitating their replication in a similarly contained real-world environment. Central to this approach is an understanding of the basic principles of behavior and the engagement of a sound methodology for the collection of data inside and outside the respective environments.

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KEYWORDS

autism; behavior analysis; serious games; social skills; gamification; Lego; neurodiversity; Minecraft; virtual worlds; virtual reality

Introduction

Minecraft [1] is a procedurally generated open-world video game that employs distinctive block-building mechanics and a pixelated esthetic. It provides a constructivist environment whose earth, flora, and fauna may be mined, felled, or culled for component parts of ore, wood, or meat, respectively. These raw materials, in turn, may be crafted into food, tools, weapons, furniture, and building supplies. Blocks that may start as earth, vegetation, or animals may be harvested and broken down into their component parts such as coal from a ground block, wood from trees, or wool and mutton from sheep. These materials, in turn, may be combined into entirely new pieces with distinct in-game properties. Coal may be used to fuel a fire, wood may be fashioned into building supplies, and mutton may be cooked and eaten by the player to restore health. Trees may be chopped down and sawn into logs, which may be used to make sticks, and when combined with cobblestone blocks, may be fashioned into rudimentary tools such as axes or pickaxes. Animals such as cows may be culled, yielding beef, which in turn may be cooked and eaten, and whose hide may be fashioned into armor. Items are either carried in a personal inventory or stored in containers, which in turn may be placed in a home location, where players may craft further items or sleep.

Players navigate this cubist world using a similarly constructed block-person avatar, and most usually view their world from a first-person camera orientation, which reinforces a sense of belonging and immersion. As players gain experience, the environment evolves through a kind of Mesolithic, Paleolithic, and Iron Age culture. Multiple modes of play are offered, including Creative Mode, a more traditional block-building environment where blocks of every type are available in an open inventory and the more competitive Survival Mode in which players need to eat and sleep and defend themselves against a plethora of hostile nonplayer characters in the form of creepers, zombies, and witches to name a few. Players who perish from natural or unnatural causes, respawn in a recent home location, but lose any inventory items they are carrying.

The open-ended narrative structure of Minecraft, especially when used in Creative Mode, facilitates constructive play of a type that resembles real-life block-building play along the lines of Lego or similar interlinking toy systems. These real-world block building toys are similarly popular among children diagnosed with autism spectrum disorder (ASD) [2] and have been shown to be effective tools for social communication learning activity for children with ASD [3]. Minecraft provides a robust, if not, rudimentary system of text communication, but more often than not players seem to prefer to communicate and collaborate through voice-based group chat by using Skype audio or similar apps for simultaneous communication while playing together on a server-based system [4].

Although many other computer games exhibit a seemingly similar constructivist architecture and open-world platform to Minecraft, from some of the earliest text-based MUDs, such as Zork [5] to rich media 3D video games such as Elder Scrolls V: Skyrim [6], it is the open-ended narrative structure of the game and the in-world capabilities of game content creation, which draw parallels to the block-building toys referred to above.

This concept of avatar presence and interactive content creation is not without precedence and was explored in an earlier paper by Cadieux [7], which looked at sandbox platforms and the process of sandboxing in software development. A sandbox, in games-level design terminology, refers to the build area within a game environment, and sandboxing is a term that comes from software development, which describes a process of testing computer software in a safe, protected environment [7]. Certain game environments facilitate group constructivist interactions such as these, where the avatars of players may be collectively present to collaborate and build additional game content from within the game environment itself. Minecraft is one such video game.

The popularity of Minecraft with children with ASD seems fairly universal and, as such, the video game has been used by educators and ASD support communities to facilitate downtime from overwhelming classroom situations and to facilitate the social interaction of children [8]:

> *With Minecraft, you can really just be yourself. The social interactions, the relationships, the communication – everything just boils down to you and your keyboard.* [Stuart Duncan, creator of Autcraft]

Autcraft is an organization that hosts a Minecraft server, specifically geared toward users with ASD. The environment is managed through a system that employs administrators who patrol the environment from within the game using avatars with enhanced privileges. They monitor and police the Autcraft environment with a remit modeled on game-play etiquette and internet safety and provide a safe environment which entirely comprises children with autism, their parents, and family members. The Autcraft community limits its remit to policing its environment to reduce greifing or virtual antisocial behavior of its members and provides in-world support to the participants.

Within the safe Autcraft environment, individuals with autism can engage in behaviors normally associated with autism in the real world; there is no perceived need for anyone to do otherwise. Examples of behaviors associated with a diagnosis of autism include deficits in social-emotional reciprocity, deficits in nonverbal communicative behaviors in social interactions, and deficits in developing, maintaining, and understanding relationships [9]. Moreover, there are no clear evidence-based examples to date of Autcraft being used to facilitate social skills learning with children diagnosed with ASD beyond those related specifically to game-play behavior. Typically, children diagnosed with autism are given access to the gaming environment, and anecdotal reports are used to draw conclusions about how the gaming experience influences behavior in the real world. Often, these reports are positive [8], but it is difficult to determine if it was time spent in-game per se or if it was something within the architecture of the gaming experience itself that produced the outcome. There are many games that require social interaction to progress through different levels. However, these interactions may not target or emulate real-world social communication skills. More often than not, the skills acquired are specifically game-related skills or skills related to social interaction and are related to Web-based behavior or social networking; therefore, they would not necessarily generalize to real-world behaviors.

This begs the question as to whether it is at all possible for any skills acquired during emersion in a virtual world to generalize to the real world. Therapeutic applications of virtual reality (VR) show some promise in a variety of clinical populations. Examples include the treatment of phobias [10], restoring lost skilled movement in children after traumas and diseases [11,12], teaching social skills to adolescents with ASD [13], and safety skills [14]. Another huge area of research involves a related nonimmersive virtual world, one that involves basic principles of learning associated with watching others learn, observational learning [15]. Within this field, video modeling has proven highly effective in teaching children with autism to engage in behaviors observed in videos [16-19]. It can be argued that Autcraft designers could take advantage of the possibilities within the game environment for members to enhance their social communication skills or explore aspects of social relationships, such as making friends, reciprocity, and social engagement. This would be an important development at many levels. For example, a recent survey in the United Kingdom by the National Autistic Society (2016) showed that although many adults diagnosed with autism would like to work (77%), only 16% are in full-time paid work. A major contributing factor involved challenges related to social communication, including social difficulties presented by job interviews. At the very least, issues related to social interaction and communication norms in virtual settings present an empirical challenge filled with opportunities to address a range of research questions.

To set the scene for a discussion of what could be done, consider how the technological goals within a game are already mirrored in the real world. This is precisely the remit of the natural science of behavior analysis when it develops behavioral technology to facilitate social exchanges, where *technology* is understood as *the use and knowledge of tools, techniques, systems, or methods in order to solve a problem or serve some purpose* [20]. Currently, most evidence-based interventions for autism are based on the principles of applied behavior analysis (ABA) [21]. Politis et al [22] explain how the strategies that are integral to the design and implementation of an intervention program using ABA also form the basis of serious game design. They include defining and measuring behavior, recording and analyzing behavior, presenting corrective feedback, and dynamically adapting to student performance. However, whereas measurable outcomes are important for technological reasons in both gaming and real-world experiences, there is a major difference between the technologies employed in both. In the general game world, the algorithms do not record data with a view to showing the development of behavior as it moves toward a specified goal. Rather, the technology provides a simple set of rules for generating images on a computer screen. Social behavior either happens or it does not. In other words, algorithms are not designed to explicitly shape behavior toward a particular goal. In contrast, measurable outcomes that are monitored in the real world when using behavioral technology are essential for evaluating the viability of an educational program. These data provide a record of progress toward a specified goal. If a goal is not attained at any point in time, then the program may be adjusted in accordance with the data obtained, so as to increase the likelihood that the skills change in the direction of the goal.

Within a virtual world, the tools used in social communication (eg, using text and graphic symbols) are not those normally used in real-world contexts. That said, from a behavioral perspective, skills that could be enhanced within the virtual world should be viewed as classes of behavior rather than discrete behaviors. In other words, it would be a mistake to consider *behavior* as something distinct from *communication*. This is because the term *communication* comprises a class of behaviors, and as such, it is defined by consequences [23], not by the topographies of individual components. The empirical question, then, is whether classes of behavior that are established in a virtual world will generalize to the real world. Empirical questions such as this are not peculiar to VR or the use of avatars. In real-world behavioral interventions for children diagnosed with ASD, every effort is made to plan for generalization outside of the learning environment [24]. This is because skills acquired in one context do not necessarily generalize to new contexts [25].

Behavioral instructors state goals in terms of student behavior. Objectives such as *understanding* are translated into observable actions that indicate when the inferred *understanding* has been achieved. These *behavioral objectives* define skills that students should have mastered by their final evaluation. Next, shaping steps, that is, the actions students take to achieve competence, are analyzed. As students respond, instructions adjust to suit individual progress. [26]

This perspective on technology was pioneered by BF Skinner, who gave birth to the field of programmed instruction [27,28]. Software engineers who developed Minecraft programmed the digital technology to respond to behaviors from a person at a workstation. There is no specified goal to reach, as in programmed instruction. However, every session terminates with the goals of various kinds being accomplished in various ways. In many respects, this open-ended environment is part of the attraction for players, and it is ideal for identifying learning opportunities for skill development.

Some of the issues being addressed here might best be discussed in the context of the following hypothetical experiment. A number of young people diagnosed with ASD are given the opportunity to play Minecraft for a fixed period of time at school. Following this, they are given the opportunity to engage with each other in a free-play situation with a block-building toy, such as Lego. The research question would be whether the social behaviors that occurred in the game world also appear in the real world. In addition, it would be important to know their similarities and differences. Without data recording in the game world, there would be no way to address this question. If there were differences in behavior across both environments, then consider the possibility that some of the differences arose because behaviors associated with ASD came to the fore in the real world. If this was indeed the finding, then the conclusion would be that although the children like to play Minecraft, there are wasted opportunities within the game for addressing (ie, practicing) social skills. Addressing social skills deficits by developing game play that has different levels of competence needed for progression might increase the likelihood that these skills would generalize to the real world.

Social Craft

Social Craft would seek to establish a framework in which key real-world social communication skills could be rehearsed in-game, with a view to facilitating their replication in a similarly contained real-world environment. Central to this approach is an understanding of how basic principles of behavior are already employed in most gaming experiences and other educational software, along with a robust methodology for the collection of data [29,30]. For example, from a digital programming point of view, there are software protocols for controlling the situations that demand executions of particular kinds of behavior and executions of particular kinds of responses to these behaviors. It goes without saying that it is because all of these behaviors and their associated consequences are monitored by software instructions that the *natural* to and fro of the gaming experience is ensured.

If researchers or therapists were to inhabit the game world by controlling a Minecraft avatar with enhanced administrator capabilities, they could witness first-hand behaviors exhibited by players as they interact. They would be able to assess behavior as they would in a real-world clinical or educational situation. Game world behaviors could be ameliorated in-game, just as real-world behaviors could be ameliorated in a clinical or educational situation. Game world data could be collected in-game, just as real world data may be collected in any social learning environment. The information collected might then be used to design an automated monitoring system that could detect examples of the kinds of difficulties encountered by some children within the game world with the goal of developing automated protocols that mimic the intervention provided by the avatar of the researcher or educationalist, offering a gamification-based solution. Alternatively, a set of protocols could be developed into a framework for volunteers for community or admin avatars to encourage behaviors related to positive social-communicative interaction. Basic principles of behavior could then be harnessed to shape these skills [31]. The kinds of social communication that would take place in the game environment are the same ones that would be reinforced in a real-world environment, for example, greeting, commenting, turn-taking, and cooperative play. What distinguishes the Minecraft environment from similarly structured environments is its open-ended structure that facilitates a type of play similar to those that may be engaged in within real-world environments. This cross-compatibility between the virtual world and the real world harbors the potential for the generalization of behavior between the real and virtual environments. Of course, there will be detractors who would argue that such an approach would destroy the game experience, but this misses the point. The gaming experience itself is an environment where contingencies of reinforcement operate, and it is the way these contingencies are designed that determine whether a game is enjoyable or not.

This analysis is not peculiar to Minecraft. Most games operate a points-based system, where various criteria must be reached before new reinforcers are made available. Interestingly, the principles that operate within games have been shown to be important for addressing many real-world social problems [32-34]. Commenting on the relation between the task of designing contingencies in real-world applications and in the game world, Morford et al [35] noted that the concept of gamification has not gone unnoticed.

For example, Skinner [36] commented on how video games are excellent examples of contingency programming, in which players interact with an arrangement of contingencies where their behavior is guaranteed to be reinforced, contacting salient and immediate consequences players are almost guaranteed to be successful when they play a video game. Skinner mentioned how other aspects in our lives could be similarly designed, stating as follows [36]:

> *No one really cares whether Pac-Man gobbles up all those little spots on the screen…What is reinforcing is successful play, and in a well-designed instructional program students gobble up their assignments.*

More recently, McGonigal [37] likewise recognized how we might capitalize on the success of games to address significant societal issues, stating as follows [37]:

> *If we take everything game developers have learned about optimizing human experience…I foresee games that fix our educational system. I foresee games that treat depression, obesity, anxiety, and attention deficit disorder…I foresee games that tackle global-scale problems such as climate change and poverty.*

Intriguingly, the notion that there are design issues regarding controlling contingencies has a mixed reception depending on whether these contingencies are designed to operate in the game world or in the real world. The history of heated debate regarding real-world applications has usually centered on the politics of who should be in control (eg, Sidman [38], Skinner [39], and Wheeler [40]). In discussions on interventions for autism, the neurodiversity movement is particularly antagonistic toward behavior analysis [41], suggesting that contingencies of reinforcement can or should not be used to change behavior. Keenan [42], however, has a different perspective on the nature of behavior analysis. The argument is made that changing the behavior of a person diagnosed with autism is tantamount to not accepting them for who they are as a person. This argument can be made with any intervention, clinical or educational, for any person. If taken to the extreme, it promotes censorship of all practices that aim to empower people with skills that are useful to them, even parenting [43]. If the argument found its way into the gaming environment, it would stifle game development because it is not possible to design a game without intentionally controlling what a person does (ie, designing contingencies) within a game. And yet, by utilizing an app already embraced by the ASD community [8] and one which is used in schools and by ASD community support groups [44], the very use of Minecraft as a tool for supporting the reinforcement of a positive social communication skillset is in a way, an approach which is aligned to, rather than opposed to, particular aspects of neurodiversity. Social Craft may, then, offer the potential to bridge in some small way divergencies in rationale between the neurodiversity community and those who would seek to ameliorate issues related to social communication through a virtual form of behavioral intervention using the Minecraft platform.

Politis et al [22] drew attention to an additional way of offsetting difficulties when designing software for individuals diagnosed with ASD. They discuss the value of involving people with disabilities in the design process, incorporating what is called user-centered design (UCD). UCD, they explain, provides a way of furnishing designers with a better understanding of the end user. Within this framework, *technology developers and users meet as equals to promote reciprocal relationships, mutual learning, and empowerment of user* [22]. What better way to demonstrate your acceptance of a person than by tuning into any difficulties they may have when progressing through a game and augmenting their skills through the design of supportive contingencies. In other words, affording a player the opportunity to develop her abilities, or in game terms, to level up to better defend against enemies. This vision has parallels with living in the real world. Deficits in social skills are only deficits if they impede progress for the individual concerned, and only then should supportive contingencies be tailored to meet their needs, with their consent of course, or the consent of their primary carer, if a disability prevents them from communicating. This is precisely the approach of behavior analysis for gaming and living in the real world [45].

An alternative or additional way in which the Social Craft method could be modeled would involve the use of the Minecraft video game environment itself to host the interaction between the behavioral programmer and the player. In many ways, this could provide a more compatible environment in which to study the social interaction of an individual among their peer Minecraft players. Just as the players of the game act as operators of their keyboard or console in the physical world, and through these same interfaces control the actions and interaction activities of their avatars, therapists and researchers could operate through their keyboard or console in the real world and through their interfaces control avatars, with enhanced administrative capabilities in the same virtual environment.

In the real world, the therapist would base the intervention on an assessment of the candidate's needs and social communication profile. From this information, a more detailed assessment would be conducted on the individual's level of communication to help identify areas that have the potential for redress. Certain communication skills, such as facial expression, gestures, or tone of voice, do not have parallels in the video games environment of Minecraft, but others, such as eye contact, turn taking, and collaborative play, have parallel interactions in both the virtual and the physical environment. It is these which, when identified may be incorporated into a plan for intervention.

When applying the Social Craft methodology, the therapist identifies troublesome behaviors and uses positive reinforcement through a token system [46,47] to reinforce alternative behavior outcomes. Of course, some of these behaviors will be related to the game environment itself, but others hold the potential to generalize beyond the virtual play area. This is why the multiple workstation laboratory environment is very important to the Social Craft method. When therapist(s) and players are present together, not only in the computer suite but also in the same server installation of Minecraft, the participants are more likely to *feel a connection* between their avatars in the game and their presence in the laboratory with their peers and therapists. In behavioral terms, the more similar the environments, the more likely it is that generalization of skills will appear [48,49].

Virtual tokens could be modeled in the virtual world through modified component blocks that could emulate props from the game such as a precious metal ingot, helmet, or gemstone, which would only be available to players who had achieved points awarded for positive communicative outcomes. These would sit in a players' inventory and could be used in-game by the players' avatars, just as in-game props are carried or worn by Minecraft players. These in-game props would be empowered with real-world properties to allow the holders to extend game-play time, access new regions, or open higher-level inventories. Holders need to maintain positive game-play practice and maintain social-communicative interaction in order to retain the items.

A similar system could be employed in the real-world environment of the computer suite by using a parallel system of tokens and rewards. Real-world tokens could consist of life-sized Minecraft props or toys of similar design and color to those offered in the virtual environment. These could be used as badges and would empower the owner with similar real-world capabilities to those offered the players in the virtual environment by affording their holders extended game-play time or access premiums as long as the players maintained positive play practice and socially acceptable interaction within the real-world environment.

Virtual tokens already exist within the Minecraft environment as specific block types, such as life-sized prop toys of the same items. Off-the-shelf versions could be used or bespoke replicas manufactured. This system of virtual and real-world token and reward could provide a cross-platform method with which to shape and increase the likelihood of generalization of specific behaviors in both the virtual world and real-world environments.

Regarding data collection from any assessments that are made, in the gaming environment software automatically records aspects of performance to determine what consequences should or should not occur. In a sense, the algorithms at the heart of the software can be viewed as digitally analogous to an observer recording outcomes. This focus on measurable outcomes is central to strategies employed by behavior analysis when designing experiences in the real world. The following advice from a behavior analyst to a parent exemplifies the relevance of this point when it comes to explaining how to think about the measurement of a child's social skills [50]:

> *Focus on observable outcomes. The fact that social skills need to be addressed is related to something observable. In other words, How do we know she needs improvement in (specific social skill)? There must be something observable that supports this objective. For instance, We know she needs improvement in engaging in social conversation with peers because she rarely if ever has such conversations. Taking this information and turning it into an observable outcome is essential. That is, "We will know when (specific social skill) has improved when we see that she (observable behaviors)."*

Within the game world, sequences of interaction from the therapist player's point of view may be recorded in real time and stored as video reference files to be analyzed in the real world by therapists or researchers. Specific behaviors that have been recorded in a game environment may be presented to and discussed with the player as examples of behaviors for potential amelioration.

For "higher functioning" children, the video-monitoring technique described by Lloyd et al [51] may be useful to assess a child's metapragmatic knowledge of communicative intent. The video-monitoring technique involves a two-step procedure. The first step is to videotape a child in a communicative situation. Lloyd et al [51] situations such as a referential communication game or a peer-tutoring task, which involve child–child interactions, and adult–child interactions may also be explored. The second step is to watch the videotape with the child and probe the child's understanding of the speaker's effectiveness in expressing intent [52].

This in-game recording of player interaction would provide a gamified equivalent to the first step of videotaping a child in a communicative situation. Watching the in-game recording with the child would parallel the second step outlined in the video-monitoring technique described above by Wetherby-Prizant.

Conclusions

In summary, within the Social Craft, the researcher or therapist would initially inhabit a Minecraft environment with enhanced Social Craft modifications and would use the enhanced capabilities of the environment to rehearse and reinforce social communication activities. At the same time, they would observe peer interaction and play, which could inform a set of protocols that could be followed by community or admin avatars or indeed could be gamified into an automated monitoring system. This game-world/real-world approach builds on platform game-world approaches used by other server-side ASD communities such as Autcraft but is geared toward developing social communication skills in-game and then reinforcing them in a parallel real-world environment. Social Craft seeks to establish mechanisms for collecting data in both the virtual world and the real world related to the generalization of social communication skills between worlds.

Conflicts of Interest

None declared.

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Abbreviations

ABA: applied behavior analysis
ASD: autism spectrum disorder
UCD: user-centered design
VR: virtual reality

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Original Paper

Gamifying Parenting Education Using an App Developed for Pacific and Other New Zealand Families (Play Kindly): Qualitative Study

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Abstract

Background: Play Kindly is a gamified animated app designed to address common behavioral problems in childhood. The interface is designed to appeal to Pacific people, a population group with a higher risk of developing clinically significant behavioral problems than most other ethnic groups in New Zealand.

Objective: The aim of this study is to explore the opinions of parents and professionals about the acceptability, usability, and content of Play Kindly.

Methods: We used qualitative and Pacific and Māori research methodologies. A total of five focus groups with 45 parents and 12 individual interviews with professionals were conducted. The five focus groups consisted of 2 pan-Pacific groups, 1 Māori group, 1 open group, and 1 group of young Pacific adults or prospective parents. The professionals were from a range of disciplines, and the majority had expertise in early childhood, parenting interventions, or research in this field.

Results: Play Kindly appealed to both parents and professionals. Participants related to the scenarios, which were created in collaboration with a playwright and animator. Although most participants liked the Pacific feel, there was some disagreement about how culturally specific the app should be. A range of issues with usability and gamification techniques were highlighted, likely attributed to the low budget and lack of initial co-design with parents as well as professionals with specific expertise in parenting. A number of parents and professionals felt that the parenting strategies were overly simplified and did not take into account the context in which the behavior occurred. Professionals suggested narrowing the focus of the app to deliver two important parenting messages: playing with your child and positively reinforcing desired behaviors.

Conclusions: Play Kindly is the first culturally adapted parenting app of its kind designed for Pacific parents and other New Zealanders with children 2-5 years of age. This app has potential in Pacific communities where there are limited culturally specific parenting resources. The results of this study will guide improvements of the app prior to testing it in an open trial.

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KEYWORDS

parenting; mHealth; Pacific peoples

Introduction

O fanau a manu e fafaga i fuga o laau, a o tama a tagata e fafaga i upu.

"The young ones of birds are fed with nectar; the children of people are fed with words" [1].

Behavioral problems are common at some time in a child's development. The way parents respond to these play a major role in how likely the child is to repeat the behavior. If behaviors start to fall outside the normal range for the child's age and stage of development, they are referred to as disruptive behavior disorders. These disorders can cause difficulties with peer relationships, school performance, aggression, and eventually substance abuse and criminality [2,3].

A number of evidence-based interventions have been shown to be effective for the prevention and treatment of disruptive behavior disorders. Early intervention with parent management training has been one of the most successful approaches in early and middle childhood [4]. In this training, facilitators teach parents a range of skills for the management of behavior. Unfortunately, there are often barriers for accessing these programs. For example, participating in parenting programs can mean loss of time spent with children and loss of earnings, which is particularly important for families facing economic hardship [5]. In New Zealand, like many other parts of the world, availability of these programs is limited by underfunding and a lack of expertise in the workforce for their delivery. There are a number of rural communities where access to consistent health care is challenging [6].

Online parenting programs have shown some positive effects on parenting strategies and skills [7-9] relative to control groups and compared with face-to-face parent seminars and bibliotherapy approaches; however, this evidence is modest. Online, gamified parenting interventions delivered on mobile phones and targeted to vulnerable communities have demonstrated reduced behavioral difficulties in children, an increase in more effective parenting strategies, and decreased parental stress [10]. Digital programs could, therefore, address problems with workforce shortages, availability of parents, and geographical isolation. In fact, consumer preference research shows that vulnerable families prefer online resources as a way of receiving parenting support [11,12].

In New Zealand, approximately 20% of children have a medium to high likelihood of having disruptive behavior [13]. Although this figure is comparable to international findings [4], the risk is higher for Pacific (24%) and Māori (28%) children [13]. One of the reasons is that a higher proportion of these children live in poverty, and the challenges of economic hardship can lead to difficulties in parenting effectively [6]. There are few parenting programs that cater specifically to Pacific and Māori parents. Despite the fact that these groups are considered to be more at risk and that retention is better in parenting programs that are specific to a culture [14], there are few programs with a focus on targeting these populations.

Pacific groups are the fourth largest major ethnic group in New Zealand [15], and the number of Pacific children is projected to increase at a higher rate than any other ethnic group in New Zealand [15]. A recent study [16] found that compared to Samoan parents in Samoa, Samoan parents living in New Zealand were more authoritarian, especially fathers, who were more likely to undertake harsh discipline. This may be due to the lifestyle in New Zealand where alcohol, drugs, and other risk factors are more prevalent [16]. New Zealand born Samoan and Pacific parents who were more highly educated and had good levels of support were more likely to discard the harsh discipline practices of their parents [17,18].

"Play Kindly" is the first app in New Zealand designed for a contemporary Pacific audience that uses gamification to teach parenting strategies for everyday behavior problems. The aim of this study was to carry out a qualitative investigation using Pacific and Māori research methods to assess the acceptability, feasibility, and perceived utility of "Play Kindly" from the perspectives of parents and professionals. These research methods are described in the "Design" section.

Methods

Intervention

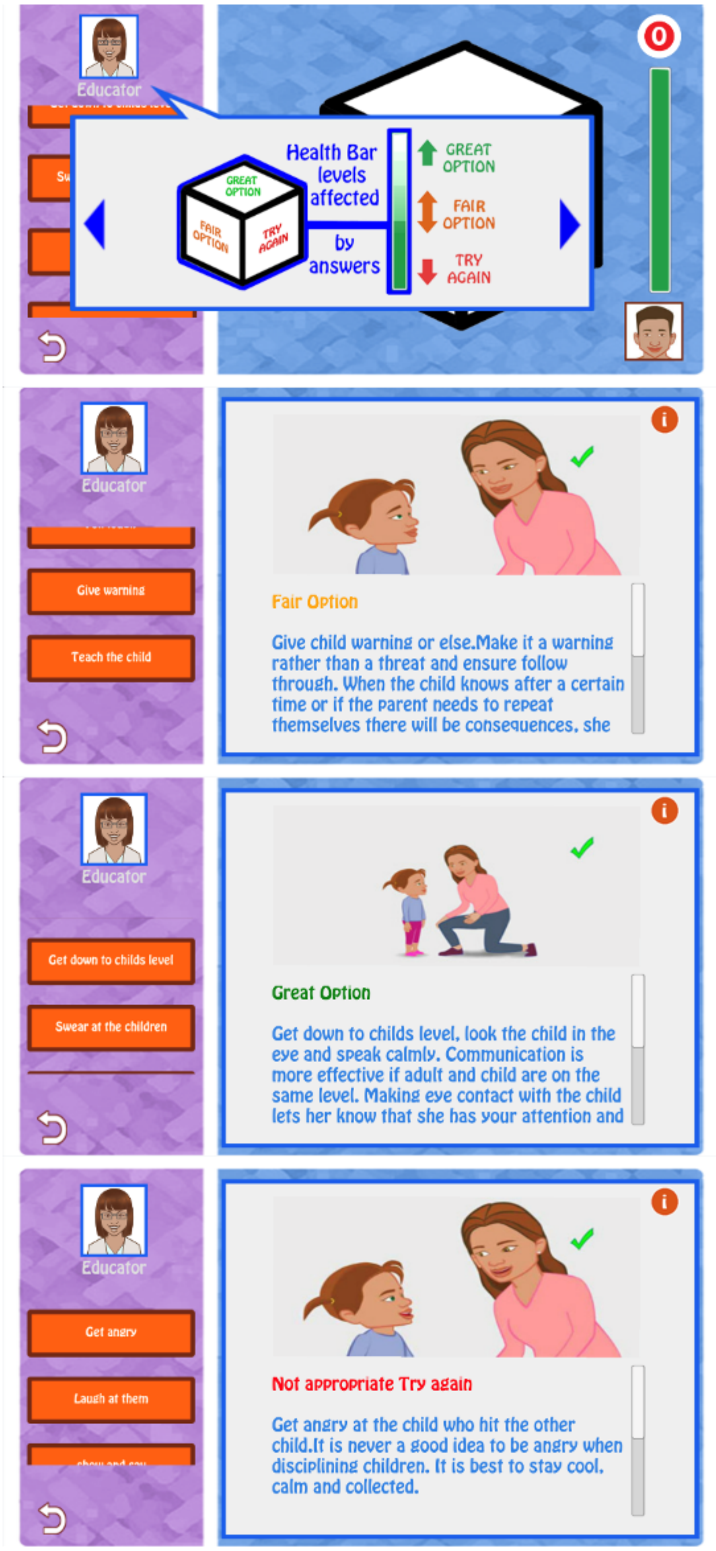
Play Kindly is an interactive, cross-platform computer game designed for use on a smartphone. The interface is designed to resonate with Pacific people (Figure 1). The ideas, scenario scripts, narration, and artwork were undertaken by a team consisting of an established Pacific academic, a Pacific playwright, and a Pacific animator working alongside researchers and health professionals. Each scenario is short and lasts a few minutes. Parents can choose to play one scenario at separate times or all of them in one sitting. For each scenario, the participant chooses from a drop-down menu the most appropriate way to manage the behavior. Three "great" (correct) answers are needed to progress to the next scenario. Feedback about "fair" or "try again" answers are delivered by an "educator" avatar, who also gives instructions about how to play the game (Figure 2). Behaviors addressed in the game are *fights over belongings, refusing to eat, refusing to be dressed, and temper tantrums.* The strategies taught are predominantly focused on effective communication with the child, such as using a calm directive voice and eye contact, using distraction, and offering alternative strategies while not engaging in aggressive or harmful strategies.

The strategies in Play Kindly build on research with Samoan parents using the interactive CD-ROM tool "Play Nicely" [19]. The authors of the original "Play Nicely" described using content from parenting resources distributed by the American Academy of Pediatrics and American Psychological Association from around the time it was developed in the late 1990s, alongside input from multiple experts in the areas of psychology, pediatrics, and early childhood education [20].

The gamification and behavioral change techniques employed were the use of rewards such as badges, different levels of play, the use of avatars, the ability to customize some features, and feedback on performance.

Figure 1. Frame from one of the parenting scenario animations in Play Kindly.

Figure 2. Play sequence from one of the Play Kindly scenarios.



Design

The qualitative method was chosen to get an in-depth understanding about how the app was viewed by parents, particularly those groups underrepresented in health research, and professionals. Pacific parents for whom the app had been designed were the main target group. Our methodologies were, therefore, chosen to engage and work effectively and appropriately with Pacific and Māori communities, include both Pacific [21] and Māori [22] approaches, and take into account Pacific and Māori health research guidelines and qualitative research methods.

Pacific health research approaches are framed around the Pacific cultural values of communal relationships, reciprocity, holism, and respect from the beginning to the end of the research process [21]. The Pacific team, in partnership with a team from the University of Auckland, collaborated to cocreate an evaluation process that incorporated Pacific values and a rigorous scientific method. The cocreation process prioritized the concept of Teu le Vā, which involves identifying and understanding the "vā," or spaces, between different stakeholders in Pacific research and development, and sharing knowledge across these spaces.

To establish the "vā," engagement was in a face-to face manner with Pacific and Māori researchers, and incorporated a welcome ceremony, sharing of food, introductions, and a meaalofa (gift). This is also consistent with Māori tikanga protocols.

The Māori ethical framework shares many principles with Pacific guidelines and emphasizes whakapapa (relationships), tika (research design), manaakitanga (cultural and social responsibility), and mana (justice and equity) [22].

Collaboration across teams and communities, and adherence to cultural guidelines demonstrated our attempt to optimize relationships, enhance Pacific and Māori capacity and capability, and conduct research within a cultural framework.

Participants

The five focus groups interviewed consisted of 2 contemporary pan-Pacific groups, 1 Māori group, 1 young Pacific adults or prospective parents group, and 1 open group. Pan-Pacific refers to individuals from the major Pacific ethnic groups in New Zealand. Contemporary refers to Pacific people predominantly fluent in English, who are more likely to have been born in New Zealand and belong to multiple ethnic groups. This subset were chosen because the majority (60%) of the Pacific population in New Zealand are in this category [15]. The open group refers to non-Māori and non-Pacific New Zealanders. Table 1 provides further details about each group.

Table 1. Type of group, numbers, sex, and ethnicity of participant focus groups.

Focus group	Participants, n	Female, n (%)	Male, n (%)	Ethnicity
Pacific focus group 1 (Pacific 1)	10	8 (80)	2 (20)	Tongan, Samoan, Samoan/European, Niuean
Pacific focus group 2 (Pacific 2)	11	8 (73)	3 (27)	Samoan, Tongan, Cook Island
Māori/Ngā Matua focus group (Māori)	6	5 (83)	1 (17)	Māori
Open focus group (open)	9	8 (89)	1 (11)	New Zealand European, South African
Pacific youth focus group (youth, 18-23 years of age)	9	4 (44)	5 (56)	Samoan, Tongan, Niuean, Cook Island

The 12 professionals interviewed individually were from a range of disciplines and had knowledge of child health and development, parenting interventions, or Pacific health. Some professionals had extensive experience in implementing evidence-based parenting interventions. The largest number of respondents were Samoan or New Zealand European. Table 2 provides further details of the professionals who conducted the interviews.

Table 2. Profession, ethnicity, and number of interviewees in the professional interviews.

Professional background	Participants interviewed, n	Ethnicity
Psychologist	5	3 NZE[a], 1 Samoan, 1 Māori
Pediatric doctor	2	1 Māori, 1 European
Research and teaching	2	2 Samoan
Early childhood education	1	1 NZE
Nurse with qualifications in child health	1	1 Asian
General practitioner	1	1 Fijian

[a]NZE: New Zealand European.

Recruitment

Pacific research team members recruited parents through snowball sampling. A total of 3 people known to one of the research assistances were contacted by telephone. The research assistant gave them information about the study, asked whether they would like to take part, and asked them to identify other potential participants. These people were contacted in the same way. This process continued until the researcher had all the participants needed.

Snowball sampling is a technique commonly used when a sample of the study is limited to a small subgroup of the population and starts through known acquaintances that fit criteria. The researchers typically ask for assistance from the participants recruited so far to help identify other people with a similar trait or interest. This method was chosen because of historical difficulties in recruiting Pacific and Māori people to take part in research. These communities have reported feeling overresearched and underinvolved in the design and feedback from research in general. This method meant that on two occasions the interviewee knew one of the research assistants, an almost unavoidable circumstance given the small and often well-connected Pacific community, so this research assistant did not conduct the interviews. A total of 55 individuals were approached; 3 individuals did not respond to the invitation to take part, and 7 did not attend the focus group interview as arranged.

Professionals were recruited by expert sampling, a form of purposive sampling needed to capture the specific expertise required to answer questions about content and cultural appeal. Expert status was defined as a person, preferably of Pacific decent with extensive knowledge based on research or occupation in the area of child health. Names of individuals were put forward by academic staff familiar with those working in the field across New Zealand. These individuals were contacted by phone or email and asked if they would like to take part. The number of professionals interviewed was determined by the emergence of data saturation. One professional knew one of the app designers and was reminded that their responses would be anonymized and kept confidential. By the end of the study, 20 professionals had been contacted by email; 7 were too busy to take part, and 1 stopped responding to emails.

Procedure

All focus groups were conducted in English. The focus groups were run by 1-2 Pacific researchers or 1 Pacific researcher and 1 European or New Zealand European researcher. The researchers held either an MD or PhD, or worked in the field of child mental health (psychiatrist or psychologist). Similarly, the Māori focus group was cofacilitated by a Māori facilitator to ensure that Kaupapa Māori research processes were followed. All interviewers were employed as researchers by the University of Auckland with the exception of the Māori facilitator. None had financial interests in the success of the app. The Pacific facilitators knew the app designers and had an interest in Pacific health initiatives in New Zealand.

Semistructured interviews were chosen to ensure that the aims of the study were addressed but gave space for new themes and ideas to emerge. In line with Kaupapa Māori and Pacific research methodologies and frameworks, focus groups included a welcome ceremony, the sharing of food, introductions, and setting the scene for the research.

Prior to the focus group or interview, all participants were asked to complete the app. If parents had not looked at the app before the interviews, the research team allowed time for them to start playing it on provided tablets before they commenced, not necessarily finishing the whole app. The focus groups lasted between 45 minutes and 1 hour, and were all face-to-face. The professional interviews lasted between 30-40 minutes and were conducted at the person's home or workplace, or over the phone. All professionals had familiarized themselves with the app by the time of the interview. Not everyone had completed all of the scenarios due to usability issues. The interviews were digitally recorded and transcribed verbatim. Script and audio were reviewed by Pacific and Māori researchers to ensure accuracy in interpretation. Transcripts were returned for participants to comment.

Data Analysis

All focus groups and individual interviews were recorded, and a general inductive approach was used for data analysis. This approach included collecting and becoming familiar with raw data, generating and revising initial codes, searching for themes, and then reviewing and defining themes and subthemes. Codes and themes were derived from the raw data and coded using NVivo software (QSR International) [23].

The coding was carried out by 1 Pacific, 1 European, and 1 Māori researcher. An initial meeting took place to discuss ideas about codes relevant to the research question. Following this, each researcher worked on transcripts separately coding everything relevant to the research question. The Māori researcher only coded the Māori focus group manuscript alongside the Pacific and European researcher. This was to ensure that codes and themes were interpreted correctly, taking into account the cultural context. Overall, 40% of the data was independently coded by at least 2 researchers, and any disagreements were resolved by discussion. The codes were then organized into broader themes related to the research question. These were reviewed and modified until it was felt that the data accurately supported the data and captured the entire data set.

Ethical Approval

Ethics approval for this research was obtained through The University of Auckland Human Participants Ethics Committee (Ref 018135).

Results

Results are summarized in Table 3 across themes that were identified of acceptability, usability, cultural specificity, and content.

The Pacific theme and real-life nature of scenarios appealed to most regardless of ethnicity. There was some disagreement about how culture specific the app should be, and opinions were likely to be influenced by how strongly the person identified with their own culture. The involvement of an artist and playwright helped to create something that felt real, but the light-hearted approach began to get lost as professionals tried to deliver parenting advice. The main point of contention for some was the virtual coach (avatar) who was referred to as an "educator."

The main concerns about content were parenting advice not being tailored for individual families, not taking into account the context in which the behavior occurred, and not providing sufficient instruction to teach strategies effectively. Addressing this could be challenging, as longer explanations would detract from the game, and video demonstrations would use too much data.

Table 3. Major themes, subthemes, descriptions, and examples from the data.

Theme and subtheme	Examples
Acceptability	
Visual appearance (mixed opinion)	• "I like the visuals, kind of simple, it's not too complex looking" (Pf[a]3) • "It looks like it's developed in the 90's, a bit old" (Māori)
Relating to scenarios	• "It didn't shy away from the reality, particularly the responses of Pacific families" (Pf3) • "It has everyday things that parents come up against" (Open)
Delivery of parenting education	• "There was kind of like academics trying to get down with the blue collars workers and you go, that would never happen in real life" (Māori) • "Why is this person (avatar) called an educator? It feels you are doing something wrong" (Youth) • "I thought it was quite informative, I wouldn't even think to do that" (Open)
Usability	
Repetitive	• "It's like ok I got it the first time...every time it keeps coming up...and I keep scrolling to the end...and I have to do it again...yea I got it the first time" (Pacific 2)
Flow	• "Maybe the flow wasn't so smooth, like it seemed a bit jittery and maybe fragmented, like no real flow going into each phase" (Pacific 1)
Progressing to the next level (unclear instructions)	• "Like I couldn't get past it, like I did the first scenario and I thought the little explanation like why those decisions are the best I really thought that was informative but I kind of couldn't get past this part" (Māori)
Cultural specificity	
Varying attitudes	• "There was a link to a Pacific peoples/Kiwis that you could actually connect with" (Pf1) • "Yes, there were brown faces, but that was about it. The rest was very westernized and clinical" (Pacific 1) • "Māori people would want Māori speaking, Māori looking things. Other Māori, bicultural Māori from bicultural and things would be ok with, they'll just take what they need 'cos they feel kind of safe and walk in both worlds" (Māori) • "Parenting isn't cultural, parenting is parenting" (Pacific 2)
Content	
Incremental challenges (unable to progress to the next level without 3 "great" answers)	• "There's a bit of an impression from it that there is a right way and a wrong way, and I personally don't feel particularly comfortable with that" (Pf2) • "I put ignore the behaviour which is what I have been doing with my kids and they stop and it went orange (fair answer) and then I went oh?" (Māori)
Amount of text	• "Like one (of the options) was 'voice' I was like, oh, okay I use my voice?" (Pacific 1) • "Get down to the child's level', people might think, well, what do you mean, do I talk like my four-year-old? Do I do what they're doing?" (Pf5) • "It would be great to have a video of someone going, this is why you get down to their level because of this, you know what I mean, because people don't like to read, I don't like to read" (Pacific 1)
Overly simplistic	• "It doesn't privilege your voice as a parent already" (Open) • "The focus is more about talking with the family about what's working for them, what are the solutions they've tried...rather than going there is a certain way to deal with this particular situation, so it wasn't a good fit for me" (Pf7)
Important information missing	• "I felt like there was some fundamental information that was needed first of all...even at like a really basic behavioural level, what you pay attention to is what you'll get more of" (Pf4) • "So definitely the front and centre stuff around building relationships, that's the big thing for me that I think's absent from this" (Pf5)

[a]Pf: professional.

To progress to the next scenario, parents needed to choose three "great" answers, but this was often not clear to them. Professionals felt that distinguishing between a "great" and a "fair" answer was unhelpful because perfect parenting was idealistic. There was also some disagreement about what should constitute a good or fair answer. Professionals were concerned about the effect on struggling parents who could not progress through the scenarios and how this might impact their view of themselves as parents.

Finally, professionals recommended that the app should focus on an aspect of parenting rather than general parenting. They suggested the inclusion of what they regarded as the most important strategies: playing with your child and positive reinforcement.

Discussion

General Discussion

This is the first time a parenting app has been designed for Pacific parents and the first time feedback from this important user group and from Māori parents has been sought. Parenting is a sensitive subject and this study highlighted the level of thought needed to deliver advice in a palatable way. Perhaps those searching for a parenting app to upskill would be less likely to object to this method of information delivery than those that participated in the groups who may not have ordinarily sought out such an app. Collaborating with marketers, game designers, and parents in the design process could help to set the correct tone.

The techniques to "gamify" the app, such as incremental challenges, a scrolling bar of options, and the use of a virtual coach, had the potential to engage with or discourage parents. Our findings support previous research that gamification techniques are only successful if gaming principles like motivational affordances (eg, levels, achievements, feedback) are implemented with specific behavioral outcomes in mind [24,25]. This further highlights that scientific institutions need to work with art industries, game developers, and marketers to create something that is acceptable to the general public and leads to behavioral change.

Concerns about the app not taking into account the context in which the child's behavior occurred and not sufficiently explaining the strategies could be mitigated by the fact that the app is aimed at children who have everyday behavioral problems. The level of intervention needed would, therefore, be low. Targeting this cohort, even if the information is brief, could prevent more significant problems from developing or act as a stepping stone for further support. The professionals' suggestions of narrowing the focus to two important strategies could potentially widen the reach of the app to parents of children with behavioral problems of different severity and could also address the issues with the amount of instructions and text.

The feedback from the professionals and parents was useful in providing a clear framework for adaptation. Play Kindly was developed on a modest budget, and many of the usability difficulties experienced could be addressed as further funding was secured. There is an increasing recognition of the importance of co-design, and greater use of this with parents and professionals at the start might also have mitigated some of the perceived problems.

Limitations

This was a small study with a sample size that is consistent with design research [26], so findings are not intended to be generalized to the population of parents in New Zealand. The diversity of the sample was compromised by snowball sampling. Two people were known to the one of the researchers, so it was ensured that the person who conducted the interview was unfamiliar to them. One participant knew one of the app designers and admitted feeling anxious about expressing their views. This was addressed by reminding them that their opinions would be confidential and anonymized. Without the involvement of a Pacific research team, it is unlikely that a sufficient number of participants would have been recruited to this study, and thus, bias was difficult to avoid. The researchers who conducted the interviews formed their own opinions about the app on the basis of the reviews from parents and professionals. This bias was reduced by asking for other members of the research team, not present at the interviews, to read the transcripts and compare with the overall report.

Many parents and professionals did not play the entire game because of usability issues and not picking the correct answers as deemed by the app. It is, therefore, possible that a number of themes were missed. The issues raised here will be addressed once the app has been modified and retested by reinterviewing users of the app.

Future Directions

This study lays the groundwork for further redevelopment of the app with the feedback obtained through the qualitative paper described here. After redevelopment, the revised app will be trialed in a feasibility trial with further refinement following and then a controlled larger scale trial. Involving stakeholders in the design of electronic interventions is highly recommended for future projects of this nature.

Conclusions

Play Kindly is the first culturally adapted parenting app of its kind designed to target Pacific parents and other New Zealanders. Aimed at everyday parenting problems, this app has potential in Pacific communities where there is limited culturally specific parenting resources and could also appeal to other New Zealanders through its visual appeal and relatability.

Iterative design is a core part of the development of digital technologies. Play Kindly was appealing, and with further development to increase the content as recommended by the professionals and address some of the usability difficulties, it appears to have the potential to be a useful tool for parents of young children.

Acknowledgments

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Conflicts of Interest

ETC-M was involved in the design and ongoing evaluation of the app. Due to the small and interconnected nature of Pacific communities, some of the researchers and participants were known to each other.

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Original Paper

Using a Virtual Serious Game (Deusto-e-motion1.0) to Assess the Theory of Mind in Primary School Children: Observational Descriptive Study

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Abstract

Background: Given the interactive media characteristics and intrinsically motivating appeal, virtual serious games are often praised for their potential for assessment and treatment.

Objective: This study aims to validate and develop normative data for a virtual serious game (Deusto-e-motion1.0) for the evaluation of emotional facial expression recognition and social skills, both of which are components of the theory of mind.

Methods: A total of 1236 children took part in the study. The children were classified by age (8-12 years old), gender (males=639, females=597), and educational level (between the third and sixth years of Primary Education). A total of 10 schools from the Basque Country and 20 trained evaluators participated in this study.

Results: Differences were found in Deusto-e-motion1.0 scores between groups of children depending on age and gender. Moreover, there was a moderately significant correlation between the emotional recognition scores of Deusto-e-motion1.0 and those of the Feel facial recognition test.

Conclusions: Deusto-e-motion1.0 shows concurrent validity with instruments that assess emotional recognition. Results support the adequacy of Deusto-e-motion1.0 in assessing components of the theory of mind in children.

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KEYWORDS

serious game; theory of mind; facial emotion recognition; children

Introduction

Serious games represent a growing area of computer applications used to improve or evaluate different skills. They are appealing, interactive, enhance ecological validity, and allow players to take on realistic roles to cope with problems and to make decisions [1,2]. Games are entertaining, but they can also be educational [3].

The use of computer software has several advantages: the environment is predictable, consistent, free from social demands, and users can work alone. Furthermore, lessons can be repeated, and motivation can be maintained through rewards and feedback [4]. Virtual and mixed realities present the possibility of creating new, immersive, and motivational places where patients can be evaluated and trained while playing [5].

There are various serious games available, such as some for training skills [6], for prevention [7], for psychological therapy [8], or for cognitive training. Other types of games help users to deal with those with special needs, such as the elderly [9], people with physical disabilities, or blind children [10]. An example of a serious game is Happy Farm [11], a software for young people designed to increase their awareness of the risks related to psychoactive substances. Another program, VEPSY (updated telemedicine and portable virtual environments for clinical psychology) [3], was created to investigate the effects of virtual reality systems aimed at dealing with several clinical disorders, such as social phobia, obesity, bulimia, or male impotence. The project combines treatments and assessments with virtual reality. Similar games have been developed to induce mood enhancement on both clinical and nonclinical samples [12]. The EMMA project (Engaging Media for Mental Health Applications) provides innovative ways of coping with distressful emotions for users who suffer psychological problems, users with restricted mobility, or the general population [13]. Another group of serious games has been created to assess and train the components of the theory of mind.

The theory of mind covers mental skills related to understanding, explaining, and predicting the psychological states of oneself and others [14]. The theory of mind was first established in animal studies with chimpanzees [15] and later in infant developmental psychology and autism [16]. The theory of mind permits typically functioning individuals to infer the mental and emotional states of others as a means of engaging reciprocal communication and maintaining relationships. Recognition of emotional facial expressions is an essential part of the theory of mind. The face is the way that emotions can be exteriorized and expressed in a nonverbal way, something essential for a person to adapt to the social environment around them, as shown in "Mind Reading: The Interactive Guide to Emotions" (Jessica Kingsley Publishers, London, United Kingdom). This is a multimedia computer program that has been used to address emotion recognition.

Attempts to teach components of the theory of mind to people with autism spectrum conditions have used computer-based training [17-19] or virtual environments [20]. Golan and Baron Cohen used "Mind Reading: The Interactive Guide to Emotions," during a study on adults with Asperger syndrome or high-functioning autism [21]. They used it as an interactive guide to teach emotions in a systematic and comprehensive format, as it includes an emotion library, a learning center, and a game zone. The results of this study revealed that the use of the program significantly improves emotional recognition skills in adults with autistic spectrum conditions.

In 2002, Bölte [18] developed a computer-based program to teach and test the ability to identify facial emotions, known as the "Frankfurt Test and Training of Social Affect" (FEFA). The training was conducted for five weeks, for two hours a week, and the participants improved significantly on the facial recognition task. The Motion Picture Mind Reading test is a naturalistic mind-reading test designed to measure individual differences among a young adult population watching TV films showing characters in various social situations [22]. There are several collections of material and databases with facial emotion information and photographs, pictures [23,24], or virtual faces [25]. Different questionnaires have been developed to assess facial recognition ability, including the Florida Affect Battery test [26] or the Feel test [27]. However, a few types of software evaluate facial emotion recognition and empathy in children through serious virtual games.

The present study evaluated a new program, Deusto-e-motion1.0, which was developed to assess and train components of the theory of mind in children between the ages of 8-11 years old. Specifically, this paper presents the development and preliminary evaluation of the Spanish version of Deusto-e-motion1.0 to test the recognition of facial emotions in a sample of 1236 children.

Methods

Participants

A sample of children between the ages of 8-11 years old was chosen. The recognition of emotional facial expression improves between the ages of 8-14 years old, a period in which maturation processes associated with brain development occur [28]. The total sample was composed of 1236 children (males=639, females=597). The mean age was 9.58 (SD 1.11), with a breakdown of 269 8 year olds (males=148, females=121), 332 9 year olds (males=169, females=163), 290 10 year olds (males=151, females=139), and 345 11 year olds (males=171, females=174). Participants were excluded if there was any indication of an existing neurological or psychiatric disorder, according to the school psychologist's criteria. The inclusion criteria were: speaking Spanish, being between 8-11 years old, between the third and sixth years of Primary Education, and having a normal IQ range (>90). For the fulfillment of the inclusion criterion of the IQ, the opinion of the team of professors of the schools in which the study was carried out was considered. Signed parental or school consent was obtained from all participants before beginning the study, and no remuneration was provided to either the students or their parents for taking part.

Instruments

E-motion1.0

This program contains two sections and requires about 20 minutes to be completed (Tables 1 and 2). It is designed to be played on a personal computer during a psychosocial skills assessment. Each level follows a preset structure that integrates static and virtual scenes. Its target audience is 8-11 year-old males and females. Deusto-e-motion1.0 has two versions: (1) a virtual version which includes a head-mounted display, a motion tracker, and a joystick input device; and (2) a serious game version. The present study presents the validation results of the serious game's Spanish version of Deusto-e-motion1.0.

Table 1. Summary of section 1 of Deusto-e-motion1.0.

Section	Emotions	Type of variable
Static faces	• Neutral • Happiness • Anger • Sadness • Fear • Surprise • Disgust	• Type of emotion chosen (nominal) • Correct/incorrect (nominal) • Reaction time (continuous)
Dynamic faces I	• Happiness • Anger • Sadness • Fear • Surprise • Disgust	• Type of emotion chosen (nominal) • Correct/incorrect (nominal) • Reaction time (continuous)
Dynamic faces II	• Neutral • Happiness • Anger • Sadness	• Type of emotion chosen (nominal) • Correct/incorrect (nominal) • Reaction time (continuous)
Static faces II	• Neutral • Happiness • Anger • Sadness • Fear • Surprise • Disgust	• Type of emotion chosen (nominal) • Correct/incorrect (nominal) • Reaction time (continuous)

Table 2. Summary of section 2 of Deusto-e-motion1.0.

Section	Items	Type of variable
Virtual scenes I	• Three static scenes • How would you feel about it? • How would he/she feel?	• Type of emotion chosen (nominal) • Reaction time (continuous)
Virtual scenes II	• Fourteen virtual scenes • How would you feel about it? • How would he/she feel?	• Type of emotion chosen (nominal) • Reaction time (continuous)

This instrument was developed by a team of multidisciplinary professionals: psychologists, psychopedagogues, and computer scientists. For the development of the first section of the instrument, visual stimuli were designed with virtual reality tools. Baron Cohen's facial emotional expression criteria were used, as found in "Mind Reading: The Interactive Guide to Emotions." Virtual stimuli were chosen because of the higher possibility of controlling expression features. This section was validated with a pilot test with students of psychology and children between the ages of 8-12 years old. Depending on the results obtained, the details of the emotional expressions were modified to obtain a percentage of agreement between emotion and facial expression of at least 90%. The expression of fear was one of the most complicated to carry out because it could be confused with the expression of surprise.

The first section of Deusto-e-motion1.0 measures the ability to recognize facially-expressed basic emotions (Figure 1). The internationally known and applied cross-cultural concept of six basic emotions (happiness, sadness, anger, disgust, fear, surprise, and neutral), proposed by Ekman [29], was the reference for the selection of the pictures. This first block consists of four sections of 24 items: (1) seven static facial emotions; (2) six dynamic facial emotions, which include faces changing from neutral to another emotion; (3) four dynamic facial emotions which show faces changing from one emotion to another; and (4) seven static facial emotions. There are two blocks with static facial emotions to control the learning effect. Each face is presented on a computer screen for a maximum 30 seconds. Subjects must classify the respective emotion by clicking on the appropriate label in a forced-choice format (happiness, sadness, anger, disgust, fear, surprise, or neutral). Responses for all tasks are scored as correct or incorrect. The Deusto-e-motion1.0 automatically records the sum of total correct answers, the sum of static facial emotions scores, the sum of dynamic facial emotions scores, the error scores, and the reaction time for each emotion.

Figure 1. First section of Deusto-e-motion1.0: facial recognition.

The second section consists of different virtual scenes placed in a virtual school setting (Figures 2 and 3). Figure 4 shows scene and answer options. This section was developed based on potential situations which may occur in the daily lives of children aged between 8-12 years old. For this reason, the school context was chosen, with a focus on the school playground. Social situations are presented that are related to problems or conflicts that can evoke emotions in other people as well as in oneself. The narrative develops through 30 items, each one lasting about half a minute or a full minute. After presenting each situation, the participant is asked to choose among the six emotions (happiness, sadness, anger, disgust, fear, surprise, and neutral). An example of a situation would be:

> *Your friends have planned an unexpected party for your birthday. How would you feel? How would they feel?*

In addition to registering the choice of answers, Deusto-e-motion1.0 recorded the time taken by participants to select and answer each question. This test has had a previous validation study [30].

Figure 2. Second section of Deusto-e-motion1.0, virtual scenes at school: social situation in relation to choice in-game.

Figure 3. Second section of Deusto-e-motion1.0, virtual scenes at school: social situation with a boy in a wheelchair.

Figure 4. Second section of Deusto-e-motion1.0, virtual scenes at school: social situation with students and teachers, and answer options.

Feel

Feel is a computer-based test that measures the ability to recognize facially-expressed basic emotions [27]. This test was used together with Deusto-e-motion1.0 to obtain concurrent validity ratings. It consists of 42 photographs showing facial displays of six basic emotions (anger, fear, sadness, happiness, surprise, and disgust), developed by Matsumoto and Ekman [23], which are presented on a computer screen. Subjects must quickly and accurately classify the respective emotion by clicking on the appropriate label in a forced-choice format. In total, 42 pictures of adults are shown, and seven examples of each six emotions are used. The Feel test score takes the correct answers, error scores, and reaction time for all emotions. The test shows the highest reliability of this form of assessment (Cronbach alpha=.77). Over the years, a database with over 600 healthy subjects has been collected [27]. This test previously had a Spanish validation study, including a sample consisting of a total of 1189 school children aged between 8-11 years old, with 594 boys and 594 girls, and with a Cronbach alpha of 0.82 [31].

Procedure

The validation test took eight months to be completed. Children were recruited from ten different schools in the Basque Country (Spain), and 20 trained volunteers and two coordinators collaborated on this research. Participants were individually tested in a quiet room outside the classroom. Each subject was told that the experimenter was going to show him some games. All testing took place in the same session without breaks, and children were initially instructed on the various tasks and questionnaires. The child, seated at a table facing the computer, was presented with the materials, and the task was always presented in the same order: Deusto-e-motion1.0 and then the Feel test [27,30]. After the individual explanation, they completed the task during thirty minutes under standardized conditions within the school setting.

The ability to recognize facial expressions of the six basic emotions was investigated by using virtual faces in Deusto-e-motion1.0. Facial stimuli were presented to the subjects in 4 different blocks in the following order: (1) seven static facial emotions: neutral, happiness, anger, sadness, fear, surprise, and disgust; (2) six dynamic facial emotions, which included faces morphing from neutral to another emotion (neutral-happiness, neutral-anger, neutral-sadness, neutral-fear, neutral-surprise, and neutral-disgust); (3) four dynamic facial emotions which show faces morphing from one emotion to another: neutral-happiness-anger-sadness; and (4) seven static facial emotions: neutral, happiness, anger, sadness, fear, surprise, and disgust. The 24 virtual faces were shown one at a time, and the subjects were asked: “How is this person feeling?” They were asked to indicate the emotion depicted by the particular face as spontaneously as possible by choosing one button according to the following categories: happiness, anger, fear, sadness, disgust, surprise, or neutral. The order in which the blocks were presented to the subjects was the same in all the presentations. The duration of the stimuli was decided by a pilot study, which revealed that children needed about 3000 milliseconds to give a response. Emotional faces and labels were visible on screen at the same time. The program provided no feedback to the participants about the accuracy of their answers.

The second section of Deusto-e-motion1.0 included 30 items presenting social interactions and interpersonal conflicts within a school setting. Subjects had to decide the possible answer by choosing between the emotions happiness, anger, fear, sadness, disgust, surprise, or neutral. Social settings were illustrated by virtual animations that also incorporated recorded speech using a narrator’s voice. The first six items presented static pictures, whereas, in the rest of the task (24 items), the scenes were dynamic. The test questions all referred explicitly to a character’s feelings and the subject’s feelings. Answer options appeared in the right of the screen with the six emotions and the neutral option, and these were selected between by pressing the appropriate key. When the question had been read, the participant was required to press a specific button on the computer keyboard.

The Feel test [27] consisted of 42 photographs of actors and actresses showing static emotional faces (anger, fear, sadness, happiness, surprise, and disgust) on a computer screen for 300 milliseconds. Clicking on the appropriate box, subjects had to decide which emotion they had previously seen. Emotional pictures and labels were not visible on the screen at the same time. The Feel score took the accuracy and reaction time of the answers into consideration and ranged between 0 to 84 points.

Participation in the study was voluntary, confidentiality was ensured, and all the requirements established by the bioethical commission for studies with human beings were met.

Statistical Analyses

Descriptive analyses were performed to assess the socio-demographic and clinical characteristics of the respondents. A Kolmogorov-Smirnov test was applied to evaluate the normal distribution of variables. The analysis showed that all variables were nonnormal. A Mann-Whitney *U* test and Kruskal Wallis test were used to investigate differences regarding age and gender for continuous variables. The chi-squared test was applied to the categorical variables and the Spearman test to the correlations. SPSS statistical package version 15 (IBM Corporation, Armonk, New York, United States) was used to analyze the data. Any $P<0.05$ was considered to be statistically significant.

Results

Content Validity and Piloting

A team of five psychologists, psychopedagogues, and computer scientists was involved in the design phase, specifically in generating ideas, characters, scenes, and instructions through brainstorming. The interjudge agreement was assessed with Kappa calculations (k=0.85). The values were within the range of fair to good agreement. The created virtual facial expressions were validated in a pilot study. For this purpose, 30 volunteers evaluated the facial material (48 faces) according to the expressed emotion. A final set of 24 items were chosen. After face and content validation, the tool was piloted. A total of 100 children were asked for their overall impression of the software, and whether any items had been challenging to answer. Following the pilot phase, the wording of item number 25 was modified slightly to prevent misunderstanding, and a section was added from the previous version because of the improvement of the static fear face. After this modification, the game was clear and understandable.

Internal Validity of E-motion1.0

The internal validity of the instrument was examined using the Spearman correlation. The total score correlated positively with the static facial emotions' score (r^2=0.812; *P*<.001) and with the dynamic facial emotions' score (r^2=0.872; *P*<.001). Static facial emotions' score correlated with dynamic facial emotions' score (r^2=0.424; *P*<.001). The reaction time scores of static faces correlated positively with the reaction time scores of dynamic faces (r^2=0.706; *P*<.001).

The Concurrent Validity of E-motion1.0

Concurrent validity compares scores of an instrument with the current performance of some other measure. In this study, it was determined through correlation analysis (Spearman rank-order correlation) of the first section of Deusto-e-motion1.0 [30], specifically the section which includes the facial recognition task, and the Feel test [27,30]. The correlation coefficient between the facial recognition total scores of Deusto-e-motion1.0 and those of the Feel was r^2=0.339 (*P*<.001). The correlation coefficient between the facial recognition`s reaction time scores of Deusto-e-motion1.0 and those of the Feel was r^2=0.508 (*P*<.001). The results showed small to moderate significant correlations between all Deusto-e-motion1.0 scales and the Feel scales in total scores and reaction time scores (Table 3).

Table 3. Spearman's Rho correlations between Emotion and Feel test (N=1236).

Feel test expressions	Deusto-e-motion1.0 expressions											
	Happiness		Surprise		Anger		Fear		Sadness		Disgust	
	C[a]	RT[b]	C	RT	C	RT	C	RT	C	RT	C	RT
Happiness	—[c]	—	—	—	—	—	—	—	—	—	—	—
C	0.180	—	—	—	—	—	—	—	—	—	—	—
P value	.02	—	—	—	—	—	—	—	—	—	—	—
RT	—	0.448	—	—	—	—	—	—	—	—	—	—
P value	—	.01	—	—	—	—	—	—	—	—	—	—
Surprise	—	—	—	—	—	—	—	—	—	—	—	—
C	—	—	0.274	—	—	—	—	—	—	—	—	—
P value	—	—	.03	—	—	—	—	—	—	—	—	—
RT	—	—	—	0.394	—	—	—	—	—	—	—	—
P value	—	—	—	.01	—	—	—	—	—	—	—	—
Anger	—	—	—	—	—	—	—	—	—	—	—	—
C	—	—	—	—	0.127	—	—	—	—	—	—	—
P value	—	—	—	—	.02	—	—	—	—	—	—	—
RT	—	—	—	—	—	0.368	—	—	—	—	—	—
P value	—	—	—	—	—	.01	—	—	—	—	—	—
Fear	—	—	—	—	—	—	—	—	—	—	—	—
C	—	—	—	—	—	—	0.191	—	—	—	—	—
P value	—	—	—	—	—	—	.26	—	—	—	—	—
RT	—	—	—	—	—	—	—	0.215	—	—	—	—
P value	—	—	—	—	—	—	—	.05	—	—	—	—
Sadness	—	—	—	—	—	—	—	—	—	—	—	—
C	—	—	—	—	—	—	—	—	0.227	—	—	—
P value	—	—	—	—	—	—	—	—	.01	—	—	—
RT	—	—	—	—	—	—	—	—	—	0.375	—	—
P value	—	—	—	—	—	—	—	—	—	.03	—	—
Disgust	—	—	—	—	—	—	—	—	—	—	—	—
C	—	—	—	—	—	—	—	—	—	—	0.105	—
P value	—	—	—	—	—	—	—	—	—	—	.04	—
RT	—	—	—	—	—	—	—	—	—	—	—	0.292
P value	—	—	—	—	—	—	—	—	—	—	—	.04

[a]C: correct.

[b]RT: reaction time.

[c]Not applicable.

Discriminant Validity

Effect of Age and Gender on Facial Recognition

A Mann-Whitney *U* test was used to compare genders. Overall, there were no significant differences except for static score (z=–2.12; *P*=.03), dynamic score (z=–2.32; *P*=.02), sadness score (z=–2.10; *P*=.04), and disgust score (z=–2.85; *P*=.004). The size effect was low (0.1) in all the situations.

A Kruskal-Wallis test was conducted to investigate age differences. There were significant differences in static score (X^2_{13}=20.9; *P*<.001), dynamic score (X^2_{10}=18.99; *P*<.001), neutral score (X^2_2=18.99; *P*<.001), disgust score (X^2_2=29.46; *P*<.001), surprise score (X^2_2=29.46; *P*<.001), and all of the reaction time scores (*P*<.001). Results showed that the older the participants, the higher the total score, and the shorter the reaction time.

Effect of Age and Gender on Virtual Scene Answers

Comparisons of the answers and reaction times' scores concerning gender and age were made using a Mann-Whitney *U* test (reaction time and gender), a Kruskal-Wallis test (reaction time and age) for a continuous variable, and the chi-squared test for categorical variables (type of answer; gender and type of answer and age). Overall, there were no significant differences in gender. However, age is an important variable to compare both total answer scores and reaction time scores (Tables 4 and 5). As in the facial recognition task, results showed that the older the participants, the slower their reaction time.

Normative Data

The percentiles for the main scales of Deusto-e-motion were calculated, as shown in Table 6.

Table 4. Answer scores in virtual scenes regarding gender and age (N=1236).

Virtual scene item	Gender/answer		Age/answer	
	X^2 (df[a])	*P* value	X^2 (df)	*P* value
8.1	—[b]	—	39.38 (21)	.009
8.2	—	—	—	—
9.1	—	—	33.61 (21)	.04
9.2	—	—	37.08 (21)	.02
10.1	—	—	58.95 (21)	<.001
10.2	—	—	46.79 (21)	.001
12	—	—	36.87 (21)	.02
14.1	—	—	—	—
14.2	—	—	41.65 (21)	.005
14.3	—	—	—	—
15.1	—	—	—	—
15.2	—	—	34.47 (21)	.03
15.3	—	—	—	—
16	—	—	36.00 (21)	.02
17	—	—	104.40 (24)	<.001
18	—	—	80.09 (21)	<.001
19.1	—	—	33.21 (21)	.04
19.2	14.31 (7)	.05	36.12 (21)	.02
20.1	—	—	34.75 (21)	.30
20.2	17.56 (7)	.01	—	—
22.1	—	—	—	—
22.2	—	—	—	—
23.1	—	—	—	—
23.2	—	—	35.20 (21)	.03
24.1	—	—	—	—
24.2	—	—	—	—
25	—	—	—	—
26	—	—	69.47 (21)	<.001
27	18.71 (7)	.009	101.02 (21)	<.001

[a]df: degrees of freedom.

[b]Not applicable.

Table 5. Reaction time scores in virtual scenes regarding gender and age (N=1236).

Virtual scene item	Gender/reaction time		Age/reaction time	
	U	*P* value	H (df[a])	*P* value
8.1	110,482	<.001	55.46 (3)	<.001
8.2	115,430	.003	35.81 (3)	<.001
9.1	—[b]	—	21.15 (3)	<.001
9.2	—	—	12.86 (3)	.005
10.1	115,506	.003	10.77 (3)	.01
10.2	—	—	42.80 (3)	<.001
12	118,489	.03	56.01 (3)	<.001
14.1	—	—	57.87 (3)	<.001
14.2	—	—	10.72 (3)	.01
14.3	—	—	56.28 (3)	<.001
15.1	117,667	.02	25.23 (3)	<.001
15.2	—	—	38.76 (3)	<.001
15.3	—	—	36.21 (3)	<.001
16	114,167	.002	9.79 (3)	.03
17	115,247	.004	16.04 (3)	.001
18	114,636	.003	—	—
19.1	117,550	.02	70.05 (3)	<.001
19.2	—	—	38.10 (3)	<.001
20.1	117,101	.02	24.88 (3)	<.001
20.2	111,511	<.001	12.97 (3)	<.001
22.1	110,845	<.001	50.09 (3)	<.001
22.2	111,859	<.001	48.27 (3)	<.001
23.1	—	—	35.05 (3)	<.001
23.2	—	—	—	<.001
24.1	112,095	<.001	10.50 (3)	.015
24.2	—	—	17.40 (3)	.001
25	—	—	—	—
26	114,896	<.001	49.32 (3)	<.001
27	109,969	.003	30.41 (3)	<.001

[a]df: degrees of freedom.

[b]Not applicable.

Table 6. Percentiles for the dimensions.

Percentiles	Total (ms)	Dynamics (ms)	Statics (ms)	RT[a] total (ms)	RT statics (ms)	RT dynamics (ms)
1	3.0000	2.00	1.00	2651.52	2071.64	2139.46
10	10.00	6.00	3.00	3374.97	3245.94	3204.25
15	10.50	7.00	3.00	3604.79	3491.47	3369.97
20	11.00	7.00	4.00	3867.94	3709.60	3553.80
25	12.00	7.00	4.00	4144.01	3996.21	3777.55
30	12.00	8.00	5.00	4256.58	4248.02	3972.95
35	13.00	8.00	5.00	4464.35	4642.24	4251.47
40	13.00	8.00	5.00	4699.64	4838.28	4569.60
45	13.00	8.00	5.00	4919.47	5017.41	4719.77
50	14.00	8.00	5.00	5095.82	5356.14	4864.15
55	14.00	9.00	6.00	5521.94	5629.10	5122.80
60	14.00	9.00	6.00	5752.88	5956.14	5333.10
65	15.00	9.00	6.00	5990.67	6332.60	5706.20
70	15.00	9.00	6.00	6210.44	6623.57	6002.10
75	15.00	9.00	6.00	6612.55	6967.42	6536.02
80	15.60	9.00	6.00	6972.70	7407.71	6954.30
90	16.00	10.00	7.00	8356.32	9064.51	8497.85
95	17.00	10.00	7.00	9810.77	10,379.68	10,230.6
99	17.00	10.00	7.00	12,219.42	13,517.41	14,087.2

[a]RT: reaction time.

Discussion

According to Salovey [32], the skills associated with emotional intelligence include the assessment, expression, and regulation of one's own emotions as well as those of others, and the understanding of emotions and their use in an adaptive way to perform other activities, such as cognitive or behavioral tasks. In this context, the face is the way that emotions can be exteriorized and expressed in a nonverbal way, something essential for children to adapt to their social environment [33].

Deusto-e-motion1.0 is a serious game designed to evaluate components of the theory of mind, specifically facial recognition and empathy in 8-11-year-old children. This study presents the design and validation of the Spanish version of the Deusto-e-motion1.0 serious game.

There is no doubt that a test with suitable psychometric properties contrasted with a representative sample of participants would be beneficial for both the evaluation of the ability to recognize emotional facial expressions and for planning individual or group intervention programs in the area of children's interpersonal relationships. Moreover, the importance of developing such instruments with demonstrated validity and reliability to have appropriate protocols and paradigms to be applied in basic research should be highlighted, as in the case of neuroimaging studies [34].

This article explores content validity and piloting, internal validity, concurrent validity, and discriminant validity. The test shows moderate concurrent validity by correlating its scores with the Feel test that assesses similar capacity for emotion recognition. These results may be mediated by the characteristics of each test, in the sense that the Deusto-e-motion1.0 test includes, on the one hand, fewer items, and on the other, items with a dynamic and static nature. When working with variables of a very diverse nature, like different types of facial expression stimuli (cultural precedence or faces, photographs versus drawings), a lower correlation will support a high relation. It is suggested that in future studies, the rate of concurrent validity is calculated with a questionnaire with a higher number of static items [35].

There were significant differences in each gender's scores for the static, dynamic, sadness, and disgust emotions. Results showed that the younger the age of the participants, the slower the reaction time. Overall, there were no significant differences in each gender's scores in the virtual scenes section. However, age is an important variable to compare both the total answer scores and reaction time scores. With increasing age, facial expression recognition becomes faster and more accurate, possibly due to increased efficiency in understanding faces [36,37]. It is generally accepted that children's ability to recognize the emotions of unfamiliar faces improves between the ages of 5-10 years old [38].

It should be noted that this study is not without its limitations, and results should be considered with caution. First, the results only indicate the comparability of the classic basic emotions, as described by Ekman. However, daily, pure basic emotions are encountered only rarely. Future research should primarily focus on investigating more ambiguous and nuanced emotional expressions. Second, the Feel test presents only static pictures of adults of Asian and European descent, whereas Deusto-e-motion1.0 presents static and dynamic virtual faces of a boy. Third, the test shows a higher percentage of masculine faces. In the development of a new version of the instrument, stimuli of female faces will be included.

Conflicts of Interest

None declared.

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Abbreviations

EMMA: Engaging Media for Mental Health Applications
FEFA: Frankfurt Test and Training of Social Affect
VEPSY: updated telemedicine and portable virtual environments for clinical psychology

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Original Paper

Development and Evaluation of Intelligent Serious Games for Children With Learning Difficulties: Observational Study

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Abstract

Background: Positive results can be obtained through game-based learning, but children with physical disabilities have fewer opportunities to participate in enjoyable physical activity. Because intelligent serious games can provide personalized learning opportunities, motivate the learner, teach 21st-century skills, and provide an environment for authentic and relevant assessment, they may be used to help children and adolescents with different kinds of learning disabilities to develop social and cognitive competences.

Objective: The aim of the study was to produce and evaluate a suite of intelligent serious games based on accessible learning objectives for improving key skills, personal development, and work sustainability among children with learning difficulties.

Methods: We conducted this research between 2016 and 2018, with pupils aged 11 to 12 years with learning disabilities who were integrated into the mainstream educational system. We used a 4-step methodology to develop learner creativity and social competences: (1) needs analysis, (2) development of learning content, (3) development of intelligent serious games, and (4) a usability evaluation focusing on the research questions and hypothesis. This was based on an initial teachers' evaluation, using a survey, of students using 2 of the games, where the main goal was to determine user motivation and initiative and to improve the games and the evaluation process. The initial evaluation was followed by a pilot evaluation, which was performed for all proposed games, in all partner countries.

Results: In an initial evaluation with 51 participants from Slovenia consisting of a pretest, followed by intelligent serious game intervention and concluding with a posttest, we observed statistically significant improvement in social and cognitive competences measured by tests. Based on these findings and observations, we improved the games and evaluation process. In the pilot test, conducted in all participating countries on a sample of 93 participants, the mean score on the teachers' observation form on the pretest (before students began using the intelligent serious games) was 3.9. In the posttest, after students had used intelligent serious games, the mean score was 4.1.

Conclusions: We focused on developing and evaluating intelligent serious games for persons with learning disabilities, particularly for students with disabilities who are integrated into the mainstream educational system. Such games provide an opportunity for personalized learning and should be tailored to ensure that every learner can achieve the highest standard possible. However, we recommend that the games be adapted based on the students' needs and capabilities and a specially developed curriculum. The collected feedback showed that (1) children with learning disabilities need appropriately developed intelligent serious games, and (2) intelligent serious games, and the pertaining didactic methodology, should be based on an interoperable curriculum, so that teachers and trainers can use them. The student survey confirmed improvements in all aspects.

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KEYWORDS
serious games, experimental; social skills; cognitive competence; intellectual disability; learning disabilities

Introduction

Background

John Amos Comenius advised teachers to organize lessons into easily assimilated steps to make learning gradual, cumulative, and pleasant [1,2]. He emphasized the significance of play as a pedagogically effective activity. Today, Comenius's ancient motto, *schola ludus*, has found new meaning in the modern use of interactive educational programs that use play and games as pedagogical tools [3]. The school-by-play philosophy was probably most importantly marked by the contributions of positive psychologist Martin Seligman [4] and the constructivist theorists Lev Vygotsky [5] and John Dewey [6,7]. Seligman described three kinds of happiness, which are also important in game-based learning: pleasure and gratification, embodiment of strengths and virtues, and meaning and purpose [4]. Playing games, including intelligent serious games (ISGs), has all the attributes needed for "flow," according to Seligman and Csikszentmihalyi [8]. Playing computer games is a challenging activity that requires skill; it contains action and demands awareness; it has clear goals; and provides the player with immediate feedback. A well-designed game transports its players to their personal *flow zones*, delivering genuine feelings of pleasure and happiness [9].

Many studies have shown that positive results can be obtained through gamification and game-based learning. However, Malone et al [10] pointed out that people with physical disabilities have fewer opportunities to participate in enjoyable physical activity. One option for increasing physical activity is playing active video games. Their research examined energy expenditure and enjoyment in adults with mobility impairment during play and demonstrated positive results. Barnes and Prescott [11] and Dunn et al [12] also hypothesized that virtual reality platforms could be used for pediatric hemophilia care, allowing clinician orchestration, and being safe and feasible for use in distraction during procedures performed as part of complex health care. All these cases describe basic approaches to the notion of ISGs, and most reference a relatively narrow target group.

The term serious game means a game designed primarily for educational purposes rather than purely for entertainment [13-15]. Intelligent game–based learning environments integrate commercial game technologies with artificial intelligence methods derived from intelligent tutoring systems and intelligent narrative technologies. ISGs can provide personalized learning opportunities, offer more motivation and engagement for the learner, teach 21st-century skills, and provide an environment for authentic and relevant assessment [16-18]. It is important for the player or learner in this context that negative consequences are not typically associated with failure. Even more, failure is seen as a typical and integral part of playing, and of learning [17,18]. In the context of school curricula and subjects, gaming provides an excellent opportunity for formative assessment [19,20]. Serious games are often mentioned as an important means for teaching 21st-century skills because they can accommodate a wide variety of learning styles and personalized learning within a complex decision-making context [21].

Personalized learning can be particularly important for students with disabilities who are integrated into the mainstream educational system. However, serious games should be adapted based on student needs. In traditional classroom settings, a student who has not grasped a concept could end up with a gap in their knowledge base, whereas serious games inherently force the player to grasp a concept in order to advance. Players can repeat the same scenario until they have grasped the concept [13,22]. This justifies the placement of serious games in the context of constructivist theory: they are considered similar to Vygotsky's zone of proximal development, which is "the distance between the actual developmental level as determined by independent problem solving and the level of potential development through problem solving under adult guidance or in collaboration with more capable peers" [5,13].

Several research projects focusing on the learning process in people with impairments (mental or sensory) have revealed that ISGs are an excellent didactic tool for reaching educational goals. The work of Carvelho et al [23] confirmed positive results in a population with visual disabilities, and Baker [24] achieved similar encouraging results working with people with autism. Schneider et al [25] also worked with persons with dyslexia. Brown et al [26] proved the effectiveness of combining ISGs with mobile apps, which can be used anywhere, to reach a higher level of independence for persons with Down syndrome. Barnes and Prescott [11] proved that therapeutic games create clinically measurable reductions in symptoms of anxiety in adolescents. Dunn et al [12] reported that serious games can provide a distraction during medical procedures.

Serious games have several advantages when used as a tool in the educational process for children with learning disabilities. According to Connolly et al [27,28], children with disabilities who are commonly integrated into mainstream school environments often feel uneasy. For them, ISGs are an interactive way of modelling and reinforcing positive behaviors. Such games help players learn how to interact with the world in safer and more controlled environments, where challenges can be gradually introduced [29,30]. A possible disadvantage of using ISGs is that they can result in a lack of interest in studying. Moreover, they can have hidden risks for students: while computers are an invaluable educational tool, they can also be a source of problems and can diminish the overall value of in-person education. Ke and Abras [31] suggested that game challenges should be open ended and allow for partial success. Game designers should also embed scaffolding features to assist recall, reflection, and metacognitive regulation to support students with special learning needs.

However, proper implementation might help keep the drawbacks to a minimum. Better planning is necessary [29,32-34]. Based on the theory of ISGs, and on feedback from the survey conducted as part of this project, we began the design of ISGs.

Objectives

This research focused on serious games, including the process of gathering requirements, as well as the design and implementation of such games, as applied in the project Intelligent Serious Games for Social and Cognitive Competence (ISG4competence) [35]. It involved the participation of 3 universities and 4 companies, from Turkey, Slovenia, Hungary, Bulgaria, and Belgium. The main goal of the project was to develop a didactic concept and, on that basis, to produce ISGs for improving social and cognitive competences of children with learning difficulties. More specifically, the aim was to help children with learning disabilities in developing creativity, social skills, cognitive skills, and work skills. Using ISGs and 3D simulations helps these children in their process of social integration and personal development [36]. In the project, we used ISGs and 3D simulations to make teaching and learning more interesting, playful, attractive, and efficient [37].

Methods

Study Design

We approached our main goal, to develop learner creativity and social competences, through a 4-step process. The research was conducted between 2016 and 2018, in lower secondary schools with pupils aged 11 to 12 years. We focused on students with learning disabilities who were integrated into the mainstream educational system.

The aim of the study was to produce and evaluate a suite of ISGs based on accessible learning objectives for improving cognitive skills, personal development, and work sustainability among children with learning difficulties. Table 1 presents the instruments used to measure outcomes and the methodological process for the study [35].

Table 1. Methodological process of the study.

Step	Methods	Instruments	Products
1. Needs analysis	Survey	Questionnaire: Q1-Q16 (Multimedia Appendix 1)	Survey report
2. Development of learning content	Development of curricula and scenario framework	N/A[a]	Curricula and scenario framework [35]
3. Development of intelligent serious games	Development of games	N/A	10 games, 2 examples
4. Usability evaluation	*Initial evaluation* in Slovenia Pre-evaluation Postevaluation *Pilot evaluation* Prepiloting Postpiloting	Observation form for teachers *Initial evaluation*: Q1-Q10 Questionnaire for students *Pilot evaluation*: Q1-Q16 (Multimedia Appendix 1)	Teacher trainer qualitative and quantitative report Evaluation report

[a]Not applicable.

In the first step, we designed a user needs survey to identify the context, for example, to analyze the target audience characteristics and learning and training needs. The second step was to develop the learning content and objectives based on user needs. The third step was to develop the games. The fourth and final step, which involved only children with disabilities who were integrated into mainstream schools, was to evaluate these games and their implementation. This pilot testing in the fourth step focused on testing the games' usability; in future, we hope to receive user feedback, in order to eventually optimize and improve the games.

First Step: Needs Analysis

We performed a needs analysis by means of per-country reports and a consolidated overall survey report on stakeholders and target groups in Turkey, Slovenia, Hungary, Bulgaria, and Belgium, resulting in a qualitative and quantitative analysis of findings (national and comparative). For the survey, we deemed both an online survey in the national language and face-to-face meetings and interviews to be appropriate tools for collecting the data we required. In the analysis of self-awareness and social awareness (as part of social competence), we also took into account the guidelines of the Trait Emotional Intelligence Questionnaire [38], that is, the guidelines for its short form (TEIQue-SF) [39,40]. According to the guidelines, we adapted the TEIQue-SF questionnaire to the needs of our study according to the table in Multimedia Appendix 1.

Second Step: Development of Learning Content

Based on the needs analysis, we identified and created the required content where we defined the learning content, methods, and structure of the games, which was the basis of the next step.

Third Step: Development of Intelligent Serious Games

The ISG4competence consortium agreed to develop ISGs [41] for desktop and mobile use based on user needs and learning content.

Fourth Step: Usability Evaluation

Sample

The purpose of the initial evaluation was to test the proposed games in a real-life learning environment, focusing on the students' motivation and concentration. Results served as the grounds for possible improvements to the games. The initial evaluation was followed by a pilot evaluation, which was performed for all proposed games, in all partner countries.

The pilot testing also involved trainers (educators) whose task was to train and guide students (ie, help them with game playing and with answering the questionnaires), and especially to evaluate and interpret the results.

Evaluation of the Intervention

The aim of the fourth step of the project was to provide a usability evaluation focusing on how the primary goals of ISGs were assessed (with regard to social competences and creativity), and whether the evaluation methods were suitable for assessing these goals. We evaluated and optimized the process in 2 steps. The aim of the *initial evaluation* was to check only some of the proposed ISGs in a real-life learning environment. This step focused especially on the appropriateness of the concept in relation to the students' motivation for and concentration in working with ISGs. For this evaluation, we also prepared an observation form for teachers. We conducted prepilot testing only in Slovenia. The *pilot evaluation* was designed to test the games' usability on a wider sample, that is, all partner countries. The purpose was to receive feedback from the users for eventual improvement and optimization of the games, with a view to incorporating end users in the process of game development.

For both evaluations, the materials included surveys. All questions in the initial and pilot evaluations were included in the pre-evaluation and postevaluation surveys, with closed-ended questions, with answers selected from a 5-point Likert scale. Multimedia Appendix 1 presents the questions. The survey consisted of recording sheets for students, which gathered information on the impact of ISGs, and an impact assessment survey for measuring the status of creativity and cognitive competences in students with learning difficulties in mainstream schools. These were aimed at ensuring that ISGs were repeatedly tested throughout the development cycle, to make sure they met their core aims.

The evaluation was conducted during classes and extracurricular activities, that is, during after-school programs (after regular classes, students can stay in school to perform various activities, including homework, remedial education, or self-tuition). The evaluation was performed for a period of 1 month. After classes and with the support of teachers (who were trained during the first week), the games were used in various learning situations for 3 consecutive weeks, approximately twice a week. The students then continued playing (testing) the games during after-school programs, partly still supported by the teachers, on average 3 times per week. They were also able to download the games onto their computers and play them at home, both individually (offline), and some of them (eg, Minecraft: Education Edition) with their classmates (online). In these cases, the choice of game and the number of repetitions were not monitored.

Results

First Step: Needs Analysis

The sample for the needs analysis comprised the following groups: 100 participants from Turkey, 78 participants from Slovenia, 92 participants from Hungary, 110 participants from Bulgaria, and 105 participants from Belgium. The respondents came from a wide range of target groups, including people with learning disabilities, parents and teachers of children with disabilities, nongovernmental organizations, special school educators, special education trainers, and training providers [35].

Significant Findings

The following 5 findings from the survey were relevant to the development of ISGs in the ISG4competence project [35].

First, formal definitions of children with learning problems and difficulties differed among countries, but in practice the same target groups were identified, while the degree of inclusive education varied considerably among the participating countries.

Second, pedagogical methodologies to support the acquisition of social competences and creativity were, in general, highly diversified, and often depended on the needs of specific target groups.

Third, there was a clear willingness to introduce ISGs into teaching environments; however, restrictions did exist, mainly owing to a lack of financing for equipment, bureaucratic issues with the process of providing permission for their implementation in mainstream schools, and a lack of time.

Fourth, learning challenges faced by children with learning difficulties were similar in all participating countries, with regard to the educational and social levels. The use of ISGs was generally limited. There was, for example, a negative correlation between the use of games and the size of the school: the bigger the school, the fewer ISGs were used.

Fifth, a wide range of pedagogical approaches (including game playing) were applied to the different beneficiary groups in all participating countries. The individual approach, which is generally recommended, is a challenge, given a lack of time and financial resources.

The effectiveness and efficiency of information and communication technology educational tools require considerable effort by the trainer or educator. Solutions should, therefore, consider providing tools for training the trainers.

Based on these findings, we produced the Curriculum and Scenarios Framework document, which can be downloaded (Intellectual Output 2) from the project website [35]. This served as a basis for the second step, that is, developing learning content.

Students' Learning Disabilities

Figure 1 shows the range of students' learning disabilities, mainly identified as mild or specific learning, by country.

Why Existing Pedagogical Approaches and Training Materials Failed

Table 2 lists reasons why existing pedagogical approaches and training materials in partner countries failed to ensure successful acquisition of cognitive competences.

Figure 1. Distribution of student's learning disabilities, by country. ADHD: attention-deficit/hyperactivity disorder.

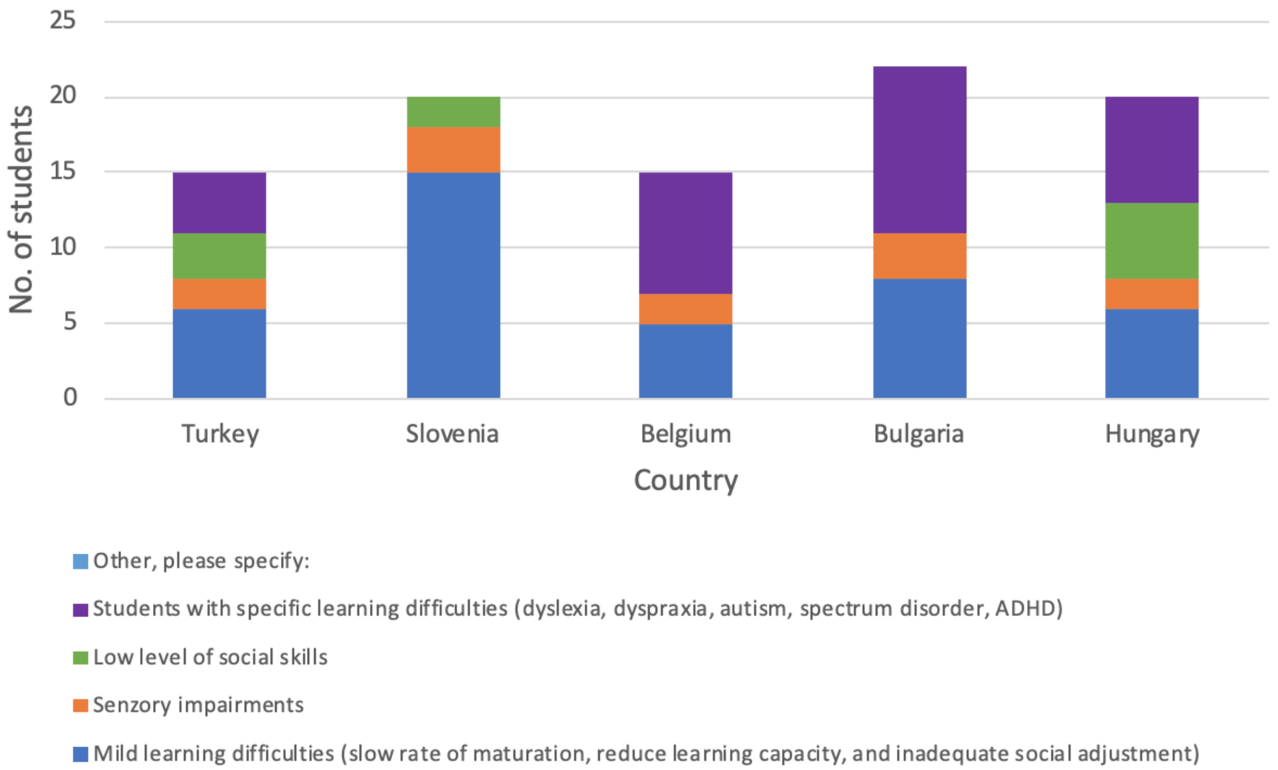


Table 2. Reasons for the failure of existing pedagogical approaches in different countries [35].

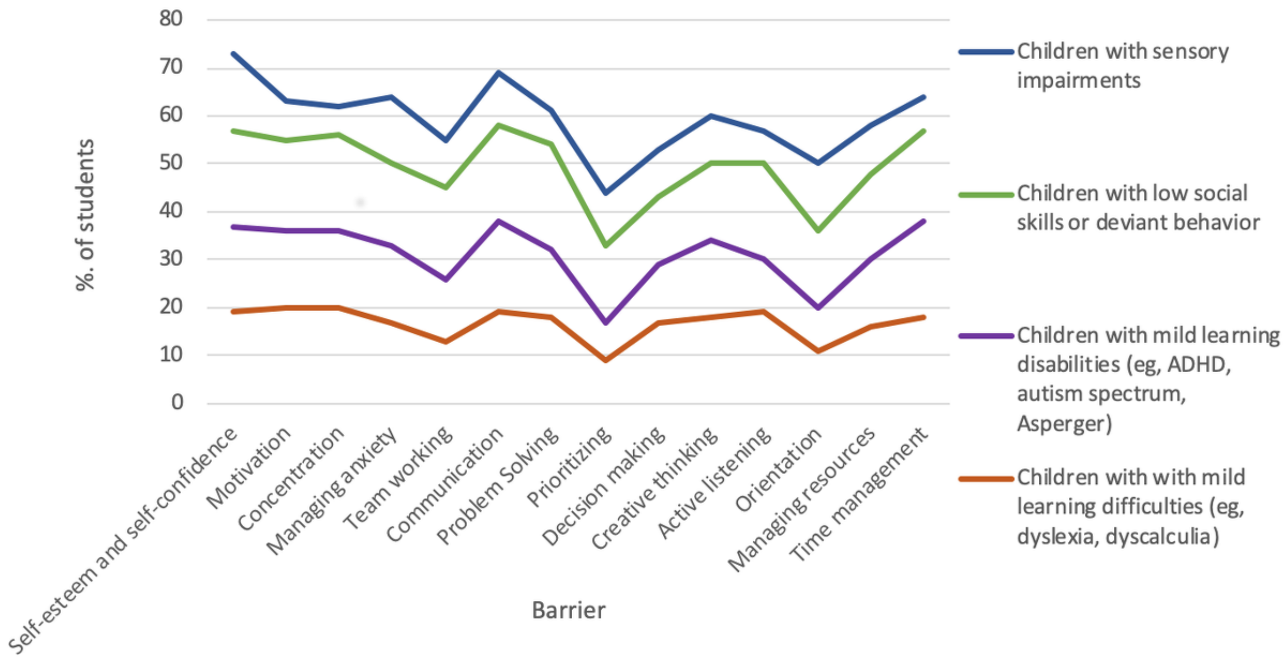
Reasons	Country				
	Turkey	Belgium	Bulgaria	Slovenia	Hungary
Lack of qualified staff, suitable application, adequate and effective process, adequate time, (financial) resources	X	X	X	X	X
Materials are not learner centered, technological approaches not sufficiently attractive or usable, class size too large	X	X	X	X	X
Inadequate prerequisite knowledge and skills, technological tool deficiencies	X	X	X	X	N/A[a]
Lack of assessment	X	X	N/A	X	N/A
App failure, environmental problems	X	X		X	X
Individual subjectivity or differences, individuality is secondary, one size does NOT fit all, lack of awareness of incomprehension	X	X	X	N/A	X
Family problems, not understanding behavioral deficiencies	X	N/A	N/A	N/A	X
Outdated methods	X	N/A	X	X	X
Children not given enough space to socialize	X	X	N/A	X	N/A
Inadequate research	X	N/A	N/A	N/A	N/A
Children were not assessed on an individual basis	X	N/A	X	N/A	X
Missing feedback	X	N/A	N/A	N/A	N/A
Teacher dependent	X	X	N/A	N/A	X
Acquisition of cognitive competences is a long and difficult process	N/A	X	X	N/A	X

[a]Not applicable.

Barriers to the Acquisition and Enhancement of Cognitive and Social Competences

The main difficulties that hampered the acquisition of cognitive competencies were similar across participating countries, but the degree to which they affected the beneficiaries differed. The feedback revealed that children with sensory impairments faced the most difficulties, whereas children with mild learning disabilities faced the most varied kinds of difficulties, especially with regard to self-esteem and self-confidence, problem solving, and time management. Figure 2 shows some of the results.

Figure 2. Main barriers to acquiring cognitive competencies, by learning disability. ADHD: attention-deficit/hyperactivity disorder.



Cognitive and Social Competence Tendencies

Students from all countries displayed similar tendencies in the cognitive and social competences that were to be achieved. In this question, students could select competences by choosing as many as they wished. When all data were consolidated, we counted the answers and to obtain the outcomes. Table 3 shows that the following social competences scored the highest: self-esteem and self-confidence, followed by communication, problem solving, concentration, teamwork, motivation, and active listening.

Table 3. Cognitive and social competences.

Competence	Number of students
Self-esteem and self-confidence	250
Motivation	211
Concentration	222
Managing anxiety	170
Team work	210
Communication	249
Problem Solving	233
Prioritizing	142
Decision making	150
Creative thinking	175
Active listening	205
Orientation	141
Managing resources	119
Time management	168
Other (please specify)	19

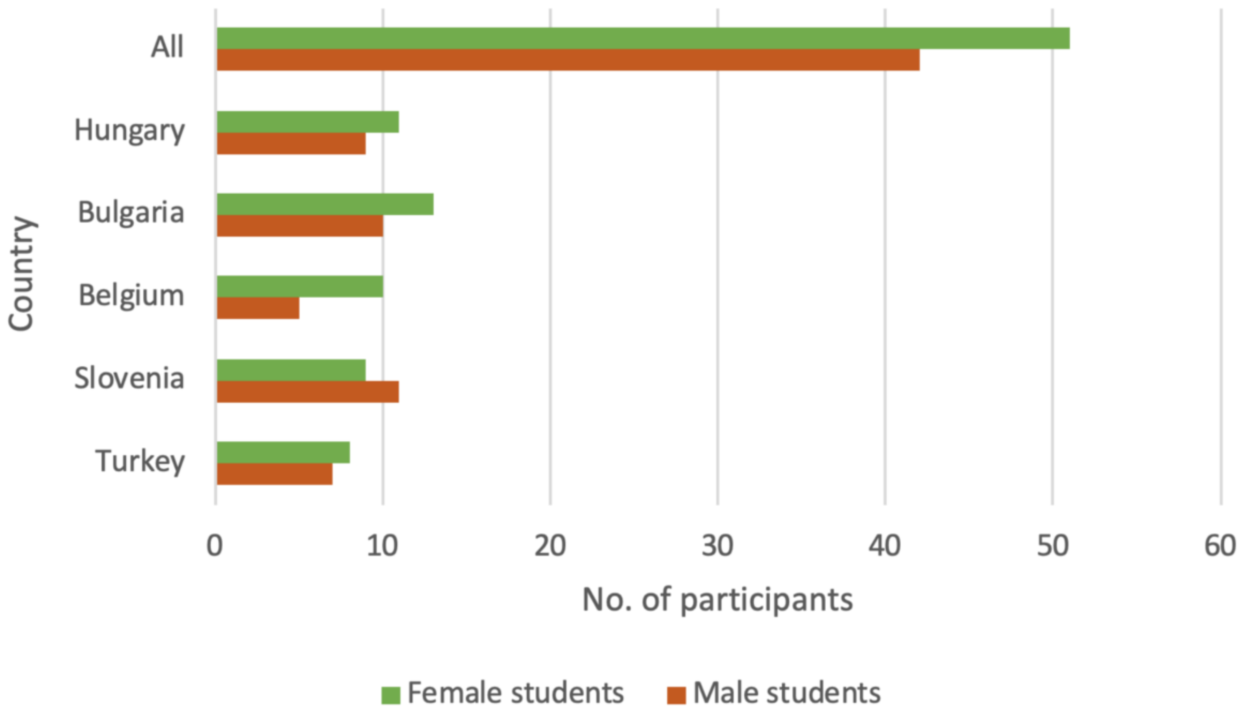
Second Step: Development of Learning Content

In this step we prepared first the syllabus for all learning content and then the teacher manuals for the ISGs.

Third Step: Development of Intelligent Serious Games

All games are available in English, Bulgarian, Dutch, Hungarian, Slovenian, and Turkish. We developed 10 games with the following titles: Math, Pair Cards, Labyrinth, Car Race, Manage Yourself, Sequence, Memory (designed to help with problems associated with a visual sequential memory deficit), Into the Forest (designed for children with speech disorders), VR Shop (a flash player game that runs on any Web browser), and Weekend Wonderland (the background theme of this story-based game [35] is a leisure park; the game offers many interesting and challenging tasks). All these games were played during the pilot phase in all partner countries. Figure 1 and Figure 3 show the characteristics of the players. Below, we discuss 2 examples in more detail.

Figure 3. Distribution of the study sample for pilot testing by country and sex.



Car Race

In this game, the user navigates the track by using 2 fingers to touch the screen (see Figure 4). One of the main advantages is that the user can navigate the game using only 1 hand, which means that it is suitable for children who can use only 1 of their hands. The game has 16 levels, 8 bonus levels, and an operating menu system; it is a side-view car app with realistic physical attributes.

Figure 4. Screenshots of the Car Race game.

Car Race was developed for the Android (Google LLC) platform using the AndEngine game engine (Nicolas Gramlich) and its plug-ins in the Eclipse Android Development Tools environment. The game is appropriate for classroom and individual use and can be downloaded for free [35]. Our research shows [35] that it is mostly useful as a tool for developing sensory motor functions, for managing anger and stress, and as a means of enhancing self-esteem, concentration, and motivation. It is suitable for users with mental and physical disabilities of any age group [42].

Minecraft: Education Edition

This is a version of the popular open world game Minecraft and is specifically designed for education to be a versatile, open platform; it can be used to teach all subjects, from mathematics and physics to history and languages [43]. By using the digital platform and classroom experience, students can develop social skills, collaboration, problem solving, communication, digital citizenship, and more. There is no limit to what students can learn in the game, and no limit to how the game can extend classroom learning.

Minecraft: Education Edition is specifically designed to enable teachers, trainers, and students to be creative in ways not possible in the real world. It has a social component, where students can cooperate and communicate in order to survive in the harsh conditions of Minecraft World. Working together helps students to build a positive classroom climate, to teach the benefits of collaboration, and to facilitate teamwork [31-43].

In the Minecraft: Education Edition, students enter the ISG4competence world, where they can develop various cognitive and social competences, such as problem solving, teamwork, and collaborative learning. We developed 3 main scenarios.

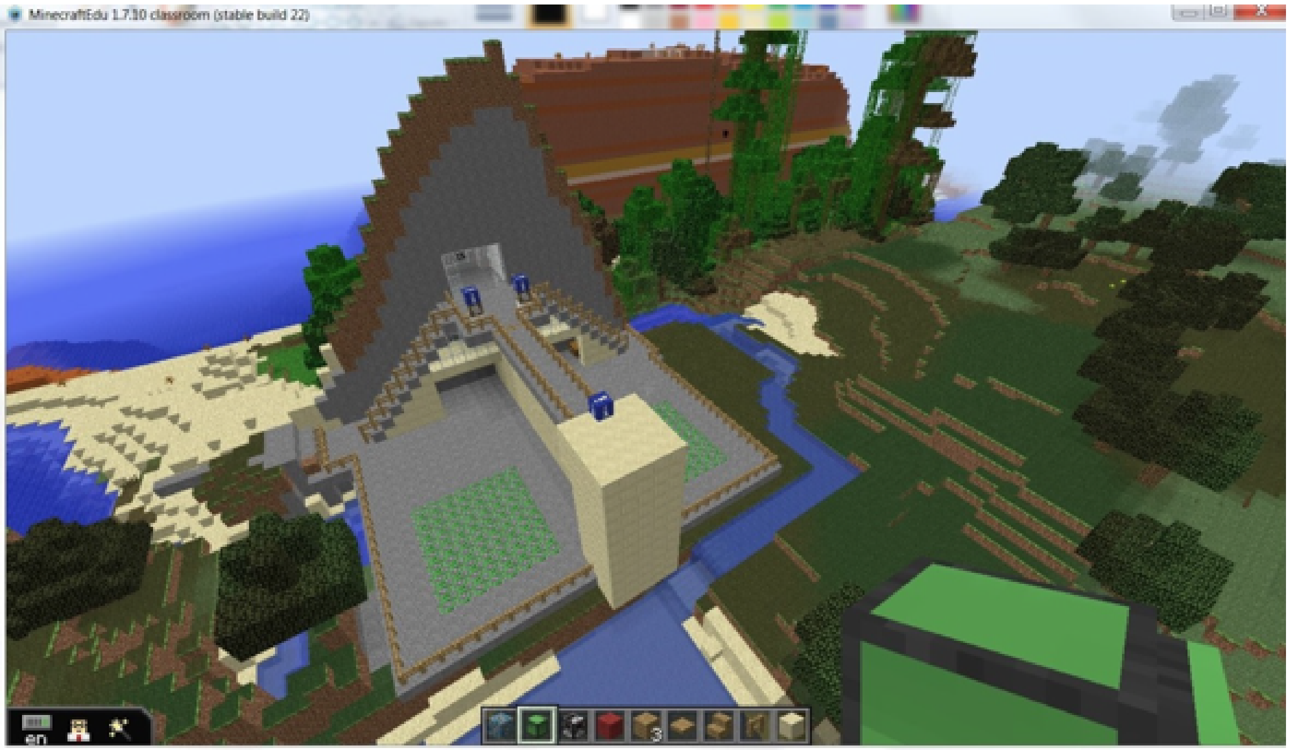
The first scenario addressed following instructions in order to solve a problem. The students are divided into 2 groups. The first group are builders and give instructions to the second group. The players in the second group try to build objects according to instructions from the first group. With this scenario, students are trained in two kinds of communication skills: to give clear instructions in the correct sequence (the first group), and to receive and follow the instructions (the second group). This communication competence is trained at 2 levels. At the first level, the students can ask additional questions if they did not understand the instruction or a part of the instruction. At the second level, they are required to understand the given instruction immediately and use this understanding, to solve the task.

In the second scenario, teamwork and team building, students are taught how to solve problems, relying on communication with and without feedback. They learn to follow instructions and ask questions, which helps to develop their cognitive and social competences.

In the fourth scenario, learning the basics of programming and robotics, students control their own virtual robot and guide it across various areas.

Figure 5 presents the main playground for developing communication competences and problem-solving skills. Two groups are separated by a wall and must communicate to solve a problem.

Figure 5. Screenshot of the ISG4competences world in Minecraft: Education Edition, for scenario 1 (following instructions in order to solve a problem).



Other serious games developed by the project team can be accessed and downloaded from the project website [35].

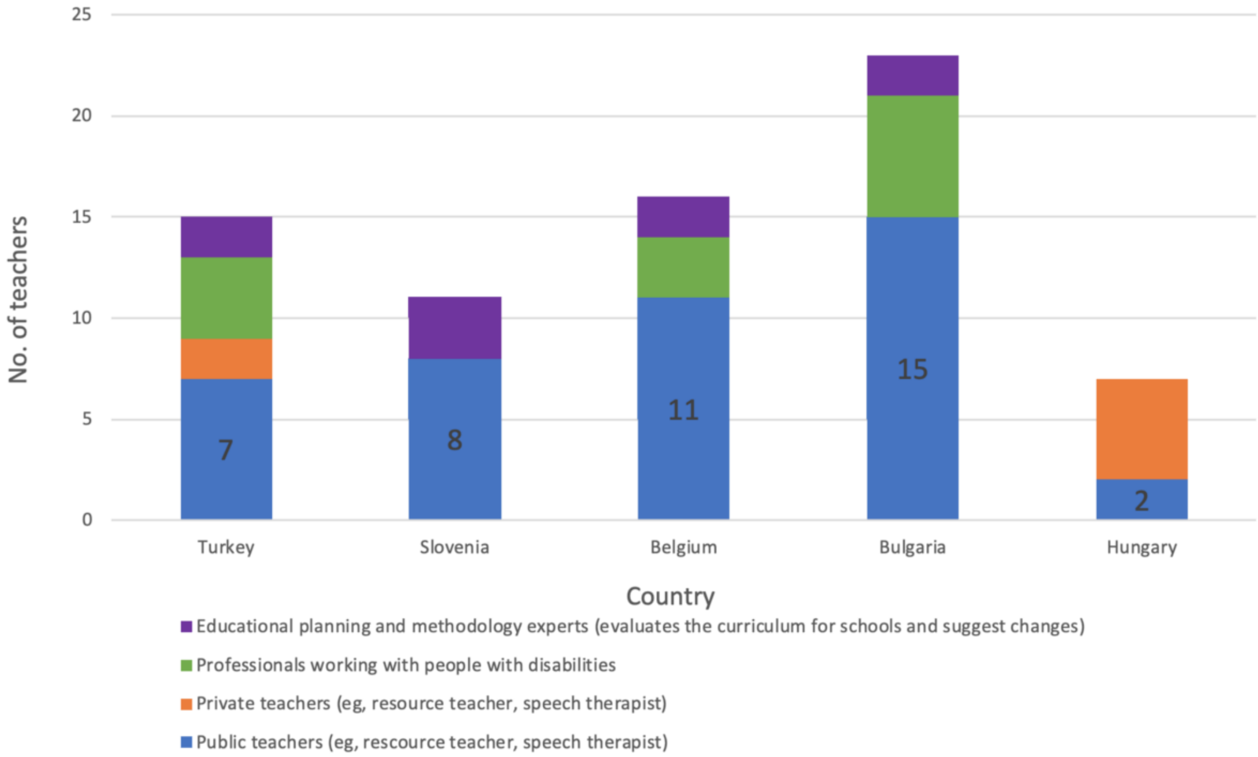
Fourth Step: Usability Evaluation

We conducted the *initial evaluation* only in Slovenia and only on learners with mild learning disabilities in mainstream lower secondary schools, in the sixth and seventh grades, that is, students aged between 11 and 12 years. The sample of 51 participants consisted of 22 (43%) boys and 29 (57%) girls. All of them provided official documentation of their mild learning disability. Our initial evaluation thus involved a relatively homogeneous, randomly selected group.

In the *pilot evaluation*, 93 students participated. The study sample was fairly homogeneous (42, 45% male students and 51, 55% female students) as Figure 3 shows.

The pilot evaluation also involved 71 trainers (educators), the majority of whom were public school teachers. Their task was to train and guide students (ie, help them with game playing and with answering the questionnaires), and especially to evaluate and interpret the results. Figure 6 shows the structure of the teacher and trainer sample.

Figure 6. Distribution of the study sample teachers and trainers.



Initial Evaluation

We conducted the preliminary evaluation of the games we had developed only in Slovenia. This served as the basis for improvement and optimization of the proposed ISGs, with an emphasis on students' motivation and concentration, using 2 of the games that are presented in this paper. In the initial evaluation, we used an observation form for teachers, in which they reported on the students (n=51) before and after they began using the ISGs for developing creativity and social competences. Table 4 presents the results of the pre-evaluation.

Table 5 present the results obtained after students played several ISGs during the initial evaluation with the same 51 students.

Table 4. Results of the initial pre-evaluation (N=51).

Questionnaire items	Answer score[a], n (%)						Score, mean (SD)
	1	2	3	4	5	Total	
Q1. Interacts nonverbally with other children with smiles, waves, nods, etc.	36 (75)	4 (8)	5 (10)	3 (6)	1 (2)	49 (100)	1.6 (0.5)
Q2. Expects a positive response when approaching others.	36 (76)	4 (9)	4 (9)	2 (4)	1 (2)	47 (100)	1.5 (0.5)
Q3. Expresses wishes and preferences clearly; gives reasons for actions and positions.	30 (65)	7 (15)	4 (9)	3 (7)	2 (4)	46 (100)	1.7 (0.4)
Q4. Asserts own rights and needs appropriately.	33 (70)	5 (10)	5 (10)	3 (6)	2 (4)	48 (100)	1.6 (0.6)
Q5. Is not easily intimidated by bullying.	36 (76)	4 (9)	4 (9)	2 (4)	1 (2)	47 (100)	1.5 (0.5)
Q6. Expresses frustrations and anger effectively, without escalating disagreements or harming others.	38 (81)	2 (4)	4 (9)	2 (4)	1 (2)	47 (100)	1.5 (0.5)
Q7. Gains access to ongoing groups at play and work.	36 (75)	4 (8)	5 (10)	3 (6)	1 (2)	49 (100)	1.6 (0.4)
Q8. Enters ongoing discussion on a topic; makes relevant contributions to ongoing activities.	35 (74)	3 (6)	5 (10)	3 (6)	1 (2)	47 (100)	1.6 (0.5)
Q9. Takes turns easily.	32 (68)	5 (10)	4 (9)	4 (9)	2 (4)	47 (100)	1.7 (0.5)
Q10. Has positive relationships with one or two peers; shows the capacity to really care about them and miss them if they are absent.	29 (4)	7 (6)	7 (11)	3 (40)	1 (38)	47 (100	1.7 (0.6)

[a]Likert scale answer options were 1, "not at all;" 2, "a little;" 3, "somewhat;" 4, "mostly;" and 5, "a lot."

Table 5. Results of the initial postevaluation (N=51).

Questionnaire items	Answer score[a], n (%)						Score, mean (SD)
	1	2	3	4	5	Total	
Q1. Interacts nonverbally with other children with smiles, waves, nods, etc.	4 (8)	4 (8)	8 (17)	15 (31)	17 (35)	48 (100)	3.8 (1.3)
Q2. Expects a positive response when approaching others.	1 (2)	4 (9)	14 (30)	20 (43)	8 (17)	47 (10%)	3.6 (0.9)
Q3. Expresses wishes and preferences clearly; gives reasons for actions and positions.	0 (0)	3 (7)	9 (20)	24 (52)	10 (22)	46 (100)	3.9 (0.8)
Q4. Asserts own rights and needs appropriately.	1 (2)	3 (6)	13 (28)	18 (38)	12 (26)	47 (100)	3.8 (1.0)
Q5. Is not easily intimidated by bullying.	1 (2)	1 (2)	12 (26)	21 (45)	12 (26)	47 (100)	3.9 (0.9)
Q6. Expresses frustrations and anger effectively, without escalating disagreements or harming others.	0 (0)	9 (19)	12 (26)	19 (40)	7 (15)	47 (100)	3.5 (1.0)
Q7. Gains access to ongoing groups at play and work.	1 (2)	1 (2)	11 (23)	21 (45)	13 (28)	47 (100)	3.9 (0.9)
Q8. Enters ongoing discussion on a topic; makes relevant contributions to ongoing activities.	0 (0)	5 (11)	6 (13)	25 (53)	11 (23)	47 (100)	3.9 (0.9)
Q9. Takes turns easily.	1 (2)	3 (6)	4 (9)	19 (40)	20 (43)	47 (100)	4.1 (1.0)
Q10. Has positive relationships with one or two peers; shows the capacity to really care about them and miss them if they are absent.	2 (4)	3 (6)	5 (11)	19 (40)	18 (38)	47 (100)	4.0 (1.1)

[a]Likert scale answer options were 1, "not at all;" 2, "a little;" 3, "somewhat;" 4, "mostly;" and 5, "a lot."

The initial evaluation revealed that the difference between the preplaying and postplaying levels of social competence was too great. Therefore, with a view to optimization, we prepared a special introductory program for all those who participated in the pilot evaluation. This introductory program provided guidelines for participation in the training, an explanation of the games, and a demonstration of how to play the games. Only after providing this program did we carry out the initial pilot evaluation.

Pilot Testing

In the pilot testing, 93 students were tested, coming from all participating countries. The survey was more detailed and contained 16 questions (Multimedia Appendix 1). Figure 7 shows the results.

Next, we applied a paired-sample *t* test, comparing the students' answers from before versus after playing ISGs. Table 6 shows the results.

Figure 7. Results of questionnaire responses before (pretest) and after (posttest) final intelligent serious games testing.

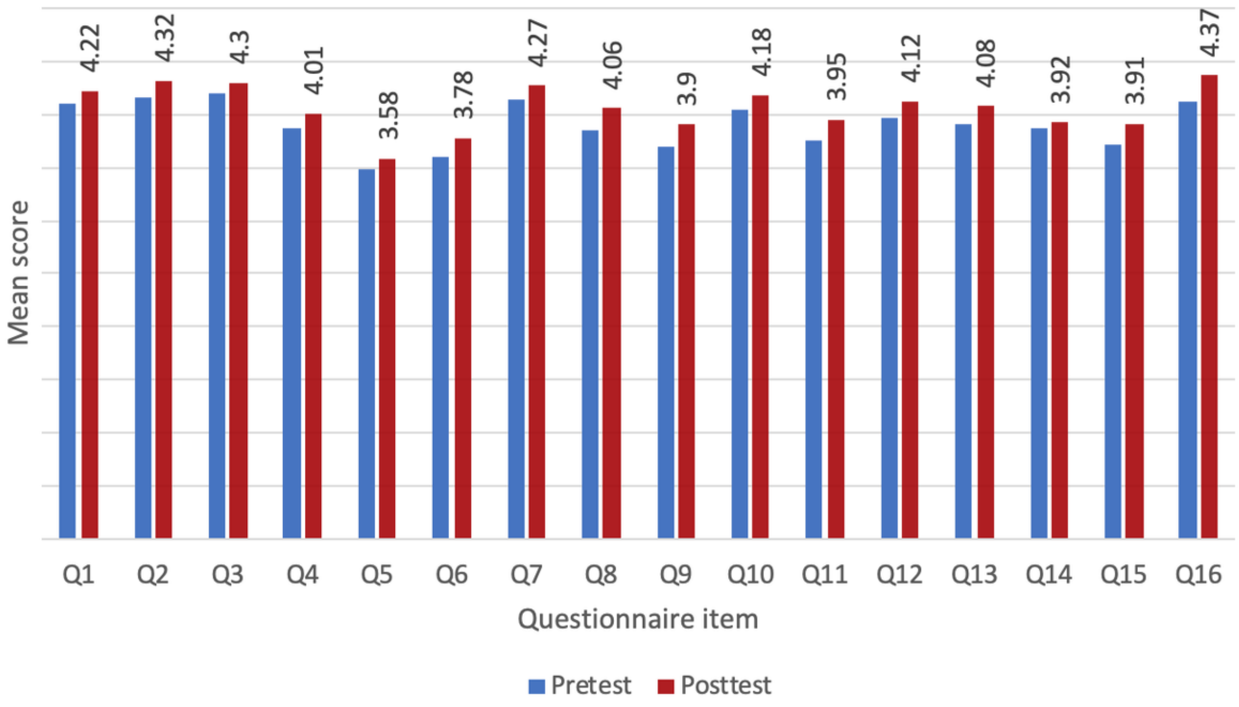


Table 6. Paired-sample *t* test (N=93).

Pair[a]	Correlation	*P* value	Cohen *d*
Pair 1 (Q1b-Q1a)	.906	.001	.35
Pair 2 (Q2b-Q2a)	.721	.002	.32
Pair 3 (Q3b-Q3a)	.435	.09	.18
Pair 4 (Q4b-Q4a)	.426	.02	.24
Pair 5 (Q5b-Q5a)	.689	.03	.23
Pair 6 (Q6b-Q6a)	.593	<.001	.46
Pair 7 (Q7b-Q7a)	.851	.001	.35
Pair 8 (Q8b-Q8a)	.58	<.001	.49
Pair 9 (Q9b-Q9a)	.522	<.001	.39
Pair 10 (Q10b-Q10a)	.776	<.001	.38
Pair 11 (Q11b-Q11a)	.698	<.001	.39
Pair 12 (Q12b-Q12a)	.871	<.001	.42
Pair 13 (Q13b-Q13a)	.857	<.001	.44
Pair 14 (Q14b-Q14a)	.583	.32	.10
Pair 15 (Q15b-Q15a)	.439	<.001	.39
Pair 16 (Q16b-Q16a)	.690	<.001	.41

[a]Pairs compare scores for each question before playing (b) and after playing (a) the game.

In the pre-evaluation, before students began using ISGs to develop their creativity and social competence, the mean score was 3.9. In the postevaluation, the mean score of the same group of students was 4.1. The student survey showed improvements in all aspects. The biggest improvement was observed in how well students believed they could do their homework using

ISGs, and with regard to their general attitude toward schoolwork and solving problems by using such games. The difference between the prepilot and postpilot evaluation results was not as great as it was in the initial evaluation. However, the test group in the initial evaluation was more homogeneous, the students were not used to playing ISGs as part of the learning process, and, above all, the basic goal of the initial evaluation was to check motivation and concentration. In addition, the subsequent pilot evaluation already considered the findings of the initial evaluation. The applied improvements, as confirmed by the results, were successful.

By successfully using ISGs, students improved their social competence and creativity by enhancing the followings skills: (1) self-esteem and self-confidence, (2) motivation to participate and learn new things, (3) positive attitude toward teamwork with peers and teachers, (4) communication and collaboration with peers and teachers, (5) problem solving ability and enhanced creative thinking (solving problems creatively), (6) classroom performance, and (7) benefits for the classroom environment (teamwork).

Discussion

Principal Findings

Two aspects of ISGs cannot be overemphasized. First, children with disabilities (in the pilot study, children with intellectual disabilities) need appropriately developed ISGs. Second, these games and the pertinent didactic methodology should be based on an interoperable curriculum, so that teachers and trainers and children with disabilities can use them across multiple learning situations for developing creativity and cognitive and social competences. The scholarly literature on ISGs refers mostly to mainstream learning situations and often overlooks the possible benefits of implementing such games in the educational process of children and adolescents with learning disabilities and other impairments. On the other hand, numerous practices and activities are undetected and unexplained in analyses of game-based learning in education.

The results of the ISG4competence project show how to combine the knowledge, science, and practice of ISGs for learning with the science and practices from the field of pedagogy for children with disabilities. The project succeeded in developing social and cognitive competences in children with disabilities through a didactic approach using specially developed ISGs. For this purpose, we performed a careful needs analysis of the targeted population and educational context in all participating countries. We defined the curricular of ISGs according to the results of this survey. The 10 games developed as part of the project were successfully implemented.

The ISGs' impact on social and cognitive competences was carefully observed during implementation and recorded with the help of a specially developed checklist for each competence defined in the game curricula. The final criterion for the decision regarding whether the games had an impact on social and cognitive competences of children with disabilities (people with intellectual disabilities or learning difficulties) was a comparison of the results of the pre-evaluation and postevaluation Likert-scale survey for social competences. This comparison showed remarkable progress in communication skills among the targeted population involved in the implementation of these games. Children included in the sample demonstrated progress in their communication competence and creativity, which was observed through their interaction with peers and teaching staff. To communicate with them, these children used both verbal and nonverbal channels. Their language messages were coherent with their body language; they used smiles, waves, and nods, and made eye contact with the addressees more often than before. With improved communication skills, self-esteem also increased in children who participated in the pilot phase of implementing these games. They became more assertive and aware of their own rights and needs, while expressing their wishes and preferences more clearly and appropriately. The competence of finding and using proper argumentation in a communication situation, in order to achieve the primary goal of the given communication act, was improved remarkably, which can be interpreted as a higher level of creativity in the students. Improvements in self-esteem and motivation were also observed in the students' attitude toward their peers. After playing ISGs, children were more likely to expect a positive response while approaching others. In addition, their problem-solving competence was improved. Children were not as easily intimidated by bullying; they were able to express their frustrations and anger without escalating disagreements or harming others. Instead, they entered ongoing discussions by expressing relevant arguments and solutions, which is indicative of a growing competence for teamwork. In addition, the progress in their communication competence became a reflection of the children's general social competence. More often than before, these children were found entering the social environment and gaining access to an ongoing group involved in either play or work. Moreover, they were successful in building a positive relationship with (1 or 2) peers, demonstrating progress in showing their capacity to care about them, and expressing that they missed their new friends if they were absent.

Conclusion

In the ISG4competence project, the development of digital teaching and learning products focused on the didactic aspect. The proposed ISGs generated dynamic learning opportunities, engaging students in productive classroom discussion by encouraging them to become engaged, to argue, and to reflect on the learning goals. The games developed in this project are applicable as a means of support for education and training in varied educational settings: classrooms in mainstream schools, extracurricular activities, private lessons, private sessions with resource tutors, sessions with psychologists or speech therapists, or activities related to adolescent volunteering and informal groups.

ISGs for persons with disabilities, specifically for those who are integrated into mainstream education, should provide an opportunity for personalized learning, and should be tailored to ensure that every learner achieves the highest standard possible. However, we recommend that the games be adapted based on student needs and capabilities.

The ideas and results of the ISG4competence project could also serve as the basis for a longitudinal study of the qualitative assessment of the project with more end users.

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Data can be accessed by contacting the authors (saved in authors' repository). Some data can also be accessed at the project website [35].

Conflicts of Interest

None declared.

Multimedia Appendix 1
Survey questionnaire.
[DOCX File , 13 KB - games_v8i2e13190_app1.docx]

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Abbreviations

ISG: intelligent serious game
ISG4competence: Intelligent Serious Games for Social and Cognitive Competence

TEIQue-SF: Trait Emotional Intelligence Questionnaire-Short Form

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Original Paper

Serious Games for Nutritional Education: Online Survey on Preferences, Motives, and Behaviors Among Young Adults at University

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Abstract

Background: Data on nutritional information and digital gameplay are limited among young adults in Germany.

Objective: This survey aimed to gather data on nutritional information sources and digital games for nutritional education (preferences, motives, and behaviors) among young adults at both Munich universities in Germany.

Methods: An online survey was developed by an multidisciplinary research group using EvaSys, an in-house survey software. The questionnaire (47 items) covered questions about baseline characteristics (eg, housing situation and weight), nutrition (eg, nutritional information sources), and digital (nutritional) gameplay (eg, preferences, motives, and behaviors). A feedback field was also provided. This publication is based on a selection of 20 questions (7 baseline characteristics, 2 nutrition, 11 gameplay). Young adults, primarily Munich university students aged from 18 to 24 years, were invited to participate by digital and nondigital communication channels between 2016 and 2017. Statistical analyses were performed using Excel 2013 (Microsoft Corp) and R version 3.1.3 (R Foundation for Statistical Computing).

Results: In total, 468 young adults (342/468, 73.1% women; 379/468, 81.0% university students) participated. Most of the participants (269/468, 57.5%) were aged 18 to 24 years with a BMI in the normal weight range (346/447, 77.4%). Mean body weight was 65.5 [SD 14.0] kg. Most participants reported getting nutritional information from the internet (372/467, 79.7%) and printed media (298/467, 63.8%), less than 1.0% (2/467, 0.4%) named digital games. Apps (100/461, 21.7%) and university/workplace (146/461, 31.7%) were the most desired sources for additional information about nutrition, while 10.0% (46/461, 10.0%) of participants stated wanting digital games. Almost two-thirds (293/468, 62.6%) of participants played digital games, while one-fifth (97/456, 21.3%) played digital games daily using smartphones or tablets. Finally, most respondents (343/468, 73.3%), mainly women, expressed interest in obtaining nutritional information during digital gameplay. However, significant gender differences were shown for nutritional acquisition behaviors and digital gameplay preferences, motives, and behaviors.

Conclusions: Our survey population reported playing digital games (especially men) and wanting nutritional information during digital gameplay (especially women). Furthermore, university or workplace are named as preferred settings for nutritional information. Therefore, a digital game app might have the potential to be a tool for nutritional education among young adults within the university or workplace environment.

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KEYWORDS
nutrition; information sources; serious games; digital gameplay; preferences; motives; behavior; university students; survey

Introduction

Background

The prevalence of overweight and obesity reached global pandemic and represents a major public health concern [1]. In Germany, 7.2% of young adults (aged 18 to 24 years) are affected by obesity [2]. Moreover, it is reported that young adults of Western nations are more vulnerable to weight gain than any other age group [3]. Obesogenic environments with increases in energy-dense foods and sedentary behaviors are the main causes for the development of overweight and obesity [1,3]. According to the German National Consumption Study II, adolescents (aged 15 to 18 years) and young adults (aged 19 to 24 years) show the highest daily intake of free sugar [4]. This also applies at the global level and for other nutrients or food groups (eg, low intake of fruits and vegetables) [3,5-7].

To address overweight and obesity among young adults, nutritional education programs can be used within different settings (eg, workplace, home, community, health care, and educational facilities) at both the individual and population level [1,8,9]. These programs are applied to change knowledge, attitudes, and beliefs about healthy dietary behaviors and also affect the dietary behaviors themselves [10-12]. For instance, serious games present a novel digital approach to nutritional education by conveying nutritional information in an entertaining format [13,14]. In recent years, the market for games and number of gaming individuals has increased. In 2017, 34.1 million people in Germany played computer and video games [15]. The literature indicates that serious gameplay might be an appealing and effective tool for nutritional education and dietary behavior change [14,16]. A few studies investigated the effects of serious games on nutritional education among (young) adults [12]. According to a narrative review, nutritional knowledge can be increased in young adults (aged 18 to 35 years) through game-based nutritional interventions [12]. A randomized controlled study among 40 persons (80% women; mean age 20 years) showed that playing a role-play computer game for 3 weeks improved knowledge about nutrition and weight management for the short term [17]. According to a 3-month study among 47 women with an average age of 30 years, playing a serious computer game resulted in significant improvements of body mass index and nutritional knowledge from baseline to the end of the study [18].

Aim

The aim of this online survey was to collect data on young adults' nutritional information sources and preferences, motives, and behaviors regarding a digital game for nutritional education purposes.

Methods

Recruitment

The Ethical Committee of the School of Medicine at the Technical University of Munich approved this open online survey (ethical vote: 164/16S), which was performed from December 2016 to July 2017 in Munich, the third largest city in Germany, with approximately 1.5 million inhabitants. The survey invitation included a password and link guiding participants to the online survey. The recruitment of young adults was conducted mainly through digital communication channels (eg, newsletters, social media, and email) at both Munich universities (Technical University of Munich and Ludwig-Maximilians University) and primarily included students, graduates, and employees. Furthermore, recruitment was extended by social media (eg, Facebook), printed flyers (eg, at canteens), and other student-affiliated distribution channels (eg, Technical University of Munich General Student Committee).

Since the exact number of invitations is unknown, it was not possible to calculate a response rate. The following inclusion criteria were applied: understanding of the German language, willingness to participate, and internet access. All participants gave informed consent to participate.

The first page of the survey provided information about the research team, aim of the survey, target group (young adults aged from 18 to 24 years), and instruction (eg, completion time of 5 to 10 minutes). Finally, information about data privacy and protection (eg, voluntary participation confidential, no personal data) was provided. Participants had to confirm the data privacy statement before starting the survey. Each question had to be answered to continue. No incentives were offered to the participants.

Questionnaire: Development and Design

The 47-item questionnaire was developed by an multidisciplinary team of nutritionists, economists, sociologists, and computer scientists using EvaSys V7.0 (2101) survey software. Questions (closed, semi-open, open; single or multiple choice) referred to nutrition (16 questions), digital games (22 questions), personal characteristics (8 questions), and feedback (1 field). Wherever possible, a "don't know," "no answer applies," or "other" option was provided. This questionnaire represents a revised version of a questionnaire developed by the same multidisciplinary research team and previously used in a survey among children and adolescents [19]. Age-specific modifications were made to ensure age adequacy. Similar to our previous survey [19], this work is based on a selection of 20 (7 baseline characteristics, 2 nutrition, 11 gameplay) of the 47 questions. Questions not presented were mainly focused on technical issues for design and development of a game.

Statistical Analyses

Only completed questionnaires were analyzed. Integrity and plausibility checks were performed. Questionnaires with missing answers for 8 or more questions or invalid answers were excluded. Descriptive data analyses (frequencies, percentages, standard deviations, and means) were performed using Excel 2013 (Microsoft Corp). Gender differences in responses were assessed using Pearson chi-square tests for categorical variables. These analyses were performed using R version 3.1.3 (R Foundation for Statistical Computing). *P* values of <.05 were considered statistically significant. The analyses are based on 20 out of 47 questions.

Results

Participant Characteristics

Table 1 presents the sociodemographic and anthropometric characteristics of the participants. In total, 468 young adults (342/468, 73.1% women), primarily university students (379/468, 81.0%), participated. Nonstudent participants were mainly those previously affiliated with a university (eg, graduates) or academic staff (eg, research assistants). Most participants were aged between 18 and 24 years (269/468, 57.5%). Body weight ranged from 35.9 kg to 190.0 kg (mean 65.5 [SD 14.0] kg) and height varied between 1.50 m and 2.02 m (mean 1.68 [SD 0.09] m). According to the body mass index (mean 22.3 [SD 3.6] kg/m^2), participants were mostly normal weight (346/447, 77.4%). Most participants either lived with their family (193/468, 41.2%) or in a flat/house share (166/468, 35.5%).

Table 1. Characteristics of survey participants.

Characteristics	Value, n (%)
Sociodemography (n=468)	
Age in years	
18-19	24 (5.1)
20-21	84 (18.0)
22-24	161 (34.4)
>24	199 (42.5)
Sex	
Female	342 (73.1)
Male	126 (26.9)
Home environment	
Family	193 (41.2)
Flat/house share	166 (35.5)
Alone	95 (20.3)
Other	14 (3.0)
Anthropometry (n=447)	
Body mass index	
Underweight (<18.5 kg/m^2)	34 (7.6)
Normal weight (18.5-24.9 kg/m^2)	346 (77.4)
Overweight (25.0-29.9 kg/m^2)	54 (12.1)
Obesity (≥30.0 kg/m^2)	13 (2.9)

Sources of Nutritional Information

Table 2 shows digital and nondigital sources of nutritional information that participants currently use or desire to additionally use. Most participants (372/467, 79.7%) responded that they use the internet for obtaining digital nutritional information (nonsignificant gender differences) with one-third (160/467, 34.4%) reported using social networks (significantly more women than men; *P*=.001).

Regarding nondigital sources, the majority (298/467, 63.8%) of respondents stated that they were informed about nutrition via books and newspapers (significantly more women than men; *P*<.001). The second most currently used nondigital information sources were partner and family (218/467, 46.7%) and friends (201/467, 43.0%; nonsignificant gender differences for both items), followed by university and workplace (164/467, 35.1%; significantly more women than men; *P*=.001).

More than a fifth (100/461, 21.7%) of participants would like to receive additional digital nutritional information via apps (nonsignificant gender differences). Television (67/461, 14.5%), internet (65/461, 14.1%), and social networks (71/461, 15.4%) were each requested as nutritional information sources by almost 15% of participants. Significant gender differences occurred for social networks only (significantly more women than men; *P*=.04). The main desired nondigital source for additional information about nutrition was university and workplace (146/461, 31.7%) followed by books and newspapers (52/461, 11.3%). No statistically significant differences were found between women and men.

Specifically regarding digital games, only two participants (2/467, 0.4%) responded that they are currently using digital games for nutritional information (nonsignificant gender differences), but 10.0% (46/461) would like to use digital games as an additional nutritional information source (significantly more women than men; *P*=.003).

Table 2. Digital and nondigital sources of nutritional information (multiple responses allowed).

Source and characteristic	All, n (%)	Female, n (%)	Male, n (%)	*P* value
Currently used[a] (n=467)				
Digital				
Television	98 (21.0)	73 (21.3)	25 (20.0)	.75
Internet	372 (79.7)	271 (79.2)	101 (80.8)	.71
Social networks	160 (34.4)	132 (38.6)	28 (22.4)	.001
Apps	66 (14.1)	61 (17.8)	5 (4.0)	<.001
Digital games	2 (0.4)	2 (0.6)	0 (0)	.39
Nondigital				
University and workplace	164 (35.1)	135 (39.5)	29 (23.2)	.001
Partner and family	218 (46.7)	153 (44.7)	65 (52.0)	.16
Friends	201 (43.0)	153 (44.7)	48 (38.4)	.22
Books and newspapers	298 (63.8)	237 (69.3)	61 (48.8)	<.001
Other				
Unknown	109 (23.3)	81 (23.7)	28 (22.4)	.77
No answer applies	7 (1.5)	3 (0.9)	4 (3.2)	.07
Additionally desired[b] (n=461)				
Digital				
Television	67 (14.5)	54 (16.1)	13 (10.4)	.13
Internet	65 (14.1)	44 (13.1)	21 (16.8)	.31
Social networks	71 (15.4)	59 (17.6)	12 (9.6)	.04
Apps	100 (21.7)	78 (23.2)	22 (17.6)	.19
Digital games	46 (10.0)	42 (12.5)	4 (3.2)	.003
Nondigital				
University and workplace	146 (31.7)	108 (32.1)	38 (30.4)	.72
Partner and family	30 (6.5)	24 (7.1)	6 (4.8)	.37
Friends	29 (6.3)	23 (6.8)	6 (4.8)	.42
Books and newspapers	52 (11.3)	42 (12.5)	10 (8.0)	.18
Other				
Unknown	40 (8.7)	35 (10.4)	5 (4.0)	.03
No answer applies	173 (37.5)	111 (33.0)	62 (49.6)	.001

[a]How are you currently informed about nutrition?

[b]How would you like to be additionally informed about nutrition?

Digital Gameplay: Preferences, Motives, and Behaviors

Table 3 shows that more than one-half of the participants (293/468, 62.6%) reported playing digital games. Men were significantly more likely to play digital games (100/126, 79.4%) compared with women (193/342, 56.4%; *P*<.001). The most frequent answer regarding the preferred team composition within a digital game was friends (274/464, 59.1%). A similar proportion of participants responded with partner and family (193/464, 41.6%) and individuals with the same eating behavior (188/464, 40.5%). There were no statistically significant differences between women and men.

The questionnaire also asked for the most preferred game character in digital games. Nearly half of participants (226/468, 48.3%) preferred a human being while almost a fifth (89/468, 19.0%) preferred a fantasy character (nonsignificant gender differences), followed by a cute animal (51/468, 10.9%), which was significantly more desired by women than by men (*P*=.01).

In addition to these preferences, Table 3 presents the frequency of digital gameplay by device. The most frequent answer of participants who reported playing digital games on smartphones or tablets was daily (97/456, 21.3%), followed by weekly (66/456, 14.5%) and monthly (65/456, 14.3%), with no statistically significant differences between women and men. Half of the participants (222/453, 49.0%), who use digital games, reported short gameplay (≤30 minutes).

One-fifth (99/463, 21.4%) of participants reported that they play digital games for more than 60 minutes continuously on PCs or consoles, and one-eighth (57/463, 12.3%) reported doing so for exactly 60 minutes (significantly more men than women: *P*<.001 vs *P*=.003).

More than 40% of the participants reported mainly playing digital games if they felt like gaming (199/442, 45.0%; significantly more men than women; *P*<.001) or were bored (190/442, 43.0%; nonsignificant gender differences*;* *P*=.13). In total, 10.4% (46/442) of participants reported playing digital games when they are happy (significantly more men than women; *P*<.001). Moreover, one-third of participants (153/442, 34.6%) reported playing digital games often alone at home (significantly more men than women; *P*=.003), and one-fifth (101/442, 22.9%) stated that they played digital games mainly on the go (significantly more women than men; *P*=.03). Significantly more men than women reported playing digital games with friends (*P*<.001).

Participants were asked whether they would like to receive nutritional information by playing digital games. Nearly two-thirds (293/468, 62.6%) of participants expressed an interest in receiving nutritional information during gameplay, with women reporting this significantly more often than men (*P*<.001). Moreover, almost three-quarters indicated they preferred being educated via answering quiz questions (323/463, 69.8%) or completing tasks (333/463, 71.9%) during digital gameplay, with significantly more women than men reporting both of these (quiz *P*<.001 vs task *P*=.001). In contrast, significantly more men than women stated that they don’t want to learn anything during digital gameplay (*P*<.001).

Table 3. Digital gameplay: preferences, motives, and behaviors.

Digital gameplay and characteristics	All, n (%)	Female, n (%)	Male, n (%)	*P* value
Preferences				
Team composition[a,b] (n=464)				
Partner and family	193 (41.6)	144 (42.5)	49 (39.2)	.53
Friends	274 (59.1)	199 (58.7)	75 (60.0)	.80
Same hobbies	132 (28.4)	97 (28.6)	35 (28.0)	.90
Same eating behavior	188 (40.5)	144 (42.5)	44 (35.2)	.16
No similarities	109 (23.5)	79 (23.3)	30 (24.0)	.88
Other	26 (5.6)	20 (5.9)	6 (4.8)	.65
No team	37 (8.0)	25 (7.4)	12 (9.6)	.43
Teammates[c,d] (n=445)				
≤5	116 (26.1)	67 (20.7)	49 (40.2)	<.001
6-10	11 (2.5)	5 (1.5)	6 (4.9)	.04
>10	8 (1.8)	3 (0.9)	5 (4.1)	.03
Alone	130 (29.2)	98 (30.3)	32 (26.2)	.40
I do not play	152 (34.2)	129 (39.9)	23 (18.9)	<.001
I do not know	28 (6.3)	21 (6.5)	7 (5.7)	.77
Game character[c,e] (n=468)				
Cute animal	51 (10.9)	45 (13.2)	6 (4.8)	.01
Impressive animal	23 (4.9)	16 (4.7)	7 (5.6)	.70
Fantasy animal	20 (4.3)	15 (4.4)	5 (4.0)	.84
Fantasy character	89 (19.0)	62 (18.1)	27 (21.4)	.42
Human being	226 (48.3)	163 (47.7)	63 (50.0)	.65
Other	26 (5.6)	18 (5.3)	8 (6.3)	.65
No answer applies	33 (7.1)	23 (6.7)	10 (7.9)	.65
Motives[a,f] (n=442)				
Emotion				
Pleasure	199 (45.0)	123 (38.3)	76 (62.8)	<.001
Happiness	46 (10.4)	20 (6.2)	26 (21.5)	<.001
Sadness	20 (4.5)	13 (4.0)	7 (5.8)	.43
Boredom	190 (43.0)	131 (40.8)	59 (48.8)	.13
Setting				
Friends	36 (8.1)	16 (5.0)	20 (16.5)	<.001
On the go	101 (22.9)	82 (25.5)	19 (15.7)	.03
University and workplace	44 (10.0)	32 (10.0)	12 (9.9)	.99
Alone at home	153 (34.6)	98 (30.5)	55 (45.5)	.003
Other situations	27 (6.1)	18 (5.6)	9 (7.4)	.47
Other				
I do not play	154 (34.8)	131 (40.8)	23 (19.0)	<.001
I do not know	0 (0)	0 (0)	0 (0)	—
Behaviors				
Digital gameplay[c,g] (n=468)				

Digital gameplay and characteristics	All, n (%)	Female, n (%)	Male, n (%)	*P* value
Yes	293 (62.6)	193 (56.4)	100 (79.4)	<.001
No	175 (37.4)	149 (43.6)	26 (20.6)	—
Duration of digital gameplay (smartphone/tablet)[c,h] (n=453)				
≤30 minutes	222 (49.0)	160 (48.6)	62 (50.0)	.80
60 minutes	5 (1.1)	5 (1.5)	0 (0.0)	.17
>60 minutes	4 (0.9)	2 (0.6)	2 (1.6)	.31
I do not play	212 (46.8)	155 (47.1)	57 (46.0)	.83
I do not know	10 (2.2)	7 (2.1)	3 (2.4)	.85
Duration of digital gameplay (PC/console)[c,i] (n=463)				
≤30 minutes	50 (10.8)	36 (10.7)	14 (11.1)	.90
60 minutes	57 (12.3)	32 (9.5)	25 (19.8)	.003
>60 minutes	99 (21.4)	45 (13.4)	54 (42.9)	<.001
I do not play	248 (53.6)	218 (64.7)	30 (23.8)	<.001
I do not know	9 (1.9)	6 (1.8)	3 (2.4)	.68
Frequency of digital gameplay (smartphone/tablet)[c,j] (n=456)				
Daily	97 (21.3)	72 (21.6)	25 (20.3)	.76
Weekly	66 (14.5)	47 (14.1)	19 (15.4)	.72
Monthly	65 (14.3)	47 (14.1)	18 (14.6)	.89
I do not play	220 (48.2)	163 (48.9)	57 (46.3)	.62
I do not know	8 (1.8)	4 (1.2)	4 (3.3)	.14
Frequency of digital gameplay (PC/console)[c,k] (n=466)				
Daily	39 (8.4)	17 (5.0)	22 (17.7)	<.001
Weekly	57 (12.2)	25 (7.3)	32 (25.8)	<.001
Monthly	97 (20.8)	64 (18.7)	33 (26.6)	.06
I do not play	257 (55.2)	225 (65.8)	32 (25.8)	<.001
I do not know	16 (3.4)	11 (3.2)	5 (4.0)	.67
Nutritional education by digital games[c,l] (n=468)				
Yes	343 (73.3)	273 (79.8)	70 (55.6)	<.001
No	125 (26.7)	69 (20.2)	56 (44.4)	—
Ways of nutritional education by digital games[a,m] (n=463)				
Quiz	323 (69.8)	253 (74.9)	70 (56.0)	<.001
Tasks	333 (71.9)	257 (76.0)	76 (60.8)	.001
Movies	150 (32.4)	114 (33.7)	36 (28.8)	.32
Mates	98 (21.2)	71 (21.0)	27 (21.6)	.89
Other	56 (12.1)	38 (11.2)	18 (14.4)	.36
No learning	31 (6.7)	12 (3.6)	19 (15.2)	<.001

Digital gameplay and characteristics	All, n (%)	Female, n (%)	Male, n (%)	*P* value
No answer applies	15 (3.2)	12 (3.6)	3 (2.4)	.54

[a]Multiple responses allowed.
[b]In a digital game about nutrition, goals are to be achieved together in a team. Who should the players on this team be?
[c]Single response allowed.
[d]How many players do you like to play digital games with?
[e]Which character would you most like to be in a digital game?
[f]When do you often play digital games?
[g]Do you play digital games (smartphone, PC, console, apps)?
[h]How long do you play digital games on your smartphone/tablet/apps without any interruption?
[i]How long do you play digital games on your PC/console without any interruption?
[j]How often do you play digital games on your smartphone/tablet/apps? "App" is not shown in table.
[k]How often do you play digital games on your PC/console?
[l]Would you like to receive nutrition information in a digital game?
[m]How would you like to learn about nutrition in a digital game?

Discussion

Principal Findings

This survey reports findings on nutritional information strategies and motives, preferences, and behaviors for digital gameplay among more than 450 young adults, mainly university students. In total, 62.6% (293/468) of the participants reported playing digital games. Our findings are in line with data from the United States. According to data from the Pew Research Center, 60% of young American adults aged between 18 and 29 years play video games often or sometimes (computer, television, game console, portable device), with young men more likely to play video games than young women [20,21]. In contrast, data from an online survey among 900 Finish and Belgian university students and employees (mean age 26.8 years) showed that only one-third of participants play mobile games [22].

Regarding device preferences, more participants reported using smartphones or tablets than PCs or consoles on a daily and weekly basis. These findings are different than results from a survey among 292 participants at a US gaming convention (68.6% male; mean age 34.2 [SD 10.6] years) showing that the computer was the preferred platform for gameplay [23]. According to the literature, smartphones, PCs, and consoles are the most preferred gaming platforms in Germany [24].

Most of the survey sample who play digital games reported doing so for more than one hour continuously on PCs or consoles. These findings are similar to data from Arnaez et al [23] demonstrating that American adults spent on average at least 2 hours per day on computers or consoles for gameplay. Lopez-Fernandez et al [22] revealed that the average time of smartphone gameplay was almost 2 hours per day, which is longer than our survey participants indicated.

Nutritional Information: Interest and Acquisition

This survey revealed that the most used nutritional information sources currently were internet (79.7%) and books and newspapers (63.8%), followed by partner and family (46.7%), friends (43.0%), university and workplace (35.1%), and social networks (34.4%). Findings are in line with results from a cross-sectional study about nutritional information sources among 192 Ghanaian young adults (51.0% women; 66% students) aged between 18 and 25 years [25]. The study showed that the most consistently used nutritional sources were online resources (92.7%), followed by traditional media (58.3%), peers and friends (29.7%), family members (29.7%), and health care professionals (4.7%) [25]. According to a survey by Percheski and Hargittai [26], social networks (89.5%) were the most used source of health information among 1060 US university students, followed by online (78.4%), medical professionals (75.5%), and traditional media (74.6%). With respect to the interpretation and comparison of our survey with other data, it must be acknowledged that the classification of nutritional information sources into digital and nondigital varies between studies. In addition, there might be some overlaps regarding the single items—for instance, the social networks resource might include digital resources (eg, internet, apps) or nondigital ones (eg, partner and family, friends). Furthermore, the subanalysis showed that there are gender-specific differences in the acquisition of nutritional information among our survey population. The literature on health information–seeking behaviors among university students in the United States indicates that women are more likely than men to use online resources or seek health information in general [26-28], which also applies to our survey results. In general, this survey as well as the literature indicate that both digital and nondigital tools and settings are used and desired for nutrition information. Considering this aspect, digital and nondigital nutrition information sources complement one another and should be offered in parallel.

It was shown that nearly three-quarters (73.3%) of participants indicated they were interested in receiving nutritional information through digital games (Table 3). This is in line with a focus group study showing that young adults (mean age 23.1 [SD 2.7] years) perceive mobile games as a reasonable nutritional education approach [6]. According to a previous survey, this interest is lower in children and adolescents [19]. In total, 0.4% of participants reported currently using digital games for obtaining nutritional information and 10.0% reported desiring them additionally. When asked whether they would like to receive nutritional information during digital gameplay, more than 70% of participants, especially women, responded yes. This question was asked at the beginning of the gameplay section, where we added a scenario to allow participants to better immerse themselves in the questions. However, the scenario might have biased participant response behavior. Finally, we assume the responses are not in contrast to each other.

Until now, data regarding the sources of nutritional information in Germany has been limited. According to a survey on German dietary and shopping behaviors conducted on behalf of the Federal Ministry of Food and Agriculture in 2017, 69% of participants preferred receiving nutritional information personally at the point of sale, whereas 42% preferred an internet/online search [29]. Social media were used for information by 14% (31% aged from 18 to 29 years) of the survey population. [29]. These findings are in line with this survey revealing that digital nutritional information is collected primarily via the internet and social networks, while books and newspapers, partner and family, and friends were the most preferred nondigital sources.

The relevance of nondigital information channels was confirmed by the German federal report [29]. European data indicates a similar picture as friends and newspapers are the most frequently used nutritional information sources for adults [30]. Our findings are in line with data from Canada demonstrating that 94% of households count at least one person using the internet for health guidance [31]. According to a cross-sectional study with almost 200 young adults, online resources were the most popular nutritional information sources, while family members and friends/peers played a minor role [25]. Moreover, most participants indicated that the most reliable sources for nutritional information are health care professionals [25]. As the option nutritional expert was not provided within this survey, there are no comparable data available.

Most survey participants reported wanting digital nutritional information sources (television, internet, social networks, apps, and digital games) in addition to the sources currently used (Table 2). This finding might be of added value in terms of developing a digital nutritional game for adults, as online information resources are available and accessible for myriad demographics with a simple dissemination [25]. Therefore, it could be assumed that young adults may be a suitable target group for nutritional education through serious games.

Since consideration of the target groups' needs, interests, perspectives, and preferences is crucial for the development of effective health games [16,32], data about learning preferences were collected in this survey as well. The majority of participants stated wanting to learn about nutrition in a digital game by playing a quiz or by solving tasks, which is consistent with data among young adults [6] and the younger population [19].

Our data showed that adults mainly prefer a human being or fantasy character in digital games. The preference for fantasy contexts or fantasy characters in serious games has already been shown for children [13,19] and students [33]. Besides the motivational nature of fantasy [13], fantasy-related contents used in video games improved the transfer of nutritional knowledge in children significantly more than no fantasy contexts [34]. Presented preferences should be considered for the development and design of a game for young adults [35]. A review on the usability of health-related games indicated that one of the main limitations of games for health is their lack in customization [36].

Strengths and Limitations

This survey addresses a rather large sample of young adults, mainly university students, an underrepresented target group in gaming research and nutritional education interventions [37,38]. Our overall purpose was to assess young adult preferences, motives, and behaviors regarding a serious game for nutritional education. The questionnaire was developed by a multidisciplinary team of scientists to ensure that perspectives of relevant disciplines were considered. Since there was no validated questionnaire available for the purpose of our survey, we developed a questionnaire from scratch according to common recommendations. A previous version of the questionnaire was pretested internally by university students. However, there are some limitations that need to be mentioned. The questionnaire also covered technical game design aspects, and we refrained from presenting these data. Moreover, there might have been some overlaps regarding the response items within the questionnaire (eg, Table 2, questions 1 and 2), because participants might be not able to distinguish between, for instance, apps and digital games, since digital games can be apps and vice versa. This might be an explanation for the observation that only a few participants used (0.4%) or wanted (10.0%) a digital game for nutritional information, but almost three-quarters (73.3%) wanted nutritional information during the gameplay of a serious nutritional game. Another explanation for this result might be that questions were asked in different contexts. Moreover, data regarding digital media consumption (frequency and duration) might be limited, since we did not discriminate between digital gameplay on weekdays and weekends. The online survey might be prone to selection bias, as participation is limited to those with internet access [39,40]. Furthermore, the survey invitation was mainly distributed via university-associated channels in the large city of Munich (Bavaria) resulting in more than 80% university students. Because the survey was not restricted to university students, nonstudents also participated. The majority of nonstudent participants indicated they were an academic (eg, graduates) or academic staff (eg, research assistants). Moreover, the sample size is mainly female, with more than 70% women. Therefore, presented data (eg, body weight, body mass index) are not representative for young adults or university students in Germany. All data were obtained by self-report.

Implications for Research and Practice

This survey revealed novel findings regarding digital gameplay in the context of nutritional education among a survey sample of more than 450 young adults, primarily female university students, in Germany. Since the game design process often lacks in the consideration of the target group's preferences, referring to this survey data might be useful for the design of a target group–specific game for young adults, especially females. Further aspects such as behavioral change techniques (eg, goal setting, self-monitoring) should be incorporated into the development of educational games. Moreover, previous studies have found young adults prefer simple and quick interfaces, gaming reward strategies, competitive incentives (eg, leader boards), and notifications [6].

As digital gameplay can be affected by high attrition rates, the implementation of different game elements (eg, simulation, adventure, and quizzes) should be considered. Compared with quizzes and adventures, simulations are perceived as more beneficial for educational purposes by students aged 18 to 33 years [41]. Finally, the target group's preferences need to be considered during all development and design stages of serious games [16].

Since the scientific evidence on the effects and effectiveness of serious games on nutritional outcomes (eg, knowledge, behavior) among young adults is limited, there is a need for addressing this topic within high-quality and long-term studies in the future [12,18]. Behavior changes are multifactorial processes. Therefore, it remains unclear whether an increase in nutritional knowledge can affect dietary behaviors at all. For instance, literature on students (mean age 21.8 [SD 1.9] years) showed that knowledge of healthy foods does not lead to the consumption of healthy snacks [42].

The design and development of serious games is a cost- and time-intensive process that requires the involvement of both experts and target groups [43,44]. Baranowski et al [43] reported that it takes three-and-a-half years to develop a health-related behavior change game. Serious games released by commercial vendors might be more attractive to players because of high-end graphical user interfaces, multiple levels, animation, and interactivity than their counterparts from research facilities. This may also have an impact on the adherence since fun affects the intrinsic motivation and intention to change behavior.

Conclusions

This survey showed that mainly male university students play digital games, but they are less willing to get nutritional education via serious games compared with female students. Nondigital tools and settings like books, newspapers, university, and workplace are used and desired for nutritional education by young adults. A digital game might have potential as a tool for nutritional information among both male and female young adults and university students, for instance, in the workplace and university environment. Further research among representative survey samples is warranted to draw final and generalizable conclusions regarding the demand and acceptability of serious games in the context of nutritional information. Finally, further research should address gender-specific differences in nutritional information acquisition and gameplay preferences, motives, and behaviors.

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Conflicts of Interest

None declared.

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Original Paper

Effect of Pokémon Go on Self-Harm Using Population-Based Interrupted Time-Series Analysis: Quasi-Experimental Study

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Abstract

Background: Pokémon Go is a very popular location-based augmented reality game with widespread influences over the world. An emerging body of research demonstrates that playing Pokémon Go can lead to improvements in physical activity and psychosocial well-being; however, whether Pokémon Go reduces self-harm incidence at the population-level is still questionable.

Objective: This study aimed to quantify how the launch of Pokémon Go in Hong Kong affected the incidence of self-harm using a quasi-experimental design.

Methods: An interrupted time-series design with Poisson segmented regression adjusted for time and seasonality trends was used on data from 2012 to 2018 to detect any changes in the number of accident and emergency attendances due to self-harm, after Pokémon Go was launched. The findings were validated using a baseline control period and using other intentional injuries and minor noninjuries as control outcomes. We also assessed intervention effects by age group.

Results: From January 1, 2012 to July 31, 2018, there were 13,463 accident and emergency attendances due to self-harm in Hong Kong. During the period after launching Pokémon Go, self-harm attendances dropped by 34% (adjusted incidence rate ratio: 0.66, 95% CI 0.61-0.73). When analyzed by age group, a reduction in self-harm incidence was only apparent in adults (18 to 24 years of age: adjusted incidence rate ratio: 0.78, *P*=.02; 25 to 39 years of age: adjusted incidence rate ratio: 0.75, *P*<.001; 40 years of age and older: adjusted incidence rate ratio: 0.57, *P*<.001).

Conclusions: Self-harm incidence in the population, particularly in adults, showed a significant decline in the period after Pokémon Go was launched. Augmented reality games such as Pokémon Go show great promise as a tool to enhance psychosocial well-being and improve mental health.

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KEYWORDS

Pokémon Go; self-harm; mobile game; injury; mHealth interventions; interrupted time-series analysis

Introduction

Self-harm refers to an act of causing physical injury to oneself without suicidal intent (for example, self-cutting, scratching oneself, hitting oneself, or intentional drug overdose). Cumulative evidence supports that a significant proportion of adolescents and adults have intentionally harmed themselves during their lifetime. Annually, in the United Kingdom, general hospitals have more than 200,000 cases related to individuals who self-harm [1]. In Hong Kong, research has found an alarming prevalence of self-harm in the male (13.4%) and female adolescent (19.7%) populations [2]. In some countries, the incidence of self-harm continues to rise steadily [3,4]. Although estimates of incidence vary among countries [5-8], self-harm is a global public health concern because of its association with suicide [9-11]. Repeated self-harm is common, with 16% and 23% repeating self-harm within one year and four years, respectively [12]. Given the substantial economic and health consequences, effective preventive interventions are urgently needed to decrease the incidence of self-harm. Research has shown that self-harm may signal distress or may be used as a way to escape from a troubling situation [6,13]. Psychosocial characteristics such as elevated stress, depression, anxiety, and feelings of lack of belonging, social isolation, or low self-esteem are common in people who self-harm [14,15]. Interventions that attempt to reduce distress and improve interpersonal skills offer promise in reducing self-harm frequency and repeated self-harm incidents [16]. Individual or group-based psychotherapy (problem-solving training, skills training, and cognitive modification training) and family therapy are typical psychosocial interventions to address self-harm [17].

Unfortunately, most people who harm themselves are reluctant either to admit that they self-harm or to seek help prior to harming themselves [18]. Hence, traditional face-to-face interventions may help only a portion of those at-risk (such as individuals who are more accepting of their mental health problems). In recent years, public health projects have used mobile technology to improve health and well-being [19-21]. Such technological advancements have extended the scope of service delivery to diverse and hidden populations. There has been a proliferation of novel interventions that incorporate technological innovation to empower young people to cope with difficult situations [22-24]. The rise of augmented reality games can improve player experience through the integration of game elements with real-world elements [25]. Notably, Pokémon Go, a location-based augmented reality game, has been widely successful around the world. The game uses geolocation to motivate players to search in real-world locations to capture virtual creatures called Pokémon. Since Pokémon appear at a location in a random sequence and for a limited period of time, players are required to visit different places to catch them to progress in the game.

Pokémon Go has attracted millions of players; in 2018, around 150 million people were actively playing the game. It has also prompted research into and discussion of the benefits and drawbacks of the game. Previous studies [26,27] have reported that the use of Pokémon Go has led to increases in physical activity. It has been found to promote social interaction, but also to increase the risk of injury and violence [28]. In Japan, the incidence of fatal traffic injuries did not change significantly after the release of Pokémon Go [29]. A few anecdotal reports and some evidence have investigated the positive effects of Pokémon Go on psychosocial well-being such as improving mood, expanding social network, and prompting individuals who mostly remain indoors to venture outside [30,31]. Given that the etiology of self-harm is complex and multifactorial involving numerous factors in physical, social, and mental health domains [32], Pokémon Go may also benefit multiple areas. The game has great potential to reduce the risk of self-harm; however, the effectiveness of Pokémon Go in preventing self-harm has not been empirically determined.

In Hong Kong, Pokémon Go was released on July 25, 2016. After the game was launched, many people in Hong Kong were drawn outdoors and to public places to play. In contrast to places of low population density, players in densely populated areas such as Hong Kong are more likely to interact with other players while playing Pokémon Go. The opportunity to engage casually with others in public has been found to mitigate feelings of loneliness because of an increased sense of belonging in the community [33]. Previous studies [30,34,35] focus on individual-level changes in physical activity, and little is known about the influences of Pokémon Go at the population level especially in Hong Kong where population is large but public spaces are limited; therefore, we carried out a quasi-experimental evaluation to examine any changes in the incidences of self-harm and other injury and noninjury events in Hong Kong after the launch of Pokémon Go.

Methods

Data Source and Participants

We extracted patient data from the Accident and Emergency Information System of the Hong Kong Hospital Authority. The Hong Kong Hospital Authority is the official managing body of public hospitals in Hong Kong and is responsible for most 24-hour accident and emergency services within the territory. In this study, data representing patients aged 12 years and older who presented to the accident and emergency department with evidence of intentional or minor noninjury events from January 1, 2012 to July 31, 2018 and from January 1, 2002 to July 31, 2008 were included. Codes from the International Classification of Diseases (ninth revision) were used to retrieve accident and emergency attendance records. The primary outcome was accident and emergency attendance for self-harm (codes E950 through E959). To validate the effect of Pokémon Go on self-harm incidence, we used two control outcomes [36]: injury events inflicted by others (common assault, indecent assault, and abuse or battering; codes E960 through E969) and minor noninjury events (all cases in nontrauma triage category 5) prior to and after the game's launch. Data were extracted from General Household Surveys and Population Census/By-census from the Hong Kong Census and Statistics Department.

Statistical Analysis

We used interrupted time-series analysis with a slope change model (equation 1) to detect changes in accident and emergency outcomes after the launch of Pokémon Go. A slope change model was selected because injury outcomes such as self-harm involve a complex causal mechanism that could result in gradual change over time [37]. Interrupted time series analysis is a quasi-experimental method used frequently in natural experiments to investigate change in the level of the outcome before and after an intervention. In this study, we defined the primary baseline control period as January 1, 2012 to July 24, 2016 (the day before Pokémon Go was released) and the primary exposure period as July 25, 2016 (the day that Pokémon Go was released) to July 31, 2018. The negative control exposure period was defined as July 25, 2006 to July 31, 2008 and the negative control baseline period was defined as January 1, 2002 to July 24, 2006. The incidence rate ratio was calculated using Poisson regression with robust standard errors with adjustments for age, sex, seasonality, and time trends. The incidence rate in the baseline control period was set as the reference value. Repeated accident and emergency attendances were removed prior to analysis. The model used accident and emergency attendance counts as the dependent variable and the time after intervention period as the primary independent variable. Population size was controlled as an offset variable to convert the monthly accident and emergency attendance counts into a rate value to control for change in the population over time [38]. The model is described by:

$$\ln(y_t) = \ln(population_t) + \beta_0 + \beta_1 * time_t + \beta_2 * time\ after\ intervention_t + \beta_3(\text{age group}) + \beta_4(\text{sex}) + \beta_5(\text{seasonality}) + e_t \quad (1)$$

where $time_t$ is the number of months from the start of the observation period, $time\ after\ intervention_t$ is the number of months after the intervention, y_t is the outcome at $time_t$, $\ln(population_t)$ is an offset used to account for the population at $time_t$, β_0 is a coefficient that estimates the baseline level of the outcome; β_1 is a coefficient that estimates trends over time; β_2 is a coefficient that estimates the change in the trend after the intervention ; β_3 is a coefficient that accounts for age, β_4 is a coefficient that accounts for sex, β_5 is a coefficient that accounts for seasonality, and e_t is the random effect at $time_t$. The coefficient of the slope term, β_2, represents the incidence rate ratio, which is a measure of relative risk. An incidence rate ratio of 1 indicated the association between the intervention (the release of Pokémon Go) and the change in accident and emergency attendance was null. An incidence rate ratio greater than 1 indicated a higher risk of self-harm in the period, whereas an incidence rate ratio less than 1 indicates a lower risk of self-harm in the period. In addition, we also compared the change in slope by age group and between early (from July 25, 2016 to July 24, 2017) and late exposure (July 25, 2017 to July 31, 2018) periods. All analyses were conducted using R statistical software (version 3.5.2), with *P*<.05 indicating statistical significance.

Results

Table 1 displays summary statistics for the entire study period. Of 13,463 accident and emergency attendances attributed to self-harm recorded for the period from January 1, 2012 to July 31, 2018, 7521 (55.9%) were female, 5942 (44.1%) were male, and most episodes (6898, 51.2%) occurred in patients aged 40 years or older. In the same period, there were 85,957 and 1,972,805 other intentional injuries and minor noninjuries, respectively.

Table 1. Accident and emergency attendance in the observation period (from January 1, 2012 to July 31, 2018).

Accident and emergency attendance	Self-harm, n (%)	Other intentional injury[a], n (%)	Minor noninjury[b], n (%)
Total	13,463 (100)	85,957 (100)	1,972,805 (100)
Gender			
Female	7521 (55.9)	32,378 (37.7)	912,587 (46.3)
Male	5942 (44.1)	53,579 (62.3)	1,060,218 (53.7)
Age (years)			
12-17	1109 (8.2)	5858 (6.8)	99,064 (5.0)
18-24	1822 (13.5)	9636 (11.2)	168,629 (8.5)
25-39	3634 (27.0)	27,740 (32.3)	431,028 (21.8)
≥40	6898 (51.2)	42,723 (49.7)	1,274,084 (64.6)

[a]Common assault, indecent assault, and abuse or battering.

[b]Minor noninjury accident and emergency attendance.

Table 2 shows that in the period following the launch of Pokémon Go, self-harm attendances decreased by 34% (incidence rate ratio 0.66, *P*<.001). In contrast, accident and emergency attendances related to other intentional injuries and minor noninjuries did not show declining trends after the game was launched. Furthermore, during the negative control exposure period in which Pokémon Go was absent, an increasing trend of self-harm attendances was found.

Attendances that were related to common assault demonstrated an increase during both the postlaunch and baseline periods. In age-specific analyses, from the immediate postlaunch to the end of the observation period, decreasing trends of self-harm attendances were only detected in adults (18 years and older). Specifically, the trend in self-harm attendances showed declines of 22% (incidence rate ratio 0.78, 95% CI 0.63-0.95) for ages 18 to 24 years, 25% (incidence rate ratio 0.75, 95% CI 0.66-0.87) for ages 25 to 39 years, and 43% (incidence rate ratio 0.57, 95% CI 0.49-0.67) for 40 years of age and older. Figure 1 illustrates self-harm incidence rate trends for ages 18 to 24 years in the observation period.

Table 2. Association between Pokémon Go and accident and emergency attendance from robust Poisson regression with adjustments for time trends, seasonal trends, age, gender, and population size.

Outcomes	Primary exposure period[a]		Negative control exposure period[b]	
	IRR[c] (95% CI)	*P* value	IRR (95% CI)	*P* value
All				
Primary outcome				
Self-harm	0.66 (0.61, 0.73)	<.001	1.74 (1.57, 1.92)	<.001
Negative control outcomes				
Common assault	1.06 (1.01, 1.11)	.03	1.05 (1.00, 1.10)	.04
Indecent assault	1.01 (0.81, 1.26)	.93	1.11 (0.92, 1.35)	.28
Abuse/battering	1.11 (1.00, 1.24)	.06	1.04 (0.94, 1.16)	.41
Minor noninjury	1.11 (1.03, 1.19)	.007	—	—
12-17 years of age				
Primary outcome				
Self-harm	0.82 (0.65, 1.04)	.10	1.39 (1.11, 1.73)	.004
Negative control outcomes				
Common assault	1.21 (1.03, 1.42)	.02	1.13 (1.02, 1.25)	.02
Indecent assault	0.97 (0.54, 1.77)	.93	1.34 (0.82, 2.20)	.24
Abuse/battering	1.14 (0.80, 1.64)	.47	1.08 (0.83, 1.40)	.57
Minor noninjury	1.17 (1.07, 1.28)	<.001	1.13 (1.02, 1.25)	.02
18-24 years of age				
Primary outcome				
Self-harm	0.78 (0.63, 0.95)	.02	1.32 (1.08, 1.60)	.006
Negative control outcomes				
Common assault	0.99 (0.90, 1.09)	.90	1.03 (0.96, 1.10)	.47
Indecent assault	1.34 (0.86, 2.10)	.20	0.96 (0.64, 1.43)	.84
Abuse/battering	1.35 (0.88, 2.08)	.17	1.32 (0.92, 1.90)	.13
Minor noninjury	1.12 (1.07, 1.18)	<.001	1.32 (1.08, 1.60)	.006
25-39 years of age				
Primary outcome				
Self-harm	0.75 (0.66, 0.87)	<.001	1.64 (1.39, 1.92)	<.001
Negative control outcomes				
Common assault	1.02 (0.96, 1.08)	.51	1.03 (0.98, 1.08)	.26
Indecent assault	1.15 (0.81, 1.64)	.44	1.12 (0.78, 1.61)	.55
Abuse/battering	1.07 (0.91, 1.25)	.41	1.01 (0.89, 1.14)	.89
Minor noninjury	1.07 (1.02, 1.12)	.004	1.03 (0.98, 1.08)	.26
≥40 years of age				
Primary outcome				
Self-harm	0.57 (0.49, 0.67)	<.001	2.15 (1.76, 2.62)	<.001
Negative control outcomes				
Common assault	1.07 (1.01, 1.12)	.01	1.05 (1.00, 1.10)	.046
Indecent assault	0.79 (0.55, 1.14)	.20	1.11 (0.81, 1.53)	.51
Abuse/battering	1.12 (0.99, 1.27)	.08	1.05 (0.93, 1.18)	.47
Minor noninjury	1.11 (1.05, 1.16)	<.001	2.15 (1.76, 2.62)	<.001

[a]Primary exposure period: July 25, 2016 to July 31, 2018; control baseline period: January 1, 2012 to July 24, 2016.
[b]Negative control exposure period: July 25, 2006 to July 31, 2008; negative control baseline period: January 1, 2002 to July 24, 2006.
[c]IRR: incidence rate ratio.

Figure 1. Monthly self-harm incidence rate of young adults in the observation period.

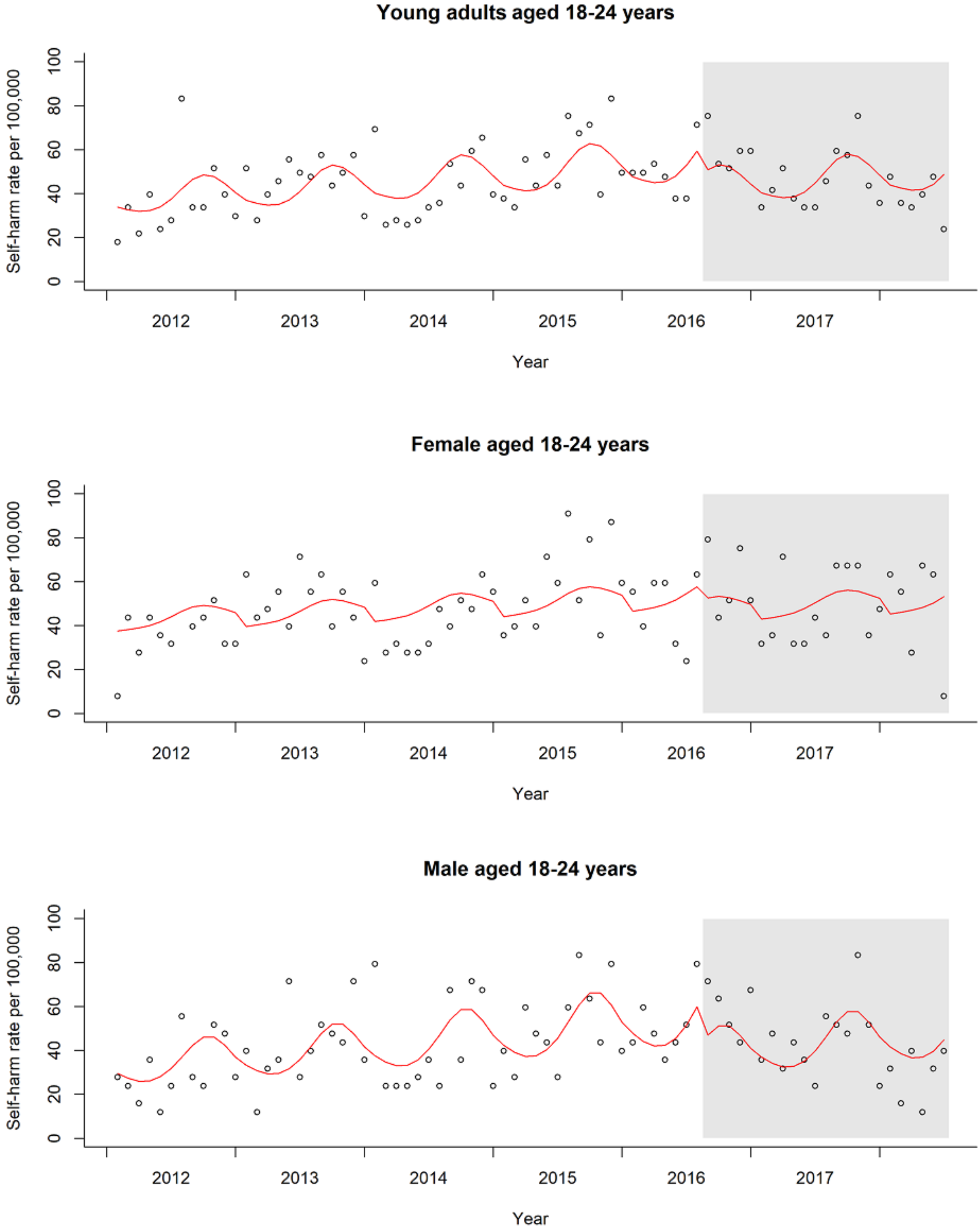

Table 3 shows the immediate and delayed effects of Pokémon Go launch on the trends of accident and emergency attendances. Both early and late exposure periods had negative slopes representing decreasing self-harm incidence, but the decrease was greater in the late exposure period than in the early exposure period overall (late: incidence rate ratio 0.57, *P*<.001; early: incidence rate ratio 0.71, *P*<.001) and for the adult age groups (late: incidence rate ratio 0.45-0.70, *P*<.001 to *P*=.007; early: incidence rate ratio 0.63-0.80, *P*<.001 to *P*=.05).

Table 3. Association between accident and emergency attendance and early and late periods after the launch of Pokémon Go from robust Poisson regression with adjustments for time trends, seasonal trends, age, gender, and population size.

Outcomes	Early exposure period[a]		Late exposure period[b]	
	IRR[c] (95% CI)	*P* value	IRR (95% CI)	*P* value
All				
Primary outcome				
Self-harm	0.71 (0.65, 0.78)	<.001	0.57 (0.51, 0.63)	<.001
Negative control outcomes				
Common assault	1.05 (0.99, 1.10)	.08	1.08 (1.02, 1.14)	.01
Indecent assault	1.02 (0.81, 1.29)	.85	0.98 (0.75, 1.29)	.90
Abuse/battering	1.08 (0.97, 1.22)	.17	1.17 (1.02, 1.34)	.02
Minor noninjury	1.09 (1.01, 1.18)	.02	1.14 (1.04, 1.25)	.005
12-17 years of age				
Primary outcome				
Self-harm	0.78 (0.60, 1.00)	.05	0.92 (0.69, 1.22)	.56
Negative control outcomes				
Common assault	1.09 (0.92, 1.29)	.30	1.47 (1.22, 1.78)	<.001
Indecent assault	0.92 (0.48, 1.76)	.79	1.10 (0.52, 2.31)	.81
Abuse/battering	0.98 (0.66, 1.47)	.93	1.51 (0.98, 2.34)	.07
Minor noninjury	1.15 (1.04, 1.26)	.005	1.22 (1.09, 1.36)	<.001
18-24 years of age				
Primary outcome				
Self-harm	0.81 (0.66, 1.00)	.05	0.70 (0.55, 0.91)	.007
Negative control outcomes				
Common assault	1.01 (0.91, 1.11)	.91	0.97 (0.86, 1.09)	.60
Indecent assault	1.31 (0.82, 2.11)	.26	1.41 (0.81, 2.48)	.23
Abuse/battering	1.35 (0.86, 2.12)	.19	1.35 (0.78, 2.33)	.29
Minor noninjury	1.11 (1.05, 1.17)	<.001	1.16 (1.08, 1.23)	<.001
25-39 years of age				
Primary outcome				
Self-harm	0.80 (0.70, 0.92)	.003	0.66 (0.55, 0.78)	<.001
Negative control outcomes				
Common assault	1.02 (0.96, 1.09)	.46	1.01 (0.94, 1.09)	.76
Indecent assault	1.09 (0.75, 1.59)	.65	1.31 (0.85, 2.02)	.22
Abuse/battering	1.06 (0.90, 1.25)	.50	1.09 (0.89, 1.33)	.40
Minor noninjury	1.06 (1.01, 1.12)	.01	1.09 (1.03, 1.16)	.005
≥40 years of age				
Primary outcome				
Self-harm	0.63 (0.54, 0.73)	<.001	0.45 (0.38, 0.54)	<.001
Negative control outcomes				
Common assault	1.05 (1.00, 1.11)	.05	1.09 (1.03, 1.16)	.005
Indecent assault	0.87 (0.61, 1.26)	.47	0.60 (0.38, 0.95)	.03
Abuse/battering	1.10 (0.96, 1.25)	.17	1.17 (1.01, 1.36)	.04
Minor noninjury	1.09 (1.04, 1.15)	.001	1.15 (1.08, 1.22)	<.001

[a]Early exposure period: July 25, 2016 to July 24, 2017; control baseline period: January 1, 2012 to July 24, 2016.
[b]Late exposure period: July 25, 2017 to July 31, 2018; control baseline period: January 1, 2012 to July 24, 2016.
[c]IRR: incidence rate ratio.

Discussion

Principal Findings

Given the substantial health care costs of self-harm, it is imperative to address and attempt to alleviate psychosocial difficulties before individuals harm themselves. Although Pokémon Go has been studied in outdoor settings for physical activity outcomes [26,27,30,34,35], there has been limited research on the effects of Pokémon Go on mental health (in particular, on its potential as a tool for the prevention of mental health disorders). Pokémon Go may lead to decreases in the frequency of self-harm by encouraging behaviors that improve mental health; however, no prior research has tested this hypothesis. This study is the first to assess and compare self-harm incidence using population-level data from before and after the release of Pokémon Go.

Based on hospital accident and emergency attendance records, after the release of Pokémon Go, decreasing trends for self-harm attendance records were found overall and in adult age groups (18 to 24 years of age, 25 to 39 years of age , and 40 years of age and older). Furthermore, the decline was larger in older ages, possibly because, as it has been suggested in various reports [30,39,40], adolescents are less likely to engage in Pokémon Go, and thus, this age group may be less affected by the game. In addition to analyses by age, analyses by exposure period showed that the effect of Pokémon Go's launch on trends of self-harm attendances was more apparent in the late exposure period. This could be because protective factors, such as enhanced positive emotions, new friendships, and increased physical activity, that improve mental health occur and accumulate over time. To confirm the effect of Pokémon Go with decreased self-harm attendances, we repeated the analyses using the number of accident and emergency attendances due to other intentional injury and noninjury events as control outcomes and using the number of accident and emergency attendances for the 10 years before the introduction of Pokémon Go as a control period. This period (starting 10 years before the primary exposure) was selected as the control period because during this period of time, the use of information technology in health research was still low [41]. We found that the declining trend of self-harm attendances occurred only in the postlaunch period, whereas other accident and emergency attendances showed no decreases in both primary exposure (postlaunch) and negative exposure periods. These findings support the claim that playing Pokémon Go is a potential preventive strategy for self-harm [30,31]. Among the outcomes, only self-harm attendances showed significant declines in the postlaunch period, possibly because gameplay may have contributed to increased optimism, excitement, and positive social interactions [42]. The finding that the trends of accident and emergency attendances due to other intentional injury and minor noninjury events did not decline during the same period supports this assumption.

Notably, the increasing trend of common assault attendances in the postlaunch period may support the claim that Pokémon Go may trigger violence [28]. Analyses by age showed an increasing trend for common assault attendances in the age groups of 12 to 17 years and 40 years and older, but the trends remained largely unchanged in young adults (ages 18 to 39 years). This finding might be explained, among other factors, by player perception. A study [43] found that older adults had more negative attitudes about playing Pokémon Go and were more likely to agree that the game encourages violence. Although more research is needed to elucidate mechanisms, biases and differences in these game-related perceptions may lead to increased hostile and aggressive behavior between players and nonplayers [44], thereby increasing the chance of assaults. Previous research [45] also found that people under 18 years of age, when playing Pokémon Go, had the greatest tendency to behave badly (for example, by violating rules and regulations, threatening the safety of others, or venturing into unsafe places) which may have given rise to the increased number of assaults in this age group. Although our findings shed some light on the effect of Pokémon Go on violent behavior, future investigations should ascertain if young adults are less susceptible to the negative influences from Pokémon Go. Research should also identify protective factors to disengage players from aggressive and illegal behavior during the gameplay.

Comparison with Prior Work

Augmented reality technology has been increasingly adopted, with promising results, in health interventions to promote physical and mental health [46,47]; however, there is a lack of evidence that confirms the effect of game-based interventions on suicide prevention. Only a few studies have investigated the benefits of playing Pokémon Go on mental health and have reported that playing Pokémon Go, both alone and with others, can positively affect the players' well-being and social life [48], possibly by helping players shut out negative thoughts or concerns through flow experience—a state of complete absorption or engagement in the game activity [49,50]. Research shows that flow experience is linked to positive affect [51], and increased levels of flow experience were found in both solo and collaborative gameplay [52,53]. Some studies [48,52] have found that playing alone was a stronger predictor of flow experience, whereas other studies [53,54] have suggested collaborative play may have greater potential to trigger positive emotional and nonviolent responses. Although this study found a significant decrease in self-harm attendances after the release of Pokémon Go, it is important to highlight that the evidence was based upon aggregate data. Aggregated data can reflect both individual-level gaming behavior and societal factors such as public events and overall atmosphere during the period of exposure (the period after the Pokémon Go game was launched). Furthermore, while video games have a potential to reduce social isolation and psychological distress [46,55,56], some studies [55] have reported that problematic use of video games can cause disorder-related symptoms. The question of how frequently and where one should play Pokémon Go to reduce self-harm is worthy of exploration in future research.

Limitations

The main limitation of this study was its ecological design. As our analyses were based on aggregate data, we could not identify whether the people presenting to accident and emergency due to self-harm had played Pokémon Go, and hence, we could not generalize our findings from the population-level to the individual-level; however, our results were consistent with previous ecological and observational study findings. Because of Pokémon Go's large number of downloads and wide popularity within the community, the game has become an ongoing social event that extends to every part of Hong Kong. Hong Kong is a densely populated city where social events or movements have pervasive and substantial effects on mental health across socioeconomic classes and which may include effects on individuals who did not directly participate [57]. It should be noted that our analyses did not take into account the change in social atmosphere due to other social events in Hong Kong occurring during the same period which may have biased our results. Nevertheless, when replicating the analyses using other intentional injury and minor noninjury outcomes and earlier exposure periods that were not be influenced by the release of Pokémon Go, we found no significant decline which supports the conclusion that the decline in self-harm rate after the launch of Pokémon Go was not as a result of unobserved confounding.

Conclusions

Augmented reality games are designed to bring the fun and exciting elements of virtual and natural environments together. The gameplay may create new and improved perceptions of everyday activities in the real world, thereby replacing intrusive and repetitive self-harm thoughts with positive feelings in players. This study found significant declines in self-harm incidence after the release of Pokémon Go. Future research should explore these possibilities and confirm the underlying mechanisms. We see promise in utilizing augmented reality games such as Pokémon Go with engaging and appealing features to reach large numbers of people and to improve their mental health.

Conflicts of Interest

None declared.

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Original Paper

Development and Validation of the Reasons to Exergame (RTEX) Scale in Young Adults: Exploratory Factors Analysis

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Abstract

Background: Exergaming is associated with positive health benefits; however, little is known about what motivates young people to exergame.

Objective: This study aimed to develop a new Reasons to Exergame (RTEX) scale and describe its psychometric properties (Study 1) including test-retest reliability (Study 2). We also examined the test-retest reliability of self-report exergaming behavior measures (Study 2).

Methods: We identified scale items in consultation with experts. In Study 1, we conducted an Exploratory Factor Analysis of RTEX and examined how the factors identified relate to exergaming frequency and intensity in a population-based sample of 272 young adults. In Study 2, we examined the test-retest reliability of RTEX factors and self-report measures of past-week exergaming frequency and intensity among 147 college students.

Results: We identified four factors in RTEX: exergaming for fitness, exergaming for enjoyment, preferring exergaming over other gaming options, and choosing exergaming over competing interests (eg, sports). Test-retest reliability of RTEX factors (ICC 0.7-0.8) and self-report exergaming frequency (ICC 0.4-0.9) was adequate. Exergaming for fitness and enjoyment were positively associated with the frequency of exergaming with friends and family, and with exergaming intensity. Preferring exergaming over other gaming options and choosing exergaming over competing interests (eg, sports) were not related to exergaming behavior.

Conclusions: RTEX is a psychometrically sound scale with four factors that measure reasons to exergame. Replication of these findings is needed in larger, more diverse samples.

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KEYWORDS

exergaming; youth; young adults; motivation; scale

Introduction

Physically active lifestyles should be promoted early in life because fewer than 60% of youth meet the recommended physical activity (PA) levels and because PA levels established in childhood track into adulthood [1-4]. However, both physical inactivity and sedentary behavior are increasing among youths [5,6], in part due to the popularity of screen activities such as television viewing and video game playing (ie, gaming). An estimated 97% of Americans aged 12-17 years [7] and 56% of young adults aged 18-25 years report past-year gaming using personal computers, laptops, consoles, or smartphones [8]. The average time spent gaming among youths has increased, and young adults in 2018 spend more than 7 hours weekly playing video games [9].

There is, however, a type of gaming that may confer physical and mental health benefits and that does not contribute to sedentary behavior. Active video game-playing, also called “exergaming,” is a contemporary alternative to traditional gaming that incorporates PA into the video game concept. Exergaming increases energy expenditure [10-15] and PA [16-18], helps players manage weight [19-21], improves mental health [22], and can replace sedentary behavior [18,22-24]. However, both anecdotal and qualitative evidence suggest that, in contrast to more sedentary gaming [25,26], motivation for exergaming can decrease over time as novelty diminishes or because of competing interests. Technical difficulties in exergaming (eg, console malfunctioning, over- or undersensitivity of controls, inaccurate tracking) [18,27,28], insufficient design features of gaming (eg, lack of compelling narratives), or PA-related discomfort during exergaming (eg, sweating, breathing hard while playing) could also contribute to declines. Similar to both traditional gaming and PA in youths (eg, males initiate gaming at a younger age than females; PA declines much earlier and more rapidly in females than males), these factors may differ by gender [29-32].

Because of the health-enhancing potential of exergaming, it is key to better understand the reasons why young people choose to exergame and maintain this behavior. Previous studies have examined exergaming motivation using scales that were not developed specifically for exergaming, such as those targeting general PA [33]. Fitzgerald et al [34] used the Self-Motivation Inventory (a 40-item questionnaire that assesses the trait of self-motivation, such as the inherent ability to persevere at a task) and the Intrinsic Motivation Inventory (a questionnaire based on Self-Determination Theory) to assess motivation for exergaming. Sun et al [35] applied the 15-item Situational Interest Scale - Elementary School to exergaming among physical education students in elementary school. However, exergaming may not be viewed as PA by young people, and these scales might not distinguish between motivation for the PA aspects of exergaming and motivation for the gaming aspects.

In the only study to date that examined motivation for exergaming using a scale specifically developed for exergaming, Staino et al [36,37] used the self-report Motivation for Exergame Play Inventory, a validated 28-item questionnaire that assesses motivation for exergaming among youths with overweight or obesity. However, the Motivation for Exergame Play Inventory measures motivation after an acute bout of exergaming related to the specific game just played, not motivation toward exergaming in general, and is therefore not ideal for examining exergaming motivation in research and surveillance. Although increased understanding of the reasons that young people choose to exergame could improve exergaming interventions as well as public health messaging about exergaming, an important gap in the literature is the lack of evidence on reasons to initiate and sustain exergaming.

The purpose of this study was to develop a new Reasons to Exergame (RTEX) scale that is useful in intervention studies, observational studies, and surveillance and to test its psychometric properties. Although assessment of reasons to exergame is also important in children and older adults, this first examination of RTEX was undertaken in young adults who are technologically sophisticated, often highly engaged in gaming, and in whom PA levels tend to decline due to competing priorities, lack of time, and lack of motivation.

After item generation for RTEX, two studies were conducted, each using different databases. Study 1 employed data from the Nicotine Dependence in Teens (NDIT) Study, a longitudinal investigation of youths aged 12-13 years at inception with follow-up to age 30 years [38]. In Study 1, we conducted an Exploratory Factor Analysis (EFA) of RTEX items and studied how factors identified in the EFA relate to the frequency and intensity of exergaming to test convergent validity. Because the NDIT data collection time points were fixed, it was not possible to collect test-retest data within the NDIT protocol. Therefore, Study 2 was undertaken to assess the test-retest reliability of both the RTEX scale and self-report measures of exergaming frequency and intensity. Study 2 used a convenience sample of college students. Methods and results are presented first for Study 1 and then for Study 2.

Methods

Study 1

Data for Study 1 were collected in self-report questionnaires completed in 2017-2019 by 630 young adults participating in the NDIT Study [38], an ongoing investigation of grade 7 students recruited in 10 Montreal-area high schools in 1999-2000. Of 2325 eligible students, 56% participated at baseline. The low response was attributable to the need for blood samples for genotyping and a labor dispute in Quebec that resulted in numerous teachers refusing to collect consent forms. No data were collected from nonrespondents [38]. Self-report questionnaires were administered at school every 3 months during the 10-month school year in grades 7-11, for a total of 20 cycles during the 5 years of high school. Post high school data were collected in self-report questionnaires in 2007-2008 (cycle 21), 2011-2012 (cycle 22), and 2017-2019 (cycle 23) when participants were aged 20, 24, and 30 years, on average, respectively. This study used data from cycle 23. The NDIT Study was approved by the Ethics Committee of the Centre de Recherche du Centre Hospitalier de l’Université de Montréal (ND 06.087).

Measures

RTEX

Items for the RTEX scale were selected by the authors in consultation with PA and exergaming experts and with reference to constructs relevant to exergaming such as general interest in gaming, social gaming preferences, degree of enjoyment in exergaming, reasons to be physically active (eg, lose weight, increase strength), and comparing exergaming to other active pastimes (such as sports). Items drew on the Gaming Motivation Scale [39], the Intrinsic Motivations to Gameplay scale [40], and the Exercise Motivations Inventory-2 [41]. Experts judged redundancy, applicability, and representativeness of the items in an exergaming context. The scale was pilot-tested among experts (PA and exergaming researchers) as well as among young adults during development of the NDIT cycle 23 questionnaire for clarity of wording, item choice, and clarity of response choices. Participants were asked to indicate how true each item was regarding their reasons to exergame using a 5-point Likert-type response format (ie, completely false, slightly false, neither true nor false, slightly true, completely true).

Frequency and Intensity of Exergaming

Items measuring exergaming behavior were modeled on the short-form self-administered usual-week International Physical Activity Questionnaire, which is used in cross-national monitoring of PA in youths and adults and demonstrates reliability and validity against the accelerometer [42]. Specifically, participants were asked, "Do you exergame using consoles such as Nintendo Wii, XBOX ONE Kinect, Sony Play Station Move, Sony Eye Toy: Kinetic, or using your cellphone and/or a mobile app? (ex. ZOMBIES, RUN! Nike+ Running App, Fit Freeway, Pokémon Go)." Response options were (yes and no). Those who responded "yes" were asked how many days per week they played active video games (or exergamed; options: 1-7 days); how many minutes (on average) they played each time (open-ended); and perceived effort of play (light, moderate, vigorous). All three measures were used in both studies. Finally, we assessed how frequently participants exergamed alone, with friends, or with family by asking, "How often do you exergame with… (friends, family, alone)?" Response options included never, rarely, sometimes, often, and very often. This measure was used only in Study 1.

Data Analysis

Exploratory Factor Analysis

Use of EFA at this phase in the development of the RTEX is appropriate, given that the items are new and there was uncertainty in how the items would load on the factors [43]. Since the 26 possible items for RTEX were expected to intercorrelate, they were subjected to an EFA using maximum likelihood and oblique promax rotation (direct oblimin) for factor derivation. Criteria [44-49] used to establish the number of factors to retain were the Cattell scree plot, >10% of variance accounted for by each factor, pattern coefficients of >0.40 on a given factor [46,47], interpretability of the factors, and internal reliability (Cronbach α) of >0.7 for each factor [44]. The Kaiser-Meyer-Olkin test was used to measure sampling adequacy for conducting a factor analysis. Factor items were determined using eigenvalues >1.

As indicated, 26 items were retained in RTEX for the initial EFA. The Kaiser-Meyer-Olkin measure of sampling adequacy (0.90) indicated adequate sample size for the analysis, and the Bartlett test of sphericity (4494.7_{325}, *P*<.001) indicated that the correlation matrix was appropriate for this analysis. Six factors with eigenvalues >1.0 [48] were extracted from the matrix, explaining 71.2% of the variance. Based on the analysis of the loadings of the rotated factors (the pattern matrix), three items were dropped from the item pool because they failed to load >0.40 on any of the 4 factors (Multimedia Appendix 1). We repeated the factor analysis with the remaining 23 items and examined the factor loadings of the new promax-rotated factor solution. Five factors emerged, which explained 70.0% of the total variance. Inspection of the pattern matrix showed that all items but one loaded >0.40 on one of the 5 factors (Multimedia Appendix 1), and none of the items had high cross-loading on other factors. Therefore, after removing the single item, the process was repeated a final time, and a 4-factor solution explaining 66% of the variance was retained (n=22 items). Factor scores were calculated by summing the individual items within a factor and averaging the score by the number of items with responses to create one score per factor (see Results section).

Convergent Validity

The associations between each RTEX factor and exergaming frequency (minutes per week) and intensity (light, moderate, intense) were examined in separate multivariable linear regression models. We also investigated the association between each RTEX factor and the frequency of exergaming alone, with friends, and with family, in three separate multivariable linear regression models. All regression models were controlled for age, sex, mother attended university (yes/no), and the other RTEX factors. Sex differences in RTEX factors and individual items were examined using independent *t* tests.

Students (54.6% female; mean age 19.5, SD 0.5) recruited in an Exercise Science Department in a large urban university (n=147) completed the RTEX on two occasions (Time 1 and Time 2) 7-9 days apart in winter 2017.

The study received approval from the ethics and protection review boards of Concordia University (30007966), and the students provided assent during questionnaire administration. Students received class credit for completing the study.

Study 2

Data Analysis

Intraclass correlations (ICCs) were used to examine test-retest reliability between responses over time for continuous variables including exergaming intensity and days per week exergaming Two-way random ICCs were computed and the average ICC was reported [49]. Adequate test-retest reliability was defined as ICC≥0.75 [11]. The weighted Kappa statistic (κ) was used to describe the test-retest reliability of categorical variables (such as ever exergamed, yes/no), and the strength of agreement between responses was defined as poor to fair (κ=0.0-0.4), moderate (κ=0.41-0.6), substantial (κ=0.61-0.8), and almost perfect (κ=0.81-1.0). Statistical significance was set at 0.05.

Results

Study 1

Table 1 shows selected characteristics of NDIT participants (N=272) who responded yes to ever exergaming and were therefore retained in the analytic sample.

Table 1. Selected characteristics of participants in Study 1 (N=272), NDIT 2017-2019.

Characteristic	Value
Age (years), mean (SD)	30.2 (0.7)
Male, n (%)	127 (46.8)
French-speaking, n (%)	98 (36.0)
Mother university-educated, n (%)	109 (40.2)
Canadian-born, n (%)	262 (96.4)
Minutes exergaming/week, mean (SD)	
All participants	30.1 (90.0)
Excluding those reporting 0 minutes	147.0 (150.7)
Exergaming intensity, n (%)	
Light	176 (64.8)
Moderate	92 (33.8)
Intense	4 (1.4)
Frequency of exergaming, mean (SD)	
Alone	2.1 (1.2)
With friends	2.1 (1.0)
With family	1.8 (0.9)

Exploratory Factor Analysis

The 4-factor solution retained identified an exergaming for fitness factor (9 items), an exergaming for enjoyment factor (8 items), a factor indicative of preferring exergaming over other gaming options (3 items), and a factor indicative of choosing exergaming over competing interests (eg, sports; 2 items; Table 2).

Table 2. Scores by sex and factor loadings of items retained in each RTEX factor (Study 1, NDIT 2017-2019).

RTEX[a] factor and items within factors	Score			*P* value for sex difference	Factor loading
	Total (N=272), mean (SD)	Males (N=130), mean (SD)	Females (n=142), mean (SD)		
Factor 1: Fitness[b]					
I exergame to maintain my weight	1.7 (1.1)	1.9 (1.2)	1.5 (1.0)	.004	0.87
I exergame to maintain my level of fitness	1.8 (1.2)	2.0 (1.3)	1.6 (1.1)	.03	0.86
I exergame to be more active	2.2 (1.3)	2.4 (1.4)	2.0 (1.2)	.004	0.70
I exergame to lose weight	1.8 (1.2)	2.0 (1.3)	1.5 (1.0)	.004	0.83
I exergame to gain strength	1.6 (1.1)	1.8 (1.2)	1.5 (1.0)	.04	0.89
I exergame to "bulk up"	1.4 (1.0)	1.3 (0.7)	1.4 (0.8)	.44	0.77
I exergame to gain flexibility	1.9 (1.1)	1.8 (1.2)	1.5 (1.0)	.07	0.90
I exergame to gain balance	1.7 (1.1)	1.8 (1.2)	1.6 (1.0)	.07	0.88
Factor 2: Enjoyment[b]					
I like to play exergames	3.2 (1.4)	3.2 (1.4)	3.2 (1.3)	.68	0.73
I like to play exergames with friends	3.3 (1.4)	3.4 (1.4)	3.2 (1.4)	.37	0.81
I like to play exergames with my family	2.8 (1.5)	2.6 (1.4)	3.0 (1.5)	.03	0.60
Exergames are boring to play (reverse coded)	3.5 (1.3)	3.5 (1.3)	3.6 (1.3)	.46	0.50
I exergame to be social	2.5 (1.5)	2.5 (1.4)	2.5 (1.5)	.85	0.60
Exergames are exciting to play	2.9 (1.3)	2.8 (1.3)	3.1 (1.2)	.02	0.67
I exergame just for fun	3.5 (1.4)	3.6 (1.4)	3.4 (1.5)	.20	0.72
I prefer exergames to watching TV[c]	2.0 (1.1)	1.8 (1.1)	2.1 (1.1)	.07	0.41
I prefer exergames to being on social media (Facebook, Instagram, Snapchat)	2.3 (1.4)	2.0 (1.2)	2.8 (1.4)	<.001	0.44
Factor 3: Gaming preference[b]					
I prefer exergames to more traditional video games[c]	2.4 (1.3)	1.8 (1.1)	2.8 (1.3)	<.001	0.60
Exergaming is the only type of video game I like	1.5 (1.1)	1.3 (0.8)	1.8 (1.2)	.001	0.81
Other types of video games bore me	1.6 (1.1)	1.4 (0.9)	1.9 (1.3)	<.001	0.81
Factor 4: Competing interests[b]					
I prefer to play exergames more than outdoor sports	1.8 (1.1)	1.8 (1.2)	1.8 (1.1)	.87	–0.90
I prefer to play exergames more than indoor sports	1.9 (1.2)	2.0 (1.2)	1.8 (1.1)	.27	–0.84

[a]Reasons to Exergame.

[b]Continuous variable.

[c]Item was not examined in test-retest analysis.

The mean (SD) for factors 1 to 4 were 1.7 (1.0), 3.3 (1.0), 1.9 (1.0), and 1.8 (1.1), respectively. The Cronbach α for the factors ranged from 0.80 to 0.95, indicating adequate internal consistency. A correlation matrix showed that the 4 factors were moderately correlated, with *r* ranging from 0.20 to 0.40. Sex differences were observed in the fitness and gaming preference factors. Females scored higher on both factors, indicating that these factors were more important or true for them as reasons to exergame (Table 3).

Table 3. Scores by sex and internal reliability coefficient (Cronbach α) of RTEX factors (Study 1, 2017-2019) and intraclass correlation coefficient for test-retest reliability of RTEX factors (Study 2, 2017).

RTEX[a] factor	NDIT[b] sample (N=627), n (%)	Study 1 (n=272)				Study 2 (n=147), ICC[c] 95% CI
		Mean (SD)	*P* value for sex difference	Range	Cronbach α	
Factor 1: Fitness			.02	1.0-4.5	0.95	0.8 (0.6-0.8)
Total	265 (42.3)	1.7 (1.0)				
Male	125 (20.0)	1.6 (0.9)				
Female	140 (22.3)	1.9 (1.0)				
Factor 2: Enjoyment value			.37	1.0-4.8	0.85	0.7 (0.4-0.6)
Total	268 (42.7)	2.9 (0.9)				
Male	127 (20.3)	3.0 (0.9)				
Female	141 (22.5)	2.9 (0.9)				
Factor 3: Gaming preference			<.001	1.0-5.0	0.80	0.8 (0.5-0.7)
Total	268 (42.7)	1.9 (1.0)				
Male	127 (20.3)	1.5 (0.7)				
Female	141 (22.5)	2.2 (1.1)				
Factor 4: Competing interests			.62	1.0-5.0	0.90	0.7 (0.6-0.8)
Total	272 (43.4)	1.8 (1.1)				
Male	130 (20.7)	1.8 (1.0)				
Female	142 (22.6)	1.8 (1.1)				

[a]Reasons to Exergame.

[b]Nicotine dependence in the teen study.

[c]ICC: intraclass correlation coefficient.

Convergent Validity

Correlations between the four RTEX factors and exergaming behavior are presented in Table 4. Multiple linear regression analyses indicated that factor 1 (fitness) was related to exergaming intensity (β= 0.2, 95% CI 0.03-0.4), frequency exergaming alone (β=0.3, 95% CI 0.1-0.5), and frequency exergaming with friends (β=–0.2, 95% CI –0.3 to –0.05). Factor 2 (enjoyment) was related to frequency exergaming alone (β=0.3, 95% CI 0.1-0.5), frequency exergaming with friends (β=0.7, 95% CI 0.6-0.8) and frequency exergaming with family (β=0.5, 95% CI 0.3-0.6). Factors 3 and 4 were not related to exergaming behavior.

Table 4. Correlations among variables used in the regression models in Study 1, NDIT 2017-2019.

Variable	Factor 1: Fitness	Factor 2: Enjoyment	Factor 3: Gaming preference	Factor 4: Competing interests	Minutes exergaming/wk	Intensity exergaming	Frequency of exergaming		
							Alone	With friends	With family
Factor 1: Fitness									
r	1	0.273[a]	0.312[a]	0.432[a]	0.042	0.325[a]	0.327[a]	0.067	0.162[a]
P value	__[b]	<.001	<.001	<.001	.51	.007	<.001	.28	.009
Factor 2: Enjoyment									
r		1	0.227[a]	0.439[a]	0.185[a]	-0.054	0.302[a]	0.625[a]	0.462[a]
P value		—	<.001	<.001	.003	.66	<.001	<.001	<.001
Factor 3: Gaming preference									
r			1	0.213[a]	0.062	0.074	0.135[a]	0.165[a]	0.230[a]
P value			—	<.001	.32	.57	.03	.007	<.001
Factor 4: Competing interests									
r				1	0.128[c]	0.034	0.285[a]	0.295[a]	0.259[a]
P value				—	.04	.78	<.001	<.001	<.001
Minutes exergaming/wk									
r					1	-0.067	0.432[a]	0.145[c]	0.065
P value					—	.56	<.001	.021	.303
Intensity exergaming									
r						1	0.301[c]	0.021	0.046
P value						—	.013	.87	.71
Frequency of exergaming									
Alone									
r							1	0.180[a]	0.118
P value							—	.003	.056
With friends									
r								1	0.527[a]
P value								—	<.001
With family									
r									1
P value									—

[a]Correlation is significant at the 0.01 level (two-tailed).

[b]Not available.

[c]Correlation is significant at the 0.05 level (two-tailed).

Study 2

Test-retest reliability coefficients of the measures of exergaming frequency and intensity ranged from 0.4 (for intensity) to 0.9 (for days per week exergaming). The weighted kappa coefficient for ever exergamed was 0.7. Test-retest reliability of RTEX factors ranged from 0.7 to 0.8 (Table 3). Percent or mean of items measuring exergaming behavior by sex is presented in Table 5.

Table 5. Items measuring exergaming behavior by sex in Study 1, NDIT 2017-2019.

Exergaming behavior	n	Exergaming behavior items	Study 1			
			Total	Males	Females	*P* value for sex difference
Ever exergamed	627[a]	Have you ever exergamed using a console, cell phone and/or mobile app? % yes	44.4	46.6	42.5	.32
How often – console[a]	257	How often do you exergame using consoles such as Nintendo Wii, XBOX ONE Kinect, Sony Play Station Move, Sony Eye Toy: Kinetic?* (never, <1/month, 1-2/month, 1-3/week, 4-6/week, everyday). Recoded ≥1/week, % yes	17.1	25.2	14.1	.012
How often – mobile[a]	268	How often do you exergame using your cellphone and/or a mobile app? (ex. ZOMBIES, RUN!, Nike+ Running App, Fit Freeway, Pokémon Go)[a] ((never, <1/month, 1-2/month, 1-3/week, 4-6/week, everyday). Recoded ≥1/week, % yes	34.3	37.7	31.2	.13
Days per week exergaming	62	In the past month, on how many days per week did you exergame using a video game console such as the Nintendo Wii, XBOX 360 Kinect, Sony Play Station Move, Sony Eye Toy: Kinetic? Write 0 if none (open-ended), mean (SD)	0.7 (1.7)	0.9 (2.0)	0.5 (1.5)	.10
Minutes per bout	62	On average how many minutes did you spend each time you did this? Write 0 if none*(open-ended), mean (SD)	44.9 (35.0)	50.2 (39.5)	37.5 (28.6)	.17
Intensity	72	What was your level of effort when you did the activity? (%) • Light • Moderate • Intense	• 63.0 • 35.7 • 1.4	• 70.0 • 27.5 • 2.5	• 56.3 • 43.8 • 0	.26

[a]In NDIT cycle 23 (44% had ever exergamed; n=272) were included in the analysis.

Discussion

This study describes the development and validation of a new scale that measures general motivation and reasons to exergame. RTEX incorporates 4 factors including exergaming for fitness, exergaming for enjoyment, preferring exergaming over other gaming choices, and choosing exergaming over competing interests (eg, sports). A total of 26 items were considered. Four were eliminated (Multimedia Appendix 1) because, according to theory and statistical criteria, they did not contribute to improving the structure of any factor. Although a key reason for conducting EFA is to eliminate items to increase reliability (precision) and readability of a scale, these four items may be appropriate in other populations and should be further investigated. RTEX factors were internally consistent and had adequate test-retest reliability. Because a primary goal of gaming is to provide motivational affordances (ie, how the game environment invites and maintains motivation) [50], identification of motivational attributes is key to designing games and gamified systems that are sustainable [24].

Two of the four factors identified in RTEX demonstrated convergent validity against exergaming frequency and intensity, which are key outcomes in evaluating exergaming as a method to increase PA and reduce sedentary behavior [51]. Specifically, participants who exergamed for fitness or enjoyment reported a higher frequency of exergaming socially. Individuals who scored higher on the fitness factor may exergame purposely to lose or maintain weight or to bulk up, which are extrinsic motivations according to the self-determination theory [52], suggesting that intrinsic rather than extrinsic motivation relates to intentions to engage in more PA [53]. The sustainability of exergaming for fitness reasons should be further investigated in the context of internal and external motivation and the self-determination theory.

Our finding that the enjoyment factor relates positively to frequency exergaming with friends, family and alone aligns with Self-Determination Theory [54]. The items in factor 2 encompass intrinsic reasons to exergame (ie, fun, competence, relatedness, enjoyment, excitement, preferences, autonomy), suggestive that games, gamified systems, and exergaming interventions should be designed to permit experiences that are intrinsically motivating [54]. This aligns with results of a study on Pokémon, in which the authors reported that the social aspect of the game was one of the strongest predictors of sustained gameplay [55]. Since enjoyment is central to increasing and maintaining motivation for PA generally and exergaming specifically, exergame developers will need to incorporate elements to increase enjoyment or that help increase intrinsic motivation among those who exergame primarily for external fitness reasons [52,53]. For example, games that provide external motivation through ongoing feedback on physical form, effort, and progress in the game may need to also include components that increase enjoyment and autonomy (eg, providing more choices within the game, goal setting). Increasing or focusing on intrinsic motivation to encourage sustainable use among those who exergame for fitness may help increase exergaming sustainability [56], and assessing an individual's motivation for exergaming will be key when prescribing exergaming in an intervention or by health practitioners [57].

Preferring exergaming over other gaming options and choosing exergaming over competing interests (eg, sports) were not related to exergaming frequency or intensity. The items in these two factors address elements that inform overall motivations and reasons to choose exergaming over traditional video games or sports, which may not be associated with exergaming behavior, at least as we have measured it. Alternatively, preferences may not translate into exergaming behavior.

Sex differences were apparent in the fitness and gaming preference factors. Specifically, compared to males, females preferred exergames over traditional video games and scored higher on the fitness factor. Consistent with previous work [58-60], females may exergame to incorporate PA into their lives, whereas males enjoy gaming, in general, as a pastime, and play for fun. If replicated, exergaming interventions may need to incorporate different "prescriptions" for males and females.

Our measures of exergaming frequency and intensity, which were modelled after the International Physical Activity Questionnaire [42], have been used in previous studies [58-60], but their test-retest reliability was unknown. In this study, retest reliability was adequate. Given the popularity of exergaming, these items (with the exception exergaming intensity, which requires further work) could be considered for use in observational and interventional studies as well as in surveillance systems.

One limitation of this study is that self-report data are subject to misclassification. In addition, our findings are limited to young adults, although exergaming may benefit all ages. Finally, we did not distinguish between mobile exergaming, which has increased in popularity, and console gaming.

Conclusion

In this study, we introduce the RTEX, which provides a valid and reliable assessment of reasons to exergame and therefore has promise in terms of increasing the evidence that informs sustainable exergaming. Future research should examine the psychometric properties of the RTEX in diverse samples including children and older adults and should measure exergaming behavior objectively using feedback from exergaming consoles or accelerometers. Our data suggest that there are sex differences in RTEX, a tenet that requires further exploration. Finally, whether the RTEX relates to other health outcomes and behaviors should be investigated.

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Conflicts of Interest

This work is part of EO's PhD dissertation.

Multimedia Appendix 1
Items removed from among original RTEX items, based on psychometric analyses.
[DOCX File , 12 KB - games_v8i2e16261_app1.docx]

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Abbreviations

EFA: exploratory factor analysis
ICC: intraclass correlation coefficient
NDIT: nicotine dependence in teens study
PA: physical activity
RTEX: reasons to exergame scale

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Original Paper

Virtual Reality Games and the Role of Body Involvement in Enhancing Positive Emotions and Decreasing Anxiety: Within-Subjects Pilot Study

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Abstract

Background: In the last few years, the introduction of immersive technologies, especially virtual reality, into the gaming market has dramatically altered the traditional concept of video games. Given the unique features of virtual reality in terms of interaction and its ability to completely immerse the individual into the game, this technology should increase the propensity for video games to effectively elicit positive emotions and decrease negative emotions and anxiety in the players. However, to date, few studies have investigated the ability of virtual reality games to induce positive emotions, and the possible effect of this new type of video game in diminishing negative emotions and anxiety has not yet been tested. Furthermore, given the critical role of body movement in individuals' well-being and in emotional responses to video games, it seems critical to investigate how body involvement can be exploited to modulate the psychological benefits of virtual reality games in terms of enhancing players' positive emotions and decreasing negative emotions and anxiety.

Objective: This within-subjects study aimed to explore the ability of commercial virtual reality games to induce positive emotions and diminish negative emotions and state anxiety of the players, investigating the effects of the level of body involvement requested by the game (ie, high vs low).

Methods: A total of 36 young adults played a low body-involvement (ie, *Fruit Ninja VR*) and a high body-involvement (ie, *Audioshield*) video game in virtual reality. The Visual Analogue Scale (VAS) and the State-Trait Anxiety Inventory, Form-Y1 (STAI-Y1) were used to assess positive and negative emotions and state anxiety.

Results: Results of the generalized linear model (GLM) for repeated-measures multivariate analysis of variance (MANOVA) revealed a statistically significant increase in the intensity of happiness (P<.001) and surprise (P=.003) and, in parallel, a significant decrease in fear (P=.01) and sadness (P<.001) reported by the users. Regarding the ability to improve anxiety in the players, the results showed a significant decrease in perceived state anxiety after game play, assessed with both the STAI-Y1 (P=.003) and the VAS-anxiety (P=.002). Finally, the results of the GLM MANOVA showed a greater efficacy of the high body-involvement game (ie, *Audioshield*) compared to the low body-involvement game (ie, *Fruit Ninja VR*), both for eliciting positive emotions (happiness, P<.001; and surprise, P=.01) and in reducing negative emotions (fear, P=.05; and sadness, P=.05) and state anxiety, as measured by the STAI-Y1 (P=.05).

Conclusions: The two main principal findings of this study are as follows: (1) virtual reality video games appear to be effective tools to elicit positive emotions and to decrease negative emotions and state anxiety in individuals and (2) the level of body involvement of the virtual video game has an important effect in determining the ability of the game to improve positive emotions and decrease negative emotions and state anxiety of the players.

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KEYWORDS
virtual reality; virtual reality gaming; video games; emotions; positive emotions; anxiety; state anxiety

Introduction

Background

As stated by Bowman and Tamborini [1], "Video games can't be understood divorced from their role as technology that persistently pushed the limits of communication." While in the 1970s, video games first emerged as simple activities that involved using a keyboard or dial to control tiny black and white objects on the screen, today's computer games are increasingly and dramatically advanced in terms of both graphics and interaction.

One of the most important points in time in the evolution of contemporary gaming is represented by the entry into the mass market of virtual reality video games in the last few years, following the mass diffusion of commercial head-mounted display (HMD) devices, such as Oculus Rift (Facebook Technologies), Vive (HTC Corporation), and PlayStation VR (Sony Interactive Entertainment) [2]. The popularity of virtual reality video games is continuously growing among users: in 2019, Oculus Quest, the first stand-alone headset (ie, it does not require any external device to work) sold out across multiple stores a week after launching [3]; as well, for the first time, the number of connected virtual reality users on the online gaming platform Steam had surpassed 1 million, as determined by data captured over the course of a month [4].

Compared to more traditional (ie, desktop display device) video games, virtual reality games have profoundly different characteristics [2,5,6]. In particular, one of the main relevant differences is the level of immersion, defined as a "quantifiable description of a technology, which includes the extent to which the computer displays are extensive, surrounding, inclusive, vivid and matching" [7]. Technologies can immerse their users in a virtual environment to different degrees, from a simple nonimmersive presentation on a computer screen (ie, desktop displays) to immersive systems, such as HMDs like Oculus Rift (Facebook Technologies) or Vive (HTC Corporation) [2]. The sense of immersion into mediated computerized environments, in general, and computer games, in particular, has previously been explained through spatial presence and flow [8,9]. Even if these concepts share conceptual similarities, such as immersive components and intense feelings, they refer to different theoretical constructs [8]. In particular, while presence relates to a sense of spatial immersion in a mediated environment [10], flow is generally defined as the optimal experience when nothing else matters [11,12]. With respect to computer games, flow has been defined as the sensation of influencing the activity in the virtual world (ie, *gaming in action*) [13], and it is recognized as a central element of exciting gaming experiences [14,15].

Interestingly, scientific studies have recently started to recognize the potential positive impact of virtual reality video games on people's health (eg, [16,17]) and cognitive abilities (eg, [18,19]). For example, a previous study [18] has reported the efficacy of a virtual reality exercise-based dance game, *DANCE*, that was created ad hoc by researchers for the training of executive functions in older people. In addition, another recent study [19] showed the feasibility of using a commercial virtual reality game to assess executive functions and cognitive abilities, as measured by a traditional neuropsychological test, the Trial Making Test (TMT) [20]. The results showed that user performance in the dance game *Audioshield* (Dylan Fitterer) predicted the TMT scores (ie, time to complete TMT-A and TMT-B) [19].

Not only are virtual reality video games potentially useful tools for the assessment and training of cognitive abilities, recent studies have also reported that they can be effective tools for people's emotional well-being. In fact, previous studies have suggested that virtual reality video games induce more emotion than do games with less-immersive technologies, such as those on a desktop display device (eg, [2,6,21-23]). With few exceptions [24,25], a higher intensity of emotional response has been observed in virtual reality games compared to desktop games, at both a psychological and a physiological level [2,6,21-23]. For example, players reported a more intense emotional experience while playing the first-person shooter (FPS) game *Half-Life 2* (Valve Corporation) in an immersive modality through an HMD compared to playing the same game on a monitor [22].

However, less is known about the ability of a virtual reality game to elicit positive emotions and decrease negative emotions and anxiety in the players, because specific studies on that subject have not yet been conducted.

Virtual Reality Video Games, Positive Emotions, and Relaxation

One of the most commonly reported motives for playing modern video games is the pleasure offered by digital games: people look for and are more willing to buy games that elicit positive emotions [26-28]. Positive emotions are considered to form the basis for the growing and flourishing self [29] and are especially important in increasing the level of subjective well-being [29-31]. As stated by broaden-and-build theory [32-34], "...certain discrete positive emotions—including joy, interest, contentment, pride, and love—although phenomenologically distinct, all share the ability to broaden people's momentary thought-action repertoires and build their enduring personal resources, ranging from physical and intellectual resources to social and psychological resources" [34].

Several studies have shown that computer games played on desktop display devices can generate positive emotions, such as joy or happiness (eg, [35-37]). For example, in a study investigating event-specific emotional responses while playing *Super Monkey Ball 2* (SEGA)—a platform game (ie, a subgenre of an action game) where the player controls a character who has to jump and climb between suspended platforms while avoiding obstacles—players who experienced not only positive events (eg, acquiring in-game goods) but also some negative events (eg, falling over the edge of the game board) were reported to elicit positively valenced arousal [26]. In another study, predominantly positive emotions were reported while playing the action game *Counter-Strike* (Valve Corporation), as assessed by an electroencephalogram (EEG) alpha index; in addition, subjective ratings of emotional responses indicated happiness, both during and after the game [37]. Furthermore, dopamine, a neurotransmitter linked to sensations of pleasure and reward, has been detected using positron emission tomography (PET) during video game playing [38]. In addition, regular players have advocated video game play as a means of relaxation [39-41], and the search for distraction and escapism is among the most often reported motives for playing video games [42-44].

Different types of desktop video games have been reported to be effective in decreasing anxiety in individuals, inducing a state of relaxation (eg, [45-49]) and positive emotions [50]. For example, video games characterized by low cognitive load and generally short time demands, such as *Tetris* (Nintendo) or *Angry Birds* (Rovio Entertainment Corporation), have proven to be able to diminish state anxiety [51,52] as well stress in players [41], even more effectively than traditional techniques, such as medical treatment [51,52] or guided meditation [53,54].

Interestingly, some recent studies have reported a greater increase in positive emotions after playing a virtual reality game compared to a game on a desktop display [2,23,55]. For instance, players showed a higher level of happiness and surprise, as assessed by self-report questionnaires, after playing an FPS game (ie, *Smash Hit* [Mediocre AB]) in virtual reality versus after playing the same game on a desktop display [2]. In addition, while the perceived feeling of happiness increased after playing the bestselling survival horror game *Resident Evil: BioHazard* (Capcom) in virtual reality, the opposite result was obtained after desktop gameplay, specifically, a decrease in the sense of happiness in comparison to the baseline [55].

Thanks to virtual reality's unique features of immersion and body involvement [56,57], virtual reality games seem to be appealing new tools to elicit positive emotions and to decrease anxiety in individuals. However, until now, no study has been conducted specifically to test the ability of this new type of interactive video game to enhance positive emotions and to decrease negative emotions and anxiety in individuals.

Body Involvement and Psychological Benefits of Video Games

In addition to differences in terms of immersion, what strongly distinguishes virtual reality video games from traditional ones is that in virtual reality, the movement of the player's body itself becomes the main interface for interacting with the virtual world [2,58,59]. In a virtual reality video game, in fact, the player can interact with virtual content not only through a joypad or a keyboard but also by using head rotation, eye movements, or specially designed controllers that respond to the position and movements of the player in a defined space [2]. Depending on the specific video game and virtual reality system adopted, the player's level of body involvement can vary significantly. For example, in *Smash Hit VR* (Mediocre AB), which is compatible with the HMD Gear VR (Samsung), it is possible to interact in the game using only head movements. In contrast, in other titles, such as *Beat Saber* (Beat Games) or *Superhot VR* (SUPERHOT Team), the movement of the whole body is required to play the game.

Studies from various disciplines have investigated the relationship between body movement and well-being, showing that body movement affects emotional processes, with an almost immediate antianxiety and antidepressive effect [60-64] and with long-term positive outcomes on physical health [65-68].

Interestingly, previous studies have reported that an increased involvement of the body while playing video games on desktop displays leads to more intense emotional and affective responses by the player [69,70]. Furthermore, recent preliminary studies have reported that exergames—ones that are considered a combination of video gaming and physical exercise requiring physical effort from the player in order to play the game [71-73]—are able to elicit positive emotions among older adults [71], inducing higher positive emotions than traditional exercise [74], and are able to reduce state anxiety in a nonclinical sample of healthy women [75].

These considerations about the critical role of body movement in individuals' well-being and in emotional responses to video games make it critical to understand how body involvement can be exploited to modulate the psychological benefits of virtual reality games in terms of enhancing players' positive emotions and decreasing their negative emotions and anxiety.

Study Objectives

Within the context described above, this within-subjects study aimed to explore the ability of commercial virtual reality games to induce positive emotions and diminish state anxiety of the players, investigating the effects of the level of body involvement requested by the game (ie, high vs low).

The main hypotheses of this study were as follows:

1. Hypothesis 1: Video games played in virtual reality will increase self-reported positive emotions (ie, joy and happiness) and will reduce negative emotions (ie, fear and sadness) and perceived state anxiety.
2. Hypothesis 2: A game with high body involvement (ie, *Audioshield* [Dylan Fitterer]) will elicit stronger positive emotions and a more intense decrease in negative emotions and state anxiety compared to a game with low body involvement (ie, *Fruit Ninja VR* [Halfbrick Studios]).

Methods

Participants

The execution of the experiment occurred between July and October 2018. No credits or economic rewards were provided during the research. Participants were recruited from among the students and personnel of the University of Milano-Bicocca and other universities in Milan, Italy, via flyers distributed to campuses and word of mouth. In order to be included in the study, individuals had to meet the following criteria: (1) be aged between 18 and 35 years, (2) have no significant visual impairment (ie, all with normal or corrected-to-normal visual acuity), and (3) have no previous experience with the video games selected for the study (ie, *Audioshield* or *Fruit Ninja*

VR). With regard to the size of the sample, a power sample analysis was conducted with a level of statistical significance equal to 5%, power set at 80%, and a medium-sized effect (ie, 0.50) expected at the upper bound [76]. An effect size equal to 0.50 corresponded to a 66% probability that persons from a given condition would experience a higher effect than persons from the other condition, if both were chosen at random. In addition, the effect size value of 0.50 was in line with other similar studies in the field of virtual reality in relation to emotional domains that highlighted a magnitude of effect size that can be considered medium to large. As a result, the suggested sample size for this kind of analysis and research design was set to 34. Before participating, all participants were provided with written information about the study and were required to give written informed consent in order to be included. The study received ethical approval from the Ethical Committee of the University of Milano-Bicocca. The research was conducted in accordance with the American Psychological Association's 2010 ethical principles and code of conduct. A total of 39 individuals were assessed for eligibility to participate in the study: 3 were excluded (8%) due to not meeting inclusion criteria and no subjects declined to participate. The final sample included 36 participants: 13 females (36%) and 23 males (64%); mean age of 25.6 years (SD 4.18); and mean length of education of 15.9 years (SD 3.1).

Psychometric Assessment

At the beginning of the experimental session, a self-report questionnaire was given to participants that included the following items:

1. Demographics: participants were asked to indicate their gender (female or male), their age, and their years of education.
2. Gaming habits and previous virtual reality experience: individuals were asked to report on their gaming habits (ie, mean hours spent gaming per week) and to assess their previous experience with virtual reality systems on a 7-point Likert scale ranging from 1 (not at all) to 7 (very much).

In addition, to assess the self-reported indexes concerning positive and negative emotions as well as state anxiety, the following questionnaires were used:

1. Visual Analogue Scale (VAS) [77]: this scale consists of a horizontal line, 10 cm in length, anchored by word descriptors at each end. Participants marked the point on the line—from 0 to 100—that they felt visually represented their perception of their current level of happiness (VAS-HP), surprise (VAS-SP), fear (VAS-FE), sadness (VAS-SD), and anxiety (VAS-A). A large number of studies have confirmed the reliability and validity of VAS measurements (eg, [78-81]).
2. State-Trait Anxiety Inventory, Form-Y1 (STAI-Y1) [82-84]: individuals were asked to specify to what extent, on a 4-point Likert scale ranging from 1 (not at all) to 4 (very much), they perceived at that moment each of the 20 indicated feelings. The STAI-Y1 scale has high internal consistency, with a Cronbach α coefficient ranging from .86 to .95 [83,85,86]; this is considered a reliable measure to capture rapid state-dependent variations in anxiety [85,86].

Video Games

The video games tested in the study were as follows:

1. *Audioshield* (Dylan Fitterer): this is a virtual reality exergame launched in April 2016 for Vive (HTC Corporation). This title is a dance game in which orbs come flying toward the player, who needs to follow the beat of the music to successfully hit them. The player uses Vive's handheld motion-sensing controls to operate two shields, blue and red: red balls must be deflected with the red shield controlled by the right hand, while blue balls must be deflected with the left hand; purple orbs require a combination of both arms. During the game, the color and the direction of the orbs that the player has to hit changes continuously; for example, the blue balls can come from the right, or red from the left, and require the user to respond correctly very quickly.
2. *Fruit Ninja VR* (Halfbrick Studios): this game represents the 2016 virtual reality version of the bestselling video game *Fruit Ninja* (Halfbrick Studios), a 2010 game for mobile devices where players were required to hit fruit by dragging their finger on the screen. In *Fruit Ninja VR*—a game compatible with Vive (HTC Corporation), Oculus Rift (Facebook Technologies), and PlayStation VR (Sony Interactive Entertainment)—the players used the handheld motion-sensing controls as swords to slice fruits, sitting or standing, and simulating slashes as if they were performing them in real life. The goal was the same as in the mobile version: cut the fruit, do not let it fall, and avoid the bombs in order to collect as many points as possible and climb the rankings.

These video games were selected since, despite the common aim of both games to hit objects that appear in front of the player, they differ profoundly in terms of the body movement required by the game. In particular, while *Audioshield* requires the player to move the whole body in the game space (eg, lateral movements to avoid obstacles and arm movements to hit the balls), in *Fruit Ninja VR* the interaction takes place only through the movements of the superior limbs. In this title, in fact, the position of the feet and superior limbs are fixed at a certain point in space, indicated graphically within the game.

Regarding the hardware, both video games were played on the same virtual reality setting, which included the following units (see Multimedia Appendix 1):

1. Vive system (HTC Corporation): a consumer-grade virtual reality system designed for use in video games. This system consists of an HMD, two controllers, and two infrared laser-emitter units. The headset offers a nominal field of view of about 110 degrees (approximately 90 per eye) through two 1080×1200-pixel displays that are updated at 90 Hz. Games played with the Vive system allow physical movement within a play area that is limited to 4×4 meters.
2. A portable computer: MSI (Micro-Star International) GT73VR, Intel Core i7 processor, GeForce GTX 1070 8GB,

17.3-inch full HD (high-definition) 1920×1080-pixel display.

Experimental Design

A within-subjects design was used to compare the emotional response, in terms of self-reported positive and negative emotions, and the perceived sense of anxiety among participants in the two experimental conditions. Specifically, the study compared the following:

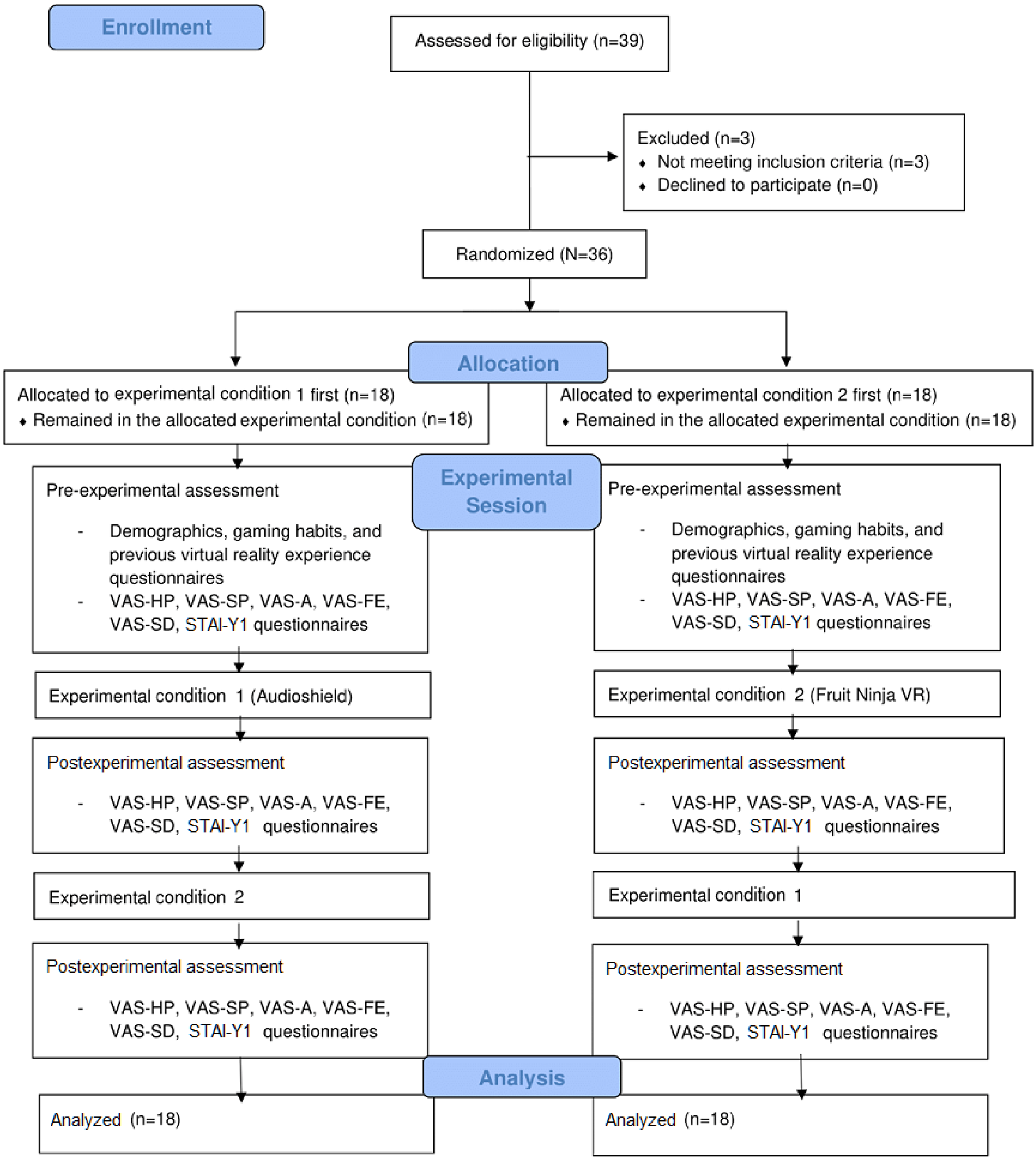
1. High body-involvement condition (*Audioshield*): after a brief explanation of the video game by the experimenter, the participants were asked to play for about 5 minutes—2 minutes of practice using the song Engage (difficulty: normal; shield: gladiator; environment: horizon), followed by 3 minutes of play to complete the song I Drop Gems (difficulty: normal; shield: gladiator; environment: horizon).
2. Low body-involvement condition (*Fruit Ninja VR*): the participants were asked to play for about 5 minutes—2 minutes of practice using the Zen mode of the video game; individuals were then asked to play twice in the classic mode, where they had to cut as much fruit as possible and prevent it from falling to the ground and losing a life: players spent a mean of 78 seconds (SD 18) for each play.

Procedure

After individuals gave written informed consent to participate, they completed the self-report questionnaire assessing demographics, gaming habits, and virtual reality knowledge, as well as the VAS-HP, VAS-SP, VAS-FE, VAS-SD, VAS-A, and STAI-Y1. Once this phase was completed, the Vive system was connected to the PC through a 5-meter cable with an HDMI (high-definition multimedia interface) connection and a USB 2.0 connection, and the system was connected to a power source. Participants were asked to wear the HMD and were given the Vive system controllers.

The audio level was set to 45 for all participants. Subjectively, tracking appeared stable when using this configuration, and the video game was playable with no visible tracker artifacts. All measurements were taken in an 8×5-meter room with a 3.2-meter-high ceiling lighted by fluorescent lighting with no reflective surfaces and no exposure to natural light. In the center of this room, a 4×4-meter grid (ie, the play area) was drawn on the floor using string and chalk, with grid lines drawn 1 meter apart. Participants were randomly assigned to start with either the high (n=18) or the low (n=18) body-involvement condition; the conditions were counterbalanced for the total individuals through an established randomization scheme obtained from the Research Randomizer website [87] run by one of the researchers involved in the study before the start of the experiments. After completing each gameplay mode, participants again answered the following self-reported questionnaires: the VAS-HP, VAS-SP, VAS-FE, VAS-SD, VAS-A, and STAI-Y1. The complete experience lasted about 40 minutes long (see Figure 1).

Figure 1. Flowchart of the study procedure. STAI-Y1: State-Trait Anxiety Inventory, Form-Y1; VAS-A: Visual Analogue Scale-anxiety; VAS-FE: Visual Analogue Scale-fear; VAS-HP: Visual Analogue Scale-happiness; VAS-SD: Visual Analogue Scale-sadness; and VAS-SP: Visual Analogue Scale-surprise.



Strategy of Data Analysis

Data were analyzed by means of a set of multivariate statistical tests. First, common assumptions (ie, normality, homogeneity of variance, and homoscedasticity) for multivariate analysis were assessed and procedures of data cleaning (ie, missing-values analysis and detection of uni- and multivariate outliers) were conducted. In general, no major violations to assumptions were found and a multivariate outlier was skipped. Multivariate outliers were identified by computing Mahalanobis distances, and the *P* value was set to be equal to .001.

In order to explore our research hypotheses, different series of generalized linear models (GLMs) were performed. For hypothesis 1, a GLM model for repeated-measures multivariate analysis of variance (MANOVA) was tested by including the four VAS measures related to positive (eg, happiness and surprise) and negative (eg, fear and sadness) emotions. Then, a second model was tested by including the two measures (eg, VAS-A and STAI-Y1 scores) of state anxiety. Such analysis is useful in measuring the effect of a *treatment* at different time points and in different groups. Furthermore, the GLM enabled evaluation of the main effect within and between the subjects as well as interaction effects between factors. Finally, the GLM estimated the magnitude of effect sizes for all variables. In this study, the GLMs were conducted in such a way that pre- and postexperiment measures were the within-subjects factors (ie, three levels), whereas the condition (ie, high vs low body-involvement video game) was the between-subjects factor. The interactive effect *within* × *between* was included in the model. For testing hypothesis 2, two GLMs were conducted in order to compare whether pre- and postexperiment differences in target variables (ie, positive emotion as well as negative emotion and anxiety) were statistically significant when low body-involvement and high body-involvement games were compared, once controlled for the order of presentation. For all tested models, effect size was reported (η^2). According to Cohen [88], effect size should be considered small for values 0.20 and lower, medium for values between 0.21 and 0.50, and large for values of 0.51 and higher.

Results

Descriptive Characteristics of Participants

Gaming habits and the previous virtual reality experience of the sample are summarized in Table 1. Zero-order correlations between positive emotions, negative emotions, and anxiety scores are presented in Multimedia Appendix 2.

Table 1. Descriptive characteristics of the sample's gaming habits and previous experience with virtual reality.

Characteristic	Mean (SD)
Hours spent gaming per week	9.5 (10.9)
Previous experience with virtual reality[a]	5.1 (2.8)

[a]Rated on a 7-point Likert scale ranging from 1 (not at all) to 7 (very much).

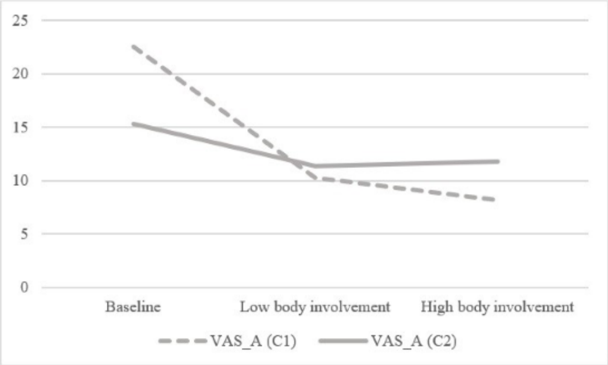
Psychological Assessment

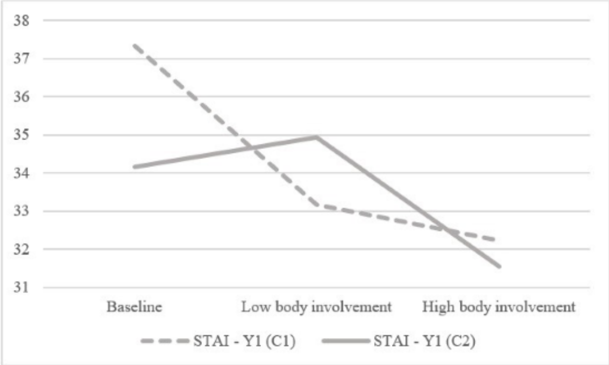
Starting from hypothesis 1 of this study, the GLM for the repeated-measures MANOVA was used to test whether video games played in virtual reality increased self-reported positive emotions (ie, VAS-SP and VAS-HP) and reduced negative emotions (ie, VAS-FE and VAS-SD) and perceived state anxiety (ie, VAS-A and STAI-Y1).

Generally speaking, the GLM testing differences among emotional scores (ie, VAS-SP, VAS-HP, VAS-FE, and VAS-SD) revealed a within-subjects statistically significant effect ($F_{8,27}$=9.64, P<.001, η^2=.741). On the contrary, the effect of the between-subjects condition (ie, low vs high body-involvement game as first stimulus) reported a nonstatistically significant effect ($F_{8,27}$=0.56, P=.80, η^2=.143), meaning that regardless of the order of presentation, there were differences in emotional levels between the baseline values and the scores obtained after a playing session. In particular, the domain of positive emotions reported statistically significant effects for both the VAS-SP ($F_{8,27}$=7.93, P=.003, η^2=.189) and the VAS-HP ($F_{8,27}$=11.62, P<.001, η^2=.255). In both cases, the scores on the high body-involvement game were higher if compared to both baseline and the low body-involvement game. Univariate tests in relation to negative emotions reported a statistically significant effect for both the VAS-FE ($F_{8,27}$=5.13, P=.01, η^2=.131) and the VAS-SD ($F_{8,27}$=10.06, P<.001, η^2=.228), meaning that negative-emotion levels were lower in high body-involvement games than what was reported at baseline and in low body-involvement games (see Multimedia Appendix 3).

Regarding self-reported state anxiety (ie, STAI-Y1 and VAS-A), the results of the GLM revealed a within-subjects statistically significant effect ($F_{4,31}$=4.58, P=.005, η^2=.372). A nonstatistically significant effect was found in terms of presentation order between the different games ($F_{2,33}$=0.01, P=.99, η^2=.001). Univariate tests revealed that both the VAS-A ($F_{4,31}$=8.01, P=.002, η^2=.191) and the STAI-Y1 ($F_{4,31}$=6.45, P=.003, η^2=.160) reported statistically significant effects, meaning that the two measures of state anxiety converged in cross-validating the idea of a reduction of anxiety levels in players during virtual reality gaming sessions (see Figure 2). As a result, the findings supported the acceptance of hypothesis 1.

Figure 2. Mean scores of the Visual Analogue Scale-anxiety (VAS-A) and the State-Trait Anxiety Inventory, Form-Y1 (STAI-Y1). The VAS-A is measured on a scale consisting of a horizontal line, 10 cm in length, with scores ranging from 0 to 100. The STAI-Y1 is measured on a 4-point Likert scale ranging from 1 (not at all) to 4 (very much). C1: Condition 1, *Fruit Ninja VR* first; and C2: Condition 2, *Audioshield* first.





With regard to hypothesis 2, the GLM MANOVA was used to test whether, and to what extent, the psychometric scores of self-reported positive and negative emotions (ie, VAS-SP, VAS-HP, VAS-FE, and VAS-SD) and state anxiety (ie, VAS-A and STAI-Y1) were related to playing low body-involvement or high body-involvement games (see Table 2).

Table 2. Self-reported emotions and anxiety scores among subjects in the experimental conditions.

Questionnaire and conditions	Mean (SD)
Visual Analogue Scale-happiness	
Baseline	62.3 (20.1)
High body involvement	77.6 (20.4)
Low body involvement	68.2 (24.2)
Visual Analogue Scale-surprise	
Baseline	50.0 (31.6)
High body involvement	66.9 (29.2)
Low body involvement	57.8 (30.8)
Visual Analogue Scale-fear	
Baseline	8.05 (11.7)
High body involvement	1.72 (4.29)
Low body involvement	2.69 (6.11)
Visual Analogue Scale-sadness	
Baseline	10.1 (15.2)
High body involvement	2.36 (5.91)
Low body involvement	5.27 (10.6)
Visual Analogue Scale-anxiety	
Baseline	18.8 (16.8)
High body involvement	10.4 (13.6)
Low body involvement	10.8 (12.6)
State-Trait Anxiety Inventory, Form-Y1	
Baseline	35.7 (8.00)
High body involvement	31.8 (7.44)
Low body involvement	34.1 (7.91)

The GLM testing between-game differences in emotional scores revealed a within-subjects statistically significant effect ($F_{4,31}$=3.86, P=.01, η^2=.333). On the contrary, the effect of the between-subjects condition (eg, low body-involvement vs high body-involvement game as first stimulus) reported a nonstatistically significant effect ($F_{4,31}$=0.41, P=.72, η^2=.050), meaning that regardless of the order of presentation, there were differences in emotional levels between the two games.

Univariate tests regarding positive emotions reported statistically significant effects for both the VAS-HP ($F_{4,31}$=12.43, P<.001, η^2=.268) and the VAS-SP ($F_{4,31}$=6.83, P=.01, η^2=.167). In both cases, the differential scores on the high body-involvement game were higher if compared to scores obtained in the low body-involvement game. Univariate tests in relation to negative emotions reported a statistically significant effect for both the VAS-FE ($F_{4,31}$=3.47, P=.05, η^2=.099) and the VAS-SD ($F_{4,31}$=5.91 P=.05, η^2=.148), meaning that decrements in negative-emotion levels were more relevant in the high body-involvement game than what was reported after the low body-involvement game.

Regarding state anxiety scores, the result of the GLM revealed a within-subjects, statistically significant effect ($F_{2,33}$=48.25, P=.01, η^2=.334). A nonstatistically significant effect was found in terms of presentation order between different games ($F_{2,33}$=2.62, P=.09, η^2=.132). Univariate tests revealed that especially for STAI-Y1 scores ($F_{2,33}$=5.41, P=.05, η^2=.137), playing in high body-involvement games lead to a greater reduction of anxiety levels. On the contrary, the VAS-A ($F_{2,33}$=0.055, P=.82, η^2=.002) did not report statistically significant effects. The results supported the acceptance of hypothesis 2, meaning that a greater increase in positive emotions, as well as a reduction of negative emotions and anxiety levels, were found in players after a high body-involvement virtual reality game session.

Discussion

Principal Findings

To summarize, the two main principal findings of this study are as follows:

1. Virtual reality video games appear to be effective tools to elicit positive emotions and to decrease negative emotions and state anxiety in individuals.
2. The level of body involvement of the virtual video game has an important effect in determining the ability of a game to improve positive emotions and decrease negative emotions and state anxiety of the players.

The results that emerged from this study appear to support the first main hypothesis (ie, the video games played in virtual reality will increase self-reported positive emotions and will be able to reduce negative emotions and perceived state anxiety). In particular, results of the GLM repeated-measures MANOVA revealed a statistically significant increase in the intensity of happiness and surprise and, in parallel, a significant decrease of fear and sadness reported by the users. Regarding the ability to improve anxiety levels in the players, the results showed a significant decrease in perceived state anxiety after game play, assessed with both the STAI-Y1 and the VAS-A.

Regarding the second main hypothesis (ie, the higher the body movement, the more the game will elicit stronger positive emotions and a more intense decrease in negative emotions and state anxiety), the results of the GLM MANOVA showed a greater efficacy by the high body-involvement game (ie, *Audioshield*) versus the low body-involvement game (ie, *Fruit Ninja VR*) to both elicit positive emotions and reduce negative emotions and state anxiety, as measured by the STAI-Y1.

Potential for Virtual Reality Gaming to Elicit Positive Emotions and Decrease Anxiety

The ability of virtual reality content to elicit positive emotions and a state of relaxation has been widely demonstrated in relation to virtual environments designed ad hoc by researchers for emotional induction, both in healthy individuals (eg, [89-91]) and in patients suffering from different mental conditions, including anxiety disorders (eg, [92, 93]). This feature has been adopted extensively to improve individuals' well-being, since, as stated by the broaden-and-build model [34], positive emotions provide the organism with nonspecific action tendencies that can lead to adaptive behavior, such as being more likely to interact with others or engage in creative challenges [94,95]. Therefore, as underlined by the positive technology approach [96], technology, including virtual reality, can be an effective tool to improve the quality of people's personal experiences [97].

Interestingly, what emerges from this study shows that not only virtual content specifically created for emotional induction but also commercial content such as virtual reality video games can be effective in inducing positive emotions and decreasing negative emotions and anxiety in individuals. Such a result appears in line with what has been reported recently, with a few exceptions [24], about the ability of virtual reality video games to elicit positive emotions such as joy in the players and to do so with a more intense effect than that of desktop video games [2,6,21]. Besides, according to the results of this study, virtual reality video games are able to not only elicit positive emotions but also decrease negative emotions (ie, sadness and fear) and state anxiety in the players.

If the results of this study are confirmed by future research, they might represent positive evidence for the adoption of virtual reality games, not just for entertainment purposes but also in the mental health panorama. Given that positive emotions are linked strongly to the use of technological products and the user's overall level of satisfaction with them—as underlined by *emotional design* [98,99], a conceptual framework that is largely adopted in the context of developing interactive technologies [100, 101]—virtual reality video games could be particularly appealing to users. Thanks to their being cost-effective, noninvasive, and nonassociated with stigma or with known side effects, virtual reality video games could offer many advantages compared to classic interventions for improving psychological well-being and decreasing anxiety, such as medication treatment, guided meditation, or cognitive behavioral therapy. In addition, virtual reality games also have several advantages compared to video games played on desktop displays, including the characteristic of requiring higher involvement both at the motor and cognitive levels and a greater engagement compared to nonimmersive games [17,55]. They also offer the possibility of collecting a wide variety of data, such as those about the player's movement within the virtual environment.

Furthermore, the fact that, in this study, these results were observed after a short period of play (ie, about 5 minutes for each video game) could suggest that even very brief interventions with games in virtual reality can be effective ways to increase players' positive emotions and decrease negative emotions and state anxiety. Since the length of the interventions with video games to enhance positive emotions and relaxation vary in the literature [56], with an average of 20-25 minutes of total gameplay (eg, [46,47]), the results obtained by this study could represent an element to broaden the reflection on this important topic, and further research is needed.

Significance of the Body's Involvement on Players' Psychological Benefits

Differences were observed in this study regarding the ability to elicit positive emotions and decrease negative emotions and state anxiety, as measured by the STAI-Y1, depending on the level of body movement requested by the game; this offers interesting insights on the role of body involvement in determining the psychological benefits of video games.

In particular, we observed a greater efficacy of the game that required high body involvement (ie, *Audioshield*) compared to the game with low body involvement (ie, *Fruit Ninja VR*). Such results appear to be consistent with previous literature reporting that an increased involvement of the body can afford the player not only a greater level of enjoyment but also a stronger emotional experience [69,70]. In the specific case of virtual reality video games, it could be hypothesized that this effect is related to the ability of body movements to enhance sense of presence [102]. However, other studies have not reported a direct effect of body involvement on sense of presence during virtual reality content [103]. Therefore, future studies should investigate this topic further.

If the results observed in this study are confirmed by future studies, it could represent valid evidence that virtual reality video games, especially those that require a high level of involvement of the player's body, promote emotional well-being in individuals. For example, it would be interesting to test the effects of a virtual reality-based exergame, a type of video game that has proven to be effective for emotional relief and for its antidepressant effect when played on desktop displays [65-67,104, 105].

Limitations

Although the results of this study could be interesting for their possible applications, this research has some important limitations that prevent a robust generalization of the findings. First, the design of the study did not include a control group (ie, a no-video-game condition). Second, in this study no physiological measure related to emotional responses (eg, heart rate variability and skin conductance responses) and/or state anxiety (eg, parasympathetic activity and cortisol level) were examined. Third, the video games were played for short time periods (ie, about 5 minutes each), and only short-term changes were considered. Finally, it is important to underline the small sample size and the specificity of the included sample (ie, young adults who played several hour per week and had medium-level knowledge of virtual reality systems). All in all, even if the results of this research can be considered promising, due to major limitations, including the probability of being underpowered, robust conclusions were still hard to achieve. In future research, it would be interesting, for example, to widen the sample in order to balance participants on the basis of their level of experience with video games and to collect baseline measures on whether they enjoy exercise in general.

Conclusions

On the basis of what emerged in this study, and as underlined in previous research (eg, [56,106]), the research question no longer seems to need to ask whether video games are good or bad for the mental health of the individual, but rather seeks to investigate how their specific characteristics (eg, genre, display device, and duration and frequency of playing) may have an impact on the efficacy of the game to improve players' well-being. In the future, it would be rather interesting to deeply investigate this topic; it would also be interesting to consider the specific characteristics of the players (eg, gender and gaming habits). In addition, future research should investigate the adoption of other commercial virtual reality systems with different characteristics in terms of immersion and interactions with the game, including other off-the-shelf virtual reality systems, such as Oculus Go (Facebook Technologies) or PlayStation VR (Sony Interactive Entertainment). These products are very appealing since, unlike the system tested in this study, they could be used easily even by nonexpert operators and are more budget friendly.

Acknowledgments

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Conflicts of Interest

None declared.

Multimedia Appendix 1
Experimental setting of the study.
[PNG File , 31 KB - games_v8i2e15635_app1.png]

Multimedia Appendix 2
Zero-order correlations between positive emotions, negative emotions, and anxiety scores (N=36).
[PNG File , 166 KB - games_v8i2e15635_app2.png]

Multimedia Appendix 3
Mean scores of the positive and negative emotional states. Positive emotions are reported in the left-hand column and negative emotions are reported in the right-hand column. C1: Condition 1, Fruit Ninja VR first; and C2: Condition 2, Audioshield first.
[PNG File , 129 KB - games_v8i2e15635_app3.png]

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Abbreviations

EEG: electroencephalogram
FPS: first-person shooter
GLM: generalized linear model
HD: high definition
HDMI: high-definition multimedia interface
HMD: head-mounted display
MANOVA: multivariate analysis of variance
MSI: Micro-Star International
PET: positron emission tomography
STAI-Y1: State-Trait Anxiety Inventory, Form Y1

TMT: Trial Making Test
VAS: Visual Analogue Scale
VAS-A: Visual Analogue Scale-anxiety
VAS-FE: Visual Analogue Scale-fear
VAS-HP: Visual Analogue Scale-happiness
VAS-SD: Visual Analogue Scale-sadness
VAS-SP: Visual Analogue Scale-surprise

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Review

Effectiveness of Exergaming in Improving Cognitive and Physical Function in People With Mild Cognitive Impairment or Dementia: Systematic Review

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Abstract

Background: Individuals with mild cognitive impairment and dementia have impaired physical and cognitive functions, leading to a reduced quality of life compared with those without such impairment. Exergaming, which is defined as a combination of exercise and gaming, is an innovative, fun, and relatively safe way to exercise in a virtual reality or gaming environment. Therefore, exergaming may help people living with mild cognitive impairment or dementia to overcome obstacles that they may experience regarding regular exercise and activities.

Objective: The aim of this systematic review was to review studies on exergaming interventions administered to elderly individuals with mild cognitive impairment and dementia, and to summarize the results related to physical and cognitive functions such as balance, gait, executive function, and episodic memory.

Methods: We searched Cochrane Central Register of Controlled Trials (CENTRAL), Medline, Embase, PsycINFO, Amed, and Nursing Database for articles published from the inception of the respective databases to January 2019. We included all clinical trials of exergaming interventions in individuals with mild cognitive impairment and dementia for review. The risk of bias was independently evaluated by two reviewers using the Cochrane Collaboration and Risk of Bias in Non-randomized Studies of Interventions tools.

Results: Ten studies involving 702 participants were included for review. There was consistent evidence from 7 studies with a low risk of bias showing statistically significant effects of exergaming on cognitive functioning in people with mild cognitive impairment and dementia. With respect to physical function, 3 of 5 full-scale studies found positive results, and the intensity of most games was classified as moderate.

Conclusions: Overall, exergaming is an innovative tool for improving physical and cognitive function in people with mild cognitive impairment or dementia, although there is high heterogeneity among studies in terms of the duration, frequency, and gaming platform used. The quality of the included articles was moderate to high. More high-quality studies with more accurate outcome indicators are needed for further exploration and validation of the benefits of exergaming for this population.

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KEYWORDS

mild cognitive impairment; dementia; exergaming; physical; cognitive

Introduction

Mild cognitive impairment is a term used to identify people who are at risk of developing dementia, but the cognitive impairment is so mild that it does not affect daily activities. Symptoms of mild cognitive impairment include memory impairment, language difficulties, attention deficits, disorientation, and altered visuospatial skills [1]. The prevalence of mild cognitive impairment in individuals older than 65 years is approximately 3% to 22% [2-4]. In addition, 5% to 15% of these cases progress to dementia annually, whereas the incidence of mild cognitive impairment in the general population is 1% to 2% per year [5-7].

Dementia is characterized by a group of chronic and progressive symptoms caused by various brain illnesses that affect memory, thinking, behavior, and ability to perform daily activities [8]. Dementia currently affects approximately 50 million people worldwide and is expected to affect 82 million people by 2030 and 152 million by 2050 [9,10]. Dementia is the second leading cause of disability in individuals aged 70 years or older and the seventh leading cause of death worldwide [10,11]. In 2015, the cost of dementia care was estimated at US $818 billion, equivalent to 1.1% of the global gross domestic product, which ranges from 0.2% for low- and middle-income countries to 1.4% for high-income countries. It is estimated that the cost of caring for people with dementia worldwide will increase to US $2 trillion by 2030, which could undermine social and economic development globally and overwhelm health and social services, especially long-term care systems [12].

Owing to the high medical and social burden of mild cognitive impairment and dementia, scientists in various fields have been searching for effective strategies to prevent or delay disease development. In view of the fact that current pharmacological treatments are not only expensive but are also accompanied by significant adverse effects [13], the Food and Drug Administration and experts in leading geriatric organizations recommended that nonpharmacologic approaches be used as the first-line treatment of cognitive impairment [14]. Nonpharmacologic approaches include, but are not limited to, reminiscence therapy [15], reality orientation [16], validation therapy [17], music therapy [18], doll therapy [19], pet therapy [20], and cognitive and physical exercise training [21]. These nonpharmacologic approaches are becoming increasingly preferred by the geriatric population because they have been shown to yield positive results, are easy to use in clinical or home settings, and are inexpensive.

In recent decades, an increasing number of studies have used games for cognitive training in people with mild cognitive impairment or dementia [22-27]. The aim of cognitive training is to maintain or improve specific cognitive functions such as attention, episodic memory, and problem-solving skills using guided training and repetitions of standardized tasks [28]. Game-based interventions are nonpharmacological readily accepted forms for training, and playing games could be an efficient mode to practice mental concentration and memory, making them appropriate for people with cognitive impairment [29-31].

Exergaming, defined as the combination of exercise and gaming, is a relatively new type of intervention in which users must perform physical movements to play games [32]. The design of the games is based on the cognitive enrichment hypothesis, which states that the behaviors of individuals (including cognitive activity, social engagement, exercise, and other behaviors) can influence their level of cognitive function [33]. One idea underlying this hypothesis is to use a rich environment to stimulate brain functioning. This rich environment is reflected when participants play these games, and there is usually a screen displaying information about the game scene. For example, the Kinect sensor incorporates an infrared light and a video camera to create a three-dimensional map in the front area, handheld controllers are also used to manipulate the games [34], and physical movements are captured by the video cameras [35] or weight-sensing platforms [36].

Exergames have been gradually implemented in rehabilitation [37,38], education [39], and other fields [40], and have been widely accepted by a range of populations from children [41,42] to the elderly [43,44]; moreover, positive results were found for individuals with various diseases such as dementia [45], stroke [46], Parkinson disease [34], multiple sclerosis [47], cystic fibrosis [48], and cancer [49]. Recent studies have demonstrated the feasibility, acceptability, and effectiveness of exergaming in improving physical functions such as gait and balance [50], motion control [51], and exercise capacity [52]. Exergaming has been found to be an acceptable method of exercising among older adults [53,54], and is also proven to be safe [55,56], easy to use [53], and enjoyable [53,54].

To the best of our knowledge, there is only one systematic review [57] that has synthesized the existing evidence of exergaming in individuals with dementia. However, due to the limitation of the retrieval strategy, the systematic review included only 3 articles involving a study with an exergaming-integrated training method and two studies using Nintendo Wii training methods. However, few systematic reviews have examined the effectiveness of exergames in improving the physical and cognitive functions in individuals with mild cognitive impairment or dementia. In addition, the latest classification of exergaming includes not only Wii but also handheld controllers, and physical movements captured by video cameras or weight-sensing platforms. Therefore, we conducted a systematic review with a high degree of evidence using the Joanna Briggs Institute methodology for systematic reviews of effectiveness evidence [58]. In reviewing the current literature, we focused on whether an exergaming intervention can indeed be beneficial to the rehabilitation of people with mild cognitive impairment and dementia.

Methods

Search Strategy

The search strategy was developed by a researcher who has conducted reviews and a university-level statistics professor. We initially conducted a limited search (with modifications as needed) in the Medline and Embase databases to identify articles relevant to the topic. The text contained in the titles and abstracts of the related articles as well as the index words used to describe the articles were adopted to develop a complete search strategy for the related databases. A combination of search terms was used to identify relevant papers (exergam* or activ* n3 video n3 gam* or activ*) AND (dementia* or alzheimer* or mild cognitive impair* or cognitive impair*), where * represents a wild card allowing the use of other suffixes, and n3 represents the adjacent retrieval operator, which allows three words to be inserted between two words and reverses the order of the words. For more details regarding the search terms, definitions, and variations of input, see Multimedia Appendix 1.

Two authors (Yinan Z and XY) independently identified studies published from the inception of the databases to January 2019. The language was restricted to English by searching the following databases systematically: Cochrane Central Register of Controlled Trials (CENTRAL), Medline, Embase, PsycINFO, Amed, and Nursing Database.

The systematic review is registered with PROSPERO: CRD42019124994. The reporting of the review is consistent with the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) guidelines [59].

Article Selection

Two reviewers (Yinan Z and XY) independently reviewed the list of potential articles found by the search strategy after removing duplicates with Mendeley reference management software. The inclusion criteria of this review were as follows: (1) randomized controlled trials (RCTs), cluster RCTs, quasiRCTs, and controlled clinical trials; (2) participants were people diagnosed with mild cognitive impairment or dementia; (3) exergaming interventions that combined real-time motions with engaging video games that can help motivate individuals to exercise; (4) comparators included groups who underwent routine exercise, other specific interventions, or no comparative group; and (5) health outcomes reported related to cognitive and physical functions, such as cognitive function, balance and gait, overall physical function, quality of life, behavioralist and neuropsychiatric symptoms, and number of falls. To synthesize more comprehensive evidence, we included both the pilot study and the full-scale study when available.

Data Extraction

Data were extracted from studies included in the review by two independent reviewers (Yinan Z and XY) using the standardized data extraction tool from the Joanna Briggs Institute Meta-Analysis of Statistics Assessment and Review Instrument [58].

The extracted data included specific details about the author, year of publication, country, study design, populations, study methods, interventions, control group, outcomes, and measurements, along with outcomes of significance to the review objective. Any disagreements that arose between the reviewers were resolved through discussion or consultation with a third reviewer. The authors of the articles were contacted to request missing or additional data when required.

Study Quality Assessment

Two reviewers independently examined the risk of bias of the included studies using the Cochrane Collaboration tool for assessing the risk of bias [60] (adapted from Higgins and Altman [61]) and Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) [62]. Any disagreements that arose between the reviewers were resolved through discussion with a third reviewer. Because some of the studies included were pilot studies with small sample sizes, we used Cohen *d* [63] to calculate the effect size.

Data Analysis

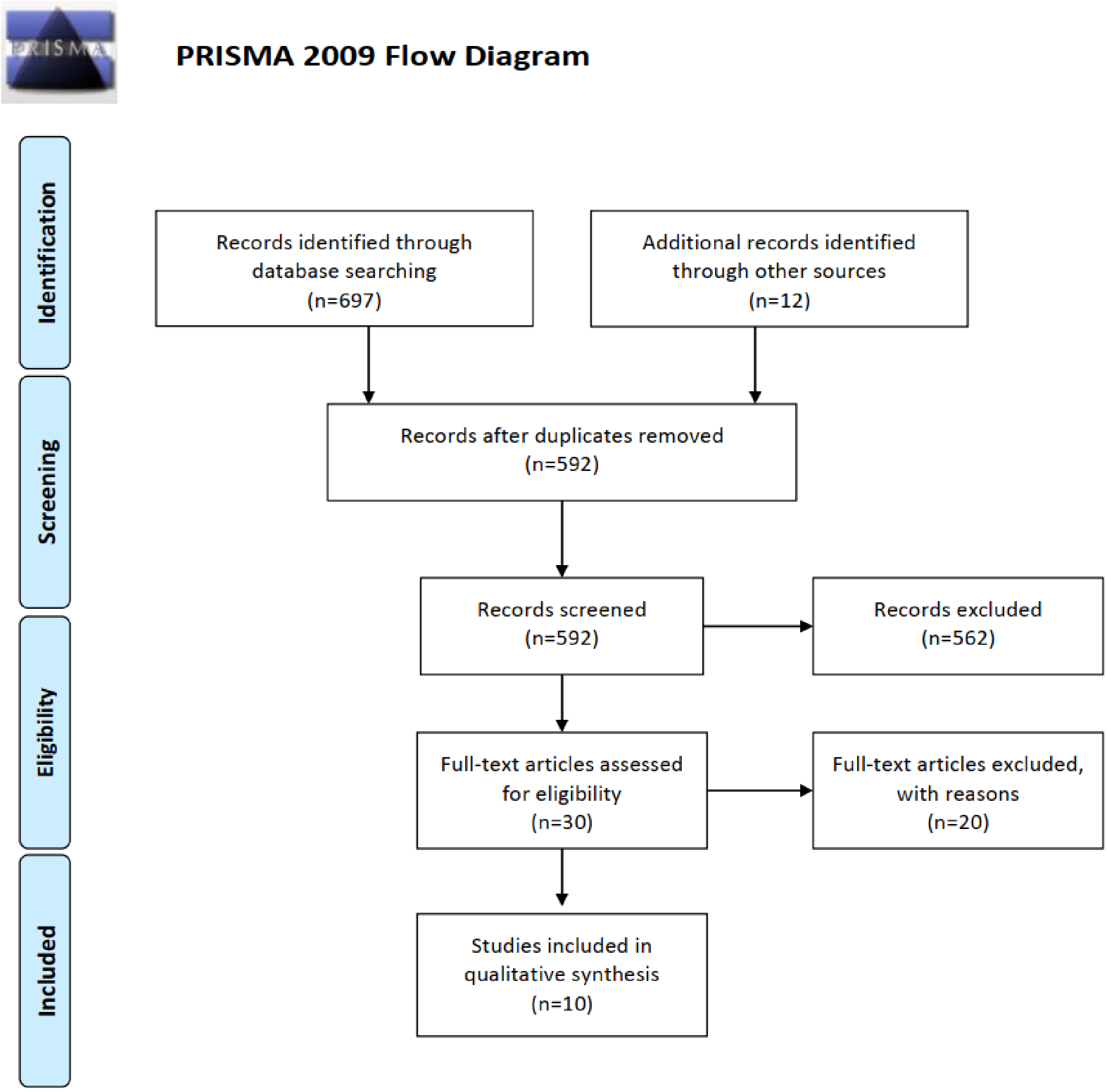
A narrative synthesis was conducted since there were insufficient data available for a statistical meta-analysis. After extracting the required data from relevant journal articles, a descriptive summary was created to summarize the interventions and assess the exergaming interventions used to improve cognitive and physical functions among people with dementia. We calculated Cohen *d* using the Psychometrica program [64]. Because an analysis based on changes from baseline is considered to be more effective and powerful than a comparison based on the final value, for each study, the differences between the baseline and final mean and SD values were included in the analysis; such a baseline change analysis removes a component of interperson variability from the analysis. In articles that did not report SDs, we calculated the SDs from the reported means, along with SEs, 95% CIs, and other relevant information [65].

Results

Search Results

A total of 697 potentially relevant studies were identified in the initial search. After duplicates were removed, the titles and abstracts of 592 records were screened for relevance according to the inclusion criteria, and 30 potentially relevant studies were identified. After viewing the full texts, 20 studies were excluded from the review. In 11 studies, the interventions were multimodal or multicomponent, excluding exergaming. In 7 studies, the participants were elderly but did not have a diagnosis of mild cognitive impairment or dementia. One study was a single-case feasibility study, and another study did not explore the outcome of physical and cognitive function. Finally, 10 articles were included in this study [45,50,52,66-72] (Figure 1).

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.



Participants

Half of the studies (n=5) were conducted in the United States and the remaining studies were conducted in Germany, Greece, the Netherlands, France, and Pakistan. A total of 702 participants were recruited for these 10 studies, and the data of 597 participants were analyzed after removing duplicates. The mean age of the participants in 9 of the 10 (90%) included studies was 79.8 (SD 7.2) years, and 408 (58.1%) were women. In 8 studies, all participants were diagnosed with mild cognitive impairment or dementia, including mild Alzheimer disease and dementia, whereas the elderly people participating in the other 2 studies included those with and without mild cognitive impairment or dementia. More details on the participants, interventions, comparisons, outcome measures, and results of the included studies are shown in Multimedia Appendix 2.

Types of Interventions

There were two main categories of exergame interventions implemented in the included studies. The first category corresponded to exergaming training such as balance training, flexible training, and aerobic training, and the second category corresponded to virtual reality-based situational tasks such as riding a bike in a park, crossing roads while avoiding cars, and shopping in a supermarket. The median duration of the intervention was 8 weeks (range 4-24 weeks), although many of the studies used durations ranging from 6 to 8 weeks. Nine articles reported the duration of the sessions, ranging from 30 to 120 minutes, and some studies reported duration ranges, as the completion time was determined by the participants in some cases.

The exergames in 5 studies were implemented on sensor-based platforms [50,67,68,71,72] such as Nintendo Wii-Fit and FitForAll; 4 studies used video camera systems such as Xbox 360 Kinect, X-Torp, and Bike Labyrinth to capture physical movements [52,66,69,70]; and another study used a handheld controller [45]. The interventions were administered by a researcher [45,50,68-70,72], therapist [66], clinical doctor [52], and family caregiver [71]. In the study of Bamidies et al [67], the intervention was carried out in a group setting with psychologists, physical education instructors, researchers, or nurses.

Outcome Measures

Different indices, including balance, gait, executive function, episodic memory, working memory, emotions, and cognitive performance, were used to evaluate the effects of the exergaming interventions on cognitive and physical functions.

Physical Functioning

Physical function was evaluated in 7 full and pilot studies; however, only 3 of these studies showed positive results. Schwent et al [72] used 3 wearable sensors attached to both the lower legs and the lower back of the participants who were instructed to stand for 30 seconds with their feet close together; they were then instructed to stand with their eyes open and closed so that their balance could be assessed, and the authors found a significant result on balance ($P<.05$). Two studies assessed balance using the Berg Balance Scale (BBS), and one showed that the mean BBS score improved to more than 45 points in both groups with the intervention; scores between 41 and 56 points indicate that an individual's balance function is good, and for elderly people, these scores indicate that they can walk independently. The BBS score improved significantly over time for both groups ($P<.001$); however, there were no significant group-by-time interaction effects on the BBS scores ($P=.56$) [50].

Cognitive Functioning

Cognitive function was evaluated in all 10 studies included in the systematic review. Among the 6 full-scale studies, 4 showed positive results. Wiloth et al [45] used a task-specific assessment that included temporal and spatial outcome parameters to measure motor-cognitive performance, and found that exergaming training significantly improved the duration and accuracy parameters ($P<.001$) Bamidis et al [67] used the average *Z*-standardized scores of episodic memories, working memory, and executive function to assess global cognition, and found significantly improved global cognition in the experimental group compared to the control group ($P=.002$). Amjad et al [66] used the Mini-Mental State Examination and Montreal Cognitive Assessment to test participants' cognitive abilities and found significant interaction effects of the group and time factors on both scores ($P<.001$). They also used the Trail Making Test to assess executive functions, which showed significant improvement ($P<.001$). Another study found that the psychomotor speed of the exergame training group was significantly higher than that of the control group after 12 weeks ($P=.004$) and there was a maintenance effect observed at the 24-week follow-up ($P=.003$); part A of the short form of the Trail Making Test and parts I and II of the abbreviated Stroop Color Word Test were used to assess psychomotor speed. In 4 pilot studies, no positive results were found on cognitive function [69].

Risk of Bias

Eight RCTs and two pretest-posttest studies with a control group design (quasiRCTs) were included in the review. The 8 RCTs were assessed for risk of bias using the Cochrane Collaboration tool [60], which includes the following 7 items: (a) generation of random sequences (selection bias), (b) allocation concealment (selection bias), (c) blinding of the participants and personnel (performance bias), (d) blinding of the outcome assessment (detection bias), (e) incomplete outcome data (attrition bias), (f) selective outcome reporting (reporting bias), and (g) other biases. Two reviewers rated the studies to have "low risk," "high risk," or "unclear risk" for each of the categories listed above, corresponding to the green, red, and yellow filled circles, respectively, shown in Figure 2. Moreover, the two quasiRCTs were assessed using the ROBINS-I tool, which has been widely used for evaluating nonrandomized studies. The evaluation results are shown in Table 1.

Figure 2. Risk of bias summary.

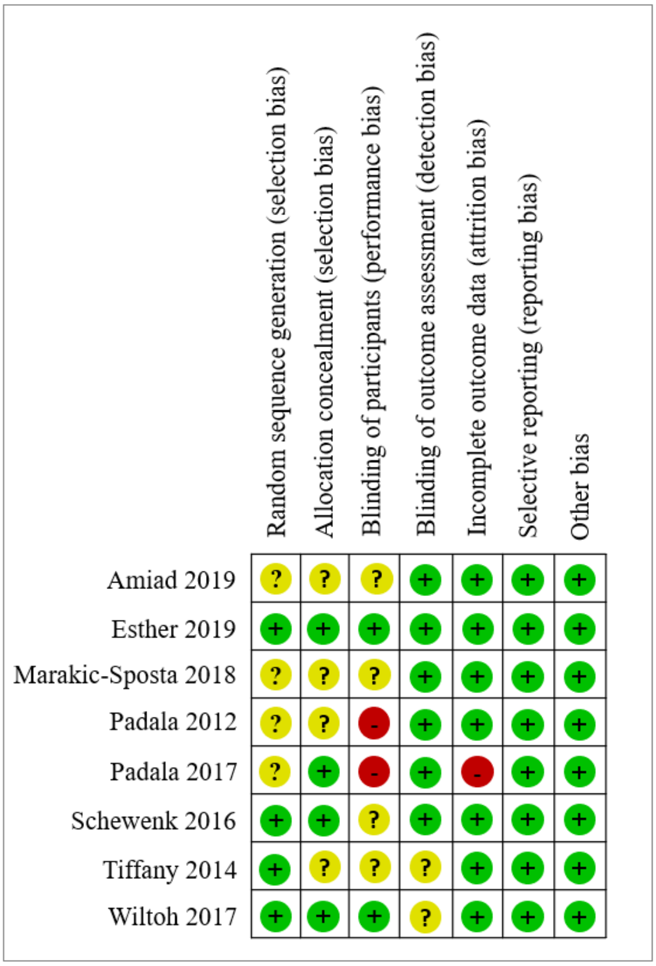


Table 1. Risk of bias assessment according to the ROBINS-I[a] tool.

Risk of bias	Bamidis et al [67]	Ben-Sadoun et al [52]
Confounding factors	Low	Moderate
Selection of participants	Low	Serious
Classification of intervention	Low	Low
Deviation from intended interventions	Low	Low
Missing data	Low	Low
Measurement of outcomes	Low	Low
Selective reporting	Low	Low
Overall judgment	Low	High

[a]Risk of Bias in Non-randomized Studies of Interventions.

Discussion

This is the first systematic review that synthesized the existing evidence of exergaming interventions administered to elderly individuals with mild cognitive impairment or dementia and to explore the effect of exergaming interventions on their cognitive and physical functions. The interventions identified in this review differed greatly across studies. The duration and frequency of the interventions also varied greatly; the duration ranged from 4 to 24 weeks, and the total intervention duration ranged from 3 to 36 hours. The frequency ranged from 1 to 5 times a week, and the median was 3, which is consistent with the study of Manera et al [73]. However, after analysis, there was no evidence that longer and more frequent interventions lead to greater improvements in function. Although exergaming is a combination of gaming and exercise, due to the diversity of the platforms used to manage the exergame interventions, it was difficult to determine which exergame was the best for improving cognitive and physical functions. Nevertheless, many studies used sensor-based platforms such as Nintendo Wii. Half of the interventions were carried out in the community, and the rest were administered in hospitals, rehabilitation wards, or nursing homes, indicating that exergaming interventions could be implemented in both environments, but were more common in a community setting. Alzheimer's Disease International estimated that globally, approximately 84% of elderly patients with dementia currently live in a community [74]. The World Health Organization's "Rehabilitation 2030" campaign launched in 2017 pointed out that rehabilitation programs should follow a holistic approach for chronic disease management, optimize independence, and prolong community engagement [75]. Because it is inexpensive [49], safe [55,56], and easy to use [53], exergaming can be performed unsupervised even for community-dwelling healthy older adults [76,77]. Exergaming interventions are gradually being used as a physical cognitive rehabilitation tool for elderly people with mild cognitive impairment or dementia living at home in the community.

In a previous literature review, the effectiveness of exergaming training in improving cognitive function was investigated in people with mild cognitive impairment or dementia. The results were consistent with those reported in the study of Karssemeijer et al [69], showing that exergame training significantly improved the psychomotor speed in elderly people with dementia compared with the control group that adopted normal exercise. Moreover, positive results were found in the study of Amjad et al [66] in elderly individuals with mild cognitive impairment, showing improvements in overall cognitive abilities and executive function, and in the study of Bamidis et al [67] in elderly individuals who were healthy or had mild cognitive impairment.

Four of the five formal studies reported that the exergaming intervention improved cognitive function, which is encouraging. In recent years, more and more studies have applied exergames to the cognitive rehabilitation in elderly people with mild cognitive impairment or dementia. The aim of cognitive rehabilitation is to use individualized intervention strategies to address cognitive impairment [78]. Previous studies have shown that an effective approach to treating cognitive impairment requires a highly individualized approach that focuses on the common goals of patients and is interactive [79], and an exergaming intervention meets these criteria. Wiloth et al [45] assigned participants to tasks of different difficulty levels according to their cognitive performance and the intervention was implemented in the presence of the clinicians. In the study of Bamidi et al [67], a group of psychologists, physical education instructors, researchers, and nurses helped each elderly person design a plan that included aerobic, resistance, and strength exercises. However, due to the small sample size, short intervention duration [70-72], and lack of specific exercises [72], a positive result was not obtained in several other preliminary experiments [50,70-72]. In addition, some studies reported "small" to "moderate" effect sizes for the cognitive function results [50,52,72,80].

In the current study, the instrumental activities of daily living and activities of daily living were used to evaluate the independence in performing physical activities of the subjects for three interventions, but only one study showed positive results. However, variations in activities of daily living performance are expected since the extent to which patients with Alzheimer disease lose the ability to perform activities of daily living varies widely [81]. Balance and gait speed are the most widely used physical measurements for evaluating physical function since gait speed [82-84] and functional decline [85] are predictors of survival among elderly people. Four studies included balance in the outcome measures, three of which found positive results and the other found a moderate effect size in physical function among participants with neurodegenerative diseases. These results indicate that exergames do improve postural control in older adults compared to walking training [50,71,72,85]. This conclusion can be supported by the theory of planned behavior, which postulates that subjective norms and behavioral attitudes determine individual behavioral intentions and the latter determines individual behaviors [86]. An interesting result was found with respect to use of the same exergaming intervention (Nintendo Wii-Fit) and control intervention (walking program), both of which lasted for 8 weeks. One study showed no significant group-by-time interaction effects on the BBS scores (P=.56) [50], but the other showed that among the participants who completed the test, there was a significant group-by-time interaction effect on the primary outcome measure, the BBS score (P<.05) [71], which we consider to be a very promising result. This discrepancy may have been partly caused by a small sample size or low test efficiency. Additional studies with sufficient sample sizes and high quality should be conducted to verify the results.

According to the literature review, in addition to cognitive and physical functions, we also found that exergames affect other outcomes. Apathy is a common neuropsychiatric syndrome observed across many neurocognitive and psychiatric disorders. In the study of Valeria et al [87], 20 experts reported that information and communications technology is "very appropriate" for apathy nonpharmacological treatment. Among all the studies included in this review, none of the studies using measurement tools detected changes in apathy before and after the intervention; however, we found some benefits in terms of motivation and compliance.

Motivation or compliance was evaluated or explored in 70% of the studies reviewed. All 7 studies that evaluated motivation or compliance agreed that the exergames increased or enhanced the participants' motivation to engage in rehabilitation activities. Although exercise therapy has been recommended to improve the cognitive and physical functions in people with dementia or mild cognitive impairment in recent years [88], there are still many barriers to exercise, such as lack of motivation and limited access to exercise facilities [89]. Exergames provide sensory feedback through auditory, visual, and tactile stimulation [90], and can further maintain the motivation of individuals [66]. Therefore, exergaming interventions have a high adherence rate among rehabilitation methods. Ben-Sadoun and colleagues [52] found that both groups in the study experienced only positive emotions, which was consistent with previous findings on exergames in subjects with mild cognitive impairment and Alzheimer disease. In the study of Hughes et al [68], the majority of participants were "very much" satisfied with the intervention. An open-label RCT among elderly people with mild cognitive impairment showed that exergaming interventions can reduce individuals' fear of falling compared with no training [72].

Despite the positive impact, some limitations of our study must be considered when interpreting the results. The studies included in this review varied substantially in terms of the consoles used, games played, participants' stages of mild cognitive impairment or dementia, and the outcomes assessed, making analyses of the effects of exergaming difficult, and a meta-analysis could not be performed. To gather comprehensive evidence, we included pilot studies with small sample sizes. Therefore, it is difficult to draw firm conclusions from the results of the analyses due to the limited statistical power.

This is the first systematic review that assessed the effectiveness of exergaming interventions in improving the cognitive and physical functions of elderly people with mild cognitive impairment or dementia. The studies included in the analysis were heterogenous in terms of the modalities used to administer the interventions, health outcome evaluations performed, and outcomes assessed. Overall, exergame interventions can improve cognitive and physical function to some extent, and more high-quality studies with more accurate outcome indicators are needed for further exploration.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Search strategy.

[DOCX File , 17 KB - games_v8i2e16841_app1.docx]

Multimedia Appendix 2

Study characteristics.

[PDF File (Adobe PDF File), 155 KB - games_v8i2e16841_app2.pdf]

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Abbreviations

BBS: Berg Balance Scale
CENTRAL: Cochrane Central Register of Controlled Trials
PRISMA: Preferred Reporting Items of Systematic Reviews and Meta-Analyses
RCT: randomized controlled trial
ROBINS-I: Risk of Bias in Non-randomized Studies of Interventions

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Original Paper

Development and Preliminary Usability Evaluation of a Somatosensory Square Dance System for Older Chinese Persons: Mixed Methods Study

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Abstract

Background: Chinese square dancing, known as guangchang wu in Chinese, is a well-known public fitness activity that provides an entertaining way for older Chinese women to improve their flexibility, lower extremity strength, overall coordination, and balance. However, injuries, noise conflicts, and lack of space are challenging aspects of this activity. Somatosensory games (SG) are an increasingly popular physical fitness approach to enhance the selective attention of older persons with indoor engagement and exercises.

Objective: The objectives of this study were to develop a newly designed somatosensory square dance system for older Chinese people and to evaluate its usability.

Methods: This is a mixed methods study. The newly designed somatosensory square dance system is a somatic training tool that provides adequate Chinese square dance fitness training based on Laban Movement Analysis (LMA) and design guidelines established in a previous stage. The usability evaluation involved a questionnaire and interviews. Twelve participants were interviewed before and after experiencing the 15-minute dancing and learning process within the program. In addition, participants scored their experience satisfaction in psychological, physiological, and relaxation sections on a scale of 1 to 5 using a questionnaire. Qualitative content analysis and quantitative analysis of the satisfaction scores supported understanding of usability problems.

Results: Based on the interview results, 6/12 (50%) of the participants thought the system could help them correct their dancing movements indoors without being affected by poor outdoor weather. Among the participants, 3/12 (25%) indicated that this indoor system could enable them to enjoy fitness activities in a private space. Moreover, 3/12 participants (25%) stated that this system could promote family relationships by providing easy dancing movements. All participants were highly satisfied with the relaxation aspect of the system (4.45/5). The participants were all psychologically satisfied and interested in the novel features of the system, with an average score of 4.16/5. Physiologically, participants affirmed that the system could help them maintain good health (4.91/5).

Conclusions: The results of this study suggest that the somatosensory square dance system can be used as an indoor fitness tool to improve older Chinese square dancers' health conditions with reasonable dance training. Noise and space conflicts can be addressed. The Laban Elated Square Dance system, which was modified by therapists based on LMA and square dance design guidelines, was highly approved by dancers because it decreased the possibility of injuries, falls, and joint damage by considering the physical and psychological difficulties of older persons. Different features will be considered in the next stage, such as greater selection of exercises and difficulty level settings. Users' social needs will also be explored in subsequent stages.

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KEYWORDS

older persons; chinese square dance; somatosensory games; somatosensory square dance system; physical exercise

Introduction

Background

In recent years, countless “dancing grannies” have been observed dancing in groups to loud and intense music in tranquil neighborhoods across China; this dance form is known as Chinese square dance (guangchang wu in Chinese). It is generally believed that Chinese square dance is an extension of line dancing, which was introduced in China around 2004 [1]. The year 2015 is called the first year of Chinese square dance because it was performed on stage at the Chinese Spring Festival Gala. In the same year, 2 government agencies, the State General Administration of Sports and the Ministry of Culture, announced the development of 12 model square dancing routines; instructors were hired and trained to introduce these routines around the country. Thereafter, square dancing was quickly acculturated by the integration of Chinese dance styles and music. For several different reasons, including fitness, socialization, and governmental promotion, Chinese square dance has become one of the most popular exercise formats in China. Due to its low cost and ease of participation, Chinese square dance is a popular pastime. According to a report by the Economist Corporate Network in 2017 [2], the size of China's sports fitness market in 2016 was close to 1.5 trillion yuan, and over 400 million Chinese people exercise regularly. Chinese square dance represents 25% of this exercise. Chinese square dance differs from traditional square dancing, in which 4 couples are arranged in a square with one couple on each side facing the middle of the square; Chinese square dance groups consist of older or retired women who spontaneously congregate in the early morning and evening at any time of year in parks, public squares, or any place they can find. Chinese square dance represents the collective aspect of Chinese culture. With lively step movements and strong rhythm, it has already become the most popular fitness approach among retired, middle-aged, and older women. It is also an effective way to maintain mental awareness; Chinese square dance can improve memory and can even delay some of the negative traits of diseases such as Alzheimer disease and other forms of dementia, which are currently becoming more frequent as people live longer. According to the data in the 2017 China Square Dance White Paper [3], people aged 18 to 52 years are the main force of Chinese square dance, with a proportion of 71%; only 27% of dancers are more than 52 years old. East China has the highest number of dancers in Generation Y, with a proportion as high as 43% or more. However, it has been reported that older people can be easily injured by falling during square dance exercise due to lack of instruction and professional guidance. When middle-aged people dance, they perform many movements using joints and muscles that are not highly stretched. Performing these movements is harmful to the body. Additionally, square dancers come into conflict with residents of the areas that surround their preferred spaces. Many younger workers have complained that the noise pollution prevents them or their families from obtaining needed rest, especially if different groups of dancers increase the volume of their music to compete with each other. To date, there is little research or study on designing indoor Chinese square dance training systems or software to prevent injury and provide fewer interruptions for other people.

Literature Review

According to previous studies, exercise and activity significantly reduce the risk of cardiovascular disease, stroke, hip fracture, osteoporosis, and falls [4-6]. Dance-based therapy has been found to improve balance and locomotion [7-9], lower body strength, flexibility, and endurance [7,10-12]; it also enhances motivation and improves psychological well-being [13]. Studies have demonstrated the value of square dance and its impact on the physiological, psychological, and social needs of individuals. Square dance has been found to could reduce the rate of decline of bone mineral density, improve balance, and decrease the risk of falls in postmenopausal women [14]. One study compared the influences of Tai Chi exercise and square dancing on individuals’ physical indices; they found that square dancing had a more significant effect on waist-hip ratio changes [15]. In one study, it was discovered that participants’ chest circumference increased gradually during square dance exercise and that their waist and hip circumference and waist-hip ratio both gradually decreased [16]. Evidence has been reported that square dancing can effectively reduce the blood glucose and HbA1c levels of patients with type 2 diabetes [17]. Square dance exercise could significantly improve the happiness index of older women, which was highest in a square dance exercise group [18]. On the other hand, this form of exercise has negative impacts, such as falls and injuries, and environmental problems also occur. One study reported that 66.6% of older persons encountered different levels of injuries in square dance fitness due to lack of risk awareness [19]. Another study noted risk factors such as lack of facilities, lack of tutoring and professional knowledge, and inadequate attention [20].

Laban Movement Analysis (LMA) is an analysis tool that is used to observe, describe, and record various human actions during dancing movements [21]. LMA enables observation and analysis of body movements, and it has been applied in various fields, including early childhood development, enterprise management, and psychiatric treatment, as well as in academic applications such as psychology, kinematics, sociology, and criminology [22]. Laban proposed that effort is the most basic tool for human movement. A process was established to record the elements of effort, which consist of four motion factors: space, weight, time, and flow. LMA experts were recruited to analyze different versions of a dance according to the space, weight, and time factors [23]. They discovered that the official version of the dance involved a higher proportion of strong effort, while two other versions involved lighter and gentler movements; strong effort was more likely to create feelings of stress and impatience in the human body. The experts concluded that the official version of the dance was undesirable because it required a large amount of strong effort; meanwhile, movements requiring sustained effort could effectively train coordination. Fitness guidelines for square dancers based on LMA to prevent falls and injuries were designed, and the researchers concluded that when the space factor was generalized as a direct effort, the movements were easy to learn. The recommended ratio for strong and light effort movements was 3:7, which could pacify the dancers’ emotion and train the muscle strength of their lower extremities. Definitions and directions of the four motion factors are provided in Tables 1 and 2.

In motion sensing technology, the human body functions as a controller. Users do not need to touch the equipment directly; their body language is located by the equipment, which receives instructions accurately. Somatosensory sensation can also be called somatic sensation; it comprises the senses of touch, pressure, temperature, pain, and body feel. Somatosensory operation is characterized by intuition, fun, and interactivity. Compared to the operation of previous controllers, a somatosensory system can be easily learned by waving and moving the hands and feet, by which users can be fully engaged and immersed. Somatosensory technology was initially used in the game industry to provide indoor entertainment. In recent years, its scope of application has gradually expanded to athlete monitoring, health care, virtual dressing rooms, rehabilitation, etc. Serious games are promising as an effective, lasting, low-impedance method to improve the social, cognitive, sensory, and emotional functions of older people [24]. Users can simultaneously realize the unified benefit of game playing, sports simulation, education, exercise, disease prevention, and rehabilitation [25].

In recent years, an interactive platform with Kinect somatosensory equipment (Microsoft Corporation) was developed that can help people with disabilities undergo treatment and rehabilitation at home [26]. Gutierrez et al [27] studied 2 groups of patients with multiple sclerosis; one group received traditional treatment, and the other received remote somatosensory treatment. After 10 weeks, the balance and posture control of the 2 groups of patients both showed significant improvement. One study applied Kinect to training exercises that were prescribed for older people; they found that the participants' sense of balance improved, but their willingness to participate was not high because the levels of entertainment and interest were not as high as expected [28].

Table 1. Definitions of the four motion factors of Laban Movement Analysis.

Motion factor	Definition
Space	The degree of change between the movement and the sense of space (condensed or loose).
Weight	The degree of change of the center of gravity in motor performance (lifted up or falling).
Time	The degree of change of the sense of time.
Flow	The body flow state associated with individual muscle changes.

Table 2. Directions of the effort elements for the four motion factors of Laban Movement Analysis.

Effort element	Direction
Direct	Affirmative and targeted action execution with a simple path and clear starting and end points.
Indirect	Action execution is not clear, focal length is loose, and motion paths have many turning points.
Strong	Action does not necessarily decrease; strong performance of center motion with a large amount of resistance force.
Light	Light and soft performance; most actions defy gravity.
Sudden	Rapid changes in operation, inability to predict the next moment of action, anxious and uneasy performance.
Sustained	Actions change slowly, calmly, and continuously and are endless.
Bound	Physical manifestations of tension and muscle force. The operating state can be stopped at any time.
Free	Physical manifestations are relaxed, at ease, and unrestrained.

Goals of This Study

In the field of Chinese square dance, few studies have focused on the development of somatosensory systems to improve training and address the problems of outdoor noise, venue availability, and privacy. In this study, we propose the following research questions: (1) How can we design and improve a more suitable Chinese square dance program using Laban Movement Analysis? To address existing problems such as injuries, falls, and lack of professional guidance, in this study, we propose a newly designed Laban Elated Square Dance system to maintain the flexibility, lower extremity muscle strength, and overall coordination and balance of older persons, thus reducing the negative physiological impacts of Chinese square dance. (2) How can we design an indoor somatosensory dance system to help resolve existing space constraints, public disturbance, and privacy issues? (3) How can we apply this somatosensory system to provide professional training instructions for older persons and incorporate this technology into family medical care?

In this study, we designed a somatosensory square dance system to provide suitable solutions for older persons with potential health problems (such as injuries and falls) and other problems (such as noise, lack of space, and privacy issues). We evaluated the usability and benefits of the Laban Elated Square Dance system and tested users' satisfaction with its physiological and psychological impacts. Many previous studies have pointed out that the application of somatosensory interaction systems has great benefits in the field of rehabilitation; however, few studies have targeted the experience satisfaction of the general middle-aged and older population when using a somatosensory system indoors. This study also addressed users' evaluations and definitions of the somatosensory Chinese square dance system.

Methods

Somatosensory Square Dance System Development

The Laban Elated Square Dance

In a previous fitness guideline paper, Yu, Rau, and Zhong [23] developed recommendations of fitness guidelines for rehabilitation therapists. Based on these guidelines, in this study, we choreographed a square dance that could aid balance training for middle-aged and older persons, called the Laban Elated Square Dance. The song "I Am From Prairie" has strong rhythmic melodies and was chosen as the background music. We designed 10 sets of movements with 16 steps in each set; dancers could repeat these movements several times during the song. Figure 1 describes the first four actions of the Laban Elated Square Dance.

Actions 1 and 2: Both hands are lifted to the chest, with palms lateral, right palm down and left palm up. The right elbow initially extends to the right and the left palm initially extends to the left until it reaches shoulder height/above shoulder height. In the opposite direction, the left and right hands are switched.

Action 3: On the first beat, the left hand extends forward at shoulder height, and the left toe taps forward; on the second beat, the left hand extends upward, in line with the body, and the left toe taps backward; on the third beat, the left hand at shoulder height extends to the left and the left toe taps to the left; on the fourth beat, the body returns to a standing position. The right arm is close to the back during the 4 beats. In the reverse direction, the left and right sides are switched.

Action 4: The arms swing back and forth behind the body, and the center of gravity shifts as the body swings; when shifting to the right, the right hand extends to the far end. The arms swing back and forth again, and when shifting to the left, the left hand extends to the far end.

Action 5: A cross step is taken to move forward, with the center of gravity on the front foot and the rear foot in the tiptoe position. The hands are held flat to the left at shoulder height. Afterward, on the left side, the front and rear legs exchange positions, with the hands at the right at shoulder height. A total of 2 steps forward are taken during the 4 beats.

Action 6: The right hand is placed on the back, with the left hand drawing a circle from front to rear, with the arm always extended, similar to stretching movements; the left toe is tapped behind for 1 beat, then is returned in 1 step to a position behind the right foot. When shifting to the right side, the left and right sides are switched. For 2 beats, the movement switches to the left, and for 2 beats, it switches to the right, while taking a total of 2 steps backward.

Action 7: Starting from the chest position, the left hand draws a semicircle parallel to the ground and is then raised. On the first 2 beats, the left foot steps a shoulder distance away. On the second 2 beats, the left foot moves to the tiptoe position behind the right foot. The right hand remains at shoulder height as at the beginning, with the right foot in a stationary state to maintain body balance.

Action 8: With wrists bent, on the first beat, the left elbow is raised to a high point and the right elbow is pressed down to a low point, with the left foot stepping a shoulder-width distance. On the second beat, the direction changes, and the right foot and the left are brought together. The above movements are 2-beat movements; after 4 beats, a total of 2 left steps are taken.

Action 9: The head movements are the same as in Action 8; the difference is that the movement is performed while standing still and circling but without moving to the left or right.

Action 10: The hands and arms are open to the sides, with the hands performing a wavelike flowing motion. As the left hand moves upward gently, the right hand is pulled down; at the same time, the lower limbs tread and step together.

Figure 2 describes actions 5-7 of the Laban Elated Square Dance. Figure 3 describes actions 8-10 of the Laban Elated Square Dance.

Figure 1. Actions 1-4 of the Laban Elated Square Dance.

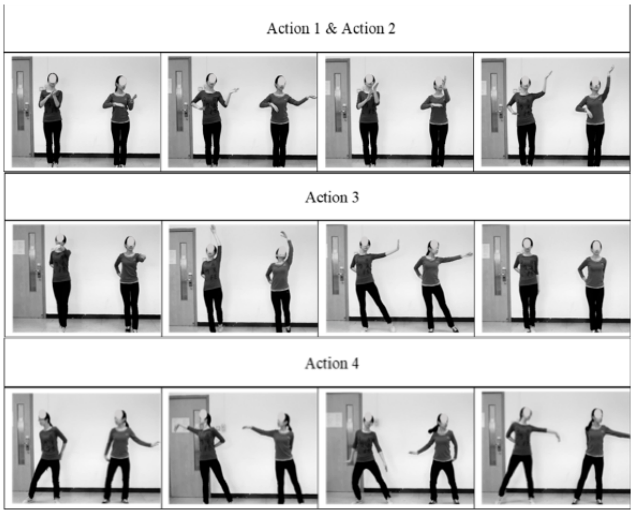


Figure 2. Actions 5-7 of the Laban Elated Square Dance.

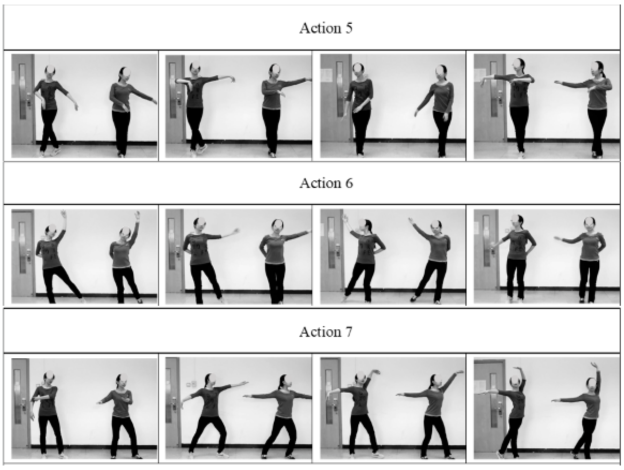
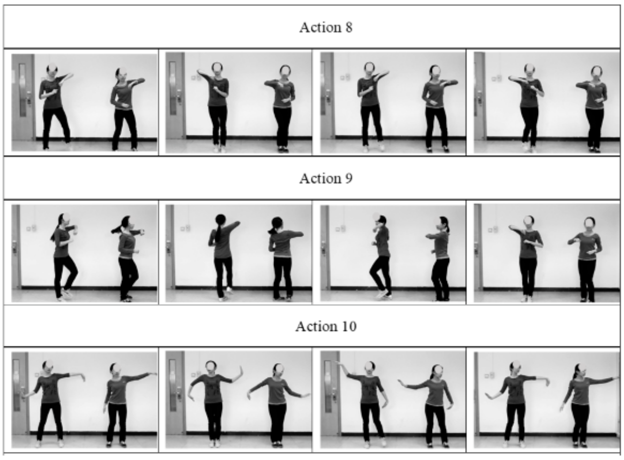


Figure 3. Actions 8-10 of the Laban Elated Square Dance.



Development of the System

The indoor somatosensory square dance system used a Kinect 2 system to collect data and RGB images to track and identify human body movements; program coding of the system was also performed. Kinect 2 can detect 25 joints; however, it does not have a graphical interface. Therefore, we applied the Open Source Computer Vision Library with a computer and camera to help identify the participants and perform further image processing of the videos. The Kinect SDK 2.0 software development package was used in this system.

This system employed Visual Gesture Builder within the Kinect software to build the gesture identification database. The steps of the basic process used by Visual Gesture Builder to establish a custom gesture and enable the program to automatically identify it are as follows.

Step 1: Kinect Studio Records the Movement

Kinect Studio is a tool in the Kinect SDK 2.0 package that can be used to preview Kinect data; machine learning technology was applied here to recognize the repetitive dance movements in the video recording. The recording interface is shown in Figure 4.

Step 2: Build Individual Movement Through Visual Gesture Builder

The recording profile was inserted into Visual Gesture Builder, and the movements were labeled manually. After all the movements which required evaluation were labeled, the gesture database was built. All the static posture and continuous movements were labeled. Figure 5 shows the Visual Gesture Builder interface used for gesture labeling.

The somatosensory square dance system was established for an older population; therefore, the visual interface was designed to be intuitive and simple. The platform consisted of a main interface and sub-interfaces that can interpret teaching and monitor practice records (Figure 6).

The system contained 80 separate dance movements; 20 points was the basis, and 1 point was added for each movement accomplished.

Figure 4. Recording interface of the Kinect Studio system.

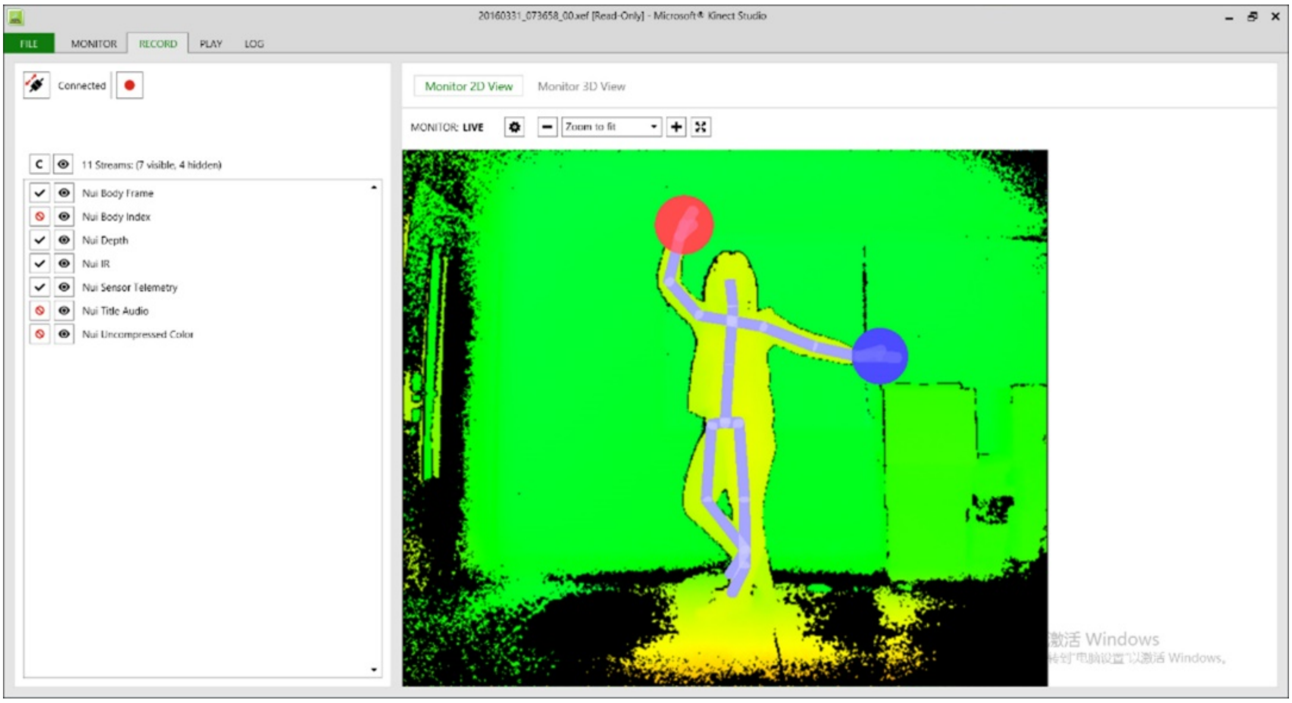


Figure 5. Video Gesture Builder interface for gesture labelling.

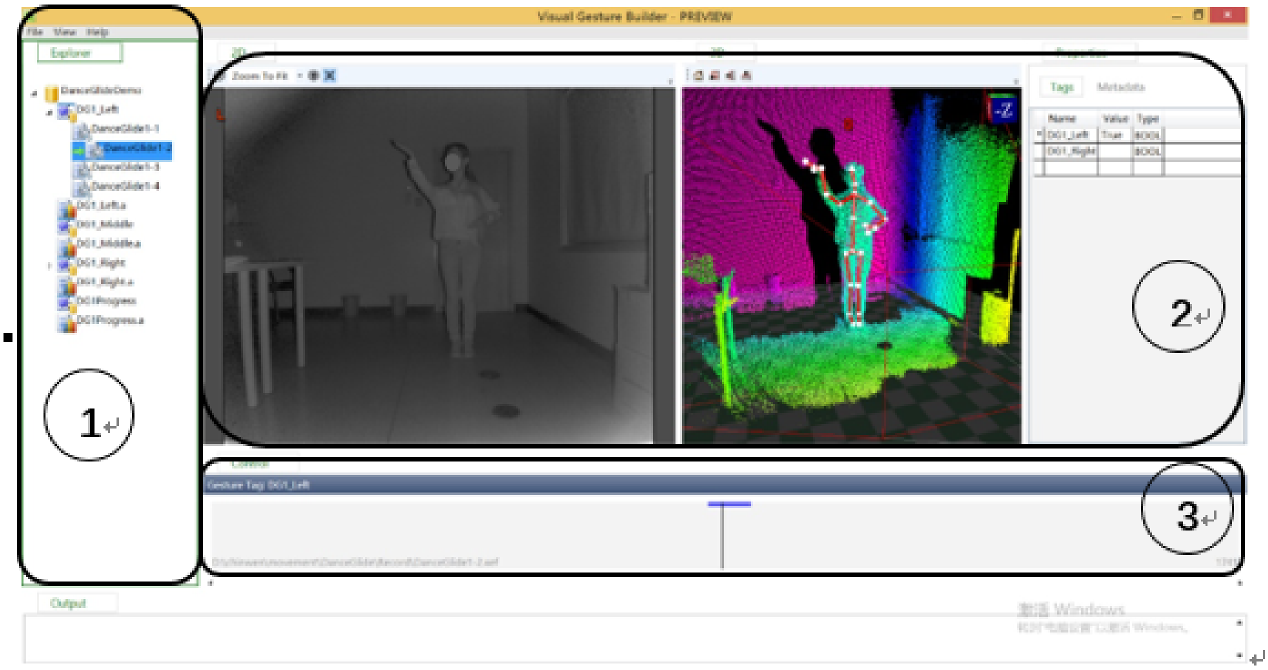


Figure 6. Interaction interface of the somatosensory square dance system.

Participants

We recruited 12 participants; 6 were older people (aged 55-68 years, mean age 60 years, SD 5.65) who were retired teachers at Tsinghua University, and 6 were younger people (aged 19-27 years, mean age 24.1 years, SD 2.71) who were undergraduate students from Tsinghua University. The young participants were recruited from the growing proportion of Generation Y, as mentioned in the Introduction [3].

Procedures

Each participant was invited to the human-computer interaction laboratory at Tsinghua University. The overall experimental process lasted approximately 40 minutes for each participant. A single participant experienced the system each time, accompanied by a laboratory researcher. Before the start of the experiment, the researcher provided a basic introduction and explained the research purpose of the experiment as well as the rights and freedoms of the participants; the researcher assured the participants that all the information they provided was protected and ensured that the participants had no other questions or requests. This research complied with the American Psychological Association Code of Ethics and was approved by the Institutional Review Board at Institute of Human Factors and Ergonomics, Tsinghua University.

After the experiment began, the researcher interviewed the participant, asking questions about the participant’s basic information, past impressions, and experience of Chinese square dance. When experiencing the somatosensory system, every participant completed the Laban Elated Square Dance without time or frequency limits. If the participant wanted to stop, they could ask the researcher to stop. In the upper right corner of the instructional video, detailed guidance was provided for every movement regarding different body parts, such as coordinated training of the whole body, increased hip joint activity, or balance training. After experiencing the system, each participant was asked to provide experience satisfaction scale scores and to answer the researcher’s interview questions, such as the difference between outdoor and indoor Chinese square dance and their feelings about the system.

The participants were instructed to stand in a rectangular area, with the initial standing point at the center. The equipment used was Kinect 2 for Windows and a computer. Figure 7 illustrates the setting in which the participants used this somatosensory square dance system. Figure 8 shows the practical routine the participants performed when experiencing the system.

Figure 7. Setting of the experiment.

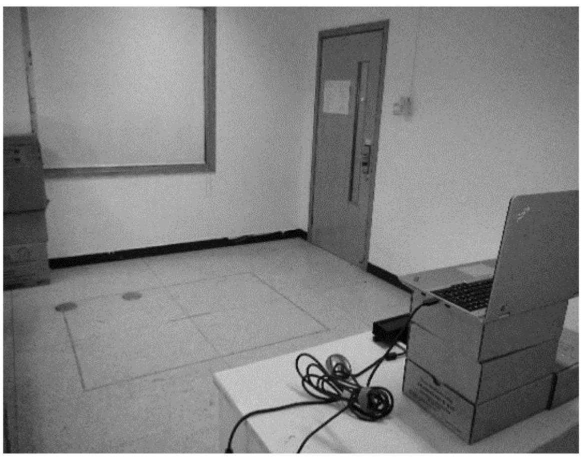
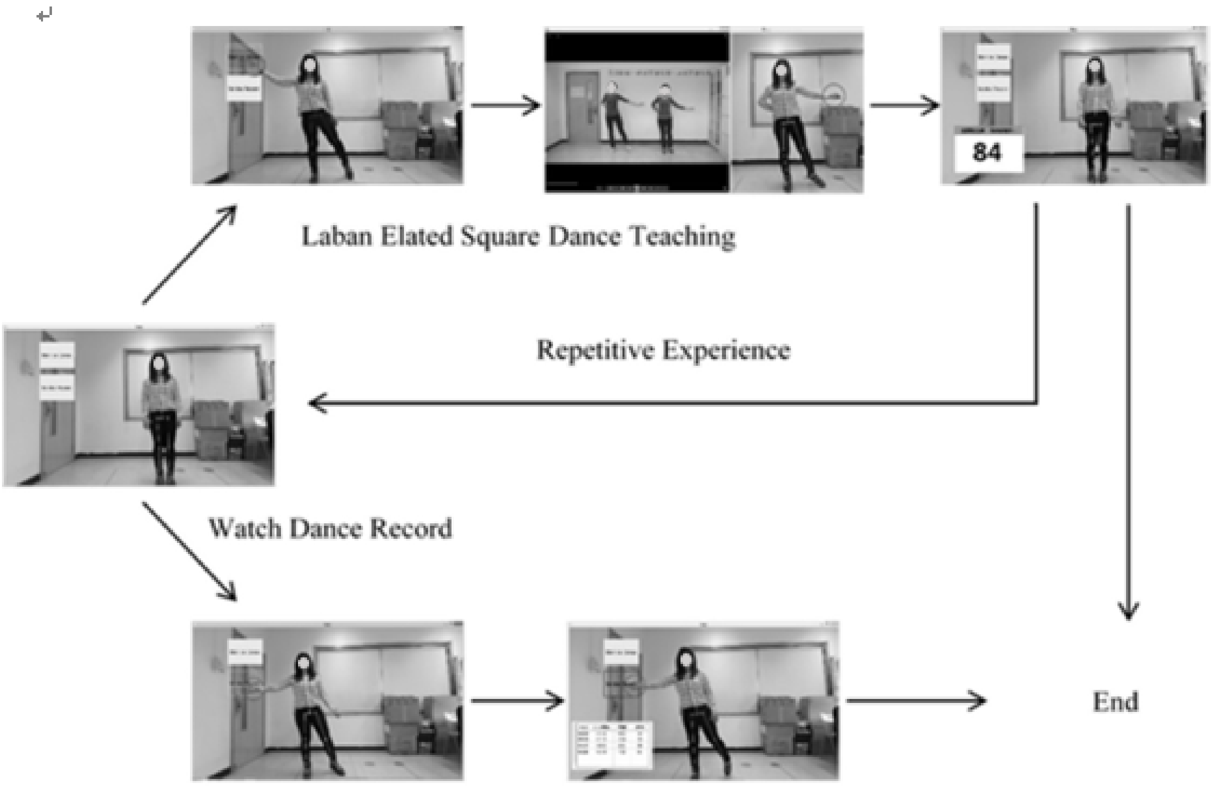


Figure 8. Practical experience of the indoor somatosensory square dance system.



Measurements

The measurements used in the experiment include psychometric tools, such as a self-reported questionnaire and interviews, and objective behavioral measurements. The objective behavioral measurements, such as the degree of motion specification and the motion trajectory, were captured by the Kinect 2 system. The experiment was also recorded on video for further analysis of the comments of the participants. We interviewed the participants before the experiment to understand their impressions and past experience in square dance and after the experiment to determine their evaluation of the system and their feelings about it after experiencing it. The interview outline is shown in Textbox 1.

The questionnaire was based on the Leisure Satisfaction Scale designed by Beard and Ragheb [29]. In this study, the questionnaire was modified to contain three sections: psychological, physiological, and relaxation. These modifications were performed because the experience satisfaction degree in this study was based on the physical, psychological, and emotional satisfaction of the somatosensory system produced by the participants after experiencing it; therefore, only three parts of the scale were used. A Likert scale was applied to score the experience satisfaction in Table 3, from 1="strongly disagree" to 5="strongly agree." All 12 participants answered the questionnaire. All statistical analyses were performed using Excel 2016 for Windows (Microsoft Corporation).

Textbox 1. Outline of interview questions before and after the participants' experience with the somatosensory system.

Before the experience

1. What is the definition of square dance?
2. What is the advantage of square dance? Or disadvantage?
3. Have you participated in square dance? What is the reason encouraging (or hindering) your continuous participation?
4. Have you experienced a somatosensory game before? How?

After the experience

1. What groups do you think this system is suitable for?
2. How does the somatosensory system square dance differ from outdoor square dance?
3. After using the somatosensory system, what would encourage or hinder your adoption of the system?
4. How did your body change after the fitness training with the somatosensory system?
5. What is your overall rating of the square dance somatosensory system?

Table 3. Psychological, physiological, and relaxation sections of the experience satisfaction scale in the questionnaire.

Section	Answer prompts
Psychological	It makes me feel interested.
	It makes me feel confident.
	It makes me feel a sense of accomplishment.
	It makes me try different techniques.
Physiological	It challenges fitness.
	It enhances physical ability.
	It increases my interest in sports.
	It keeps me healthy.
Relaxation	It can help me relax.
	It can help me release stress.
	It can make me joyful.
	It can help my emotional health.

Results

User Statistics

A summary of the demographic data and personal information of the participants is provided in Table 4.

Interviews

Participants' comments were collected and analyzed descriptively based on the interview outline. Based on their feedback, 5 responses were classified.

In response to question 1, "What kind of groups do you think this system is suitable for?", 6/12 participants (50%) suggested that the user group could include older women with a fixed habit of outdoor square dance. Participants stated that with this system, they could correct and refine their skills; additionally, they could work out at home when weather conditions were poor. Additionally, 3/12 participants (25%) recommended that the user group could include people unfamiliar with square dance, such as young people and older men, who may be interested in square dance but would prefer a private space to learn; 3/12 participants (25%) recommended the system as a family game, since existing somatosensory games are more intense games. It was suggested that this system could be used as a substitute for television and could be a great style of entertainment.

In response to question 2, "What is the difference between the somatosensory system square dance and the outdoor square dance?", 6/12 participants (50%) mentioned the advantages of social activity in traditional outdoor square dance, including greeting neighbors and interacting with teachers. Moreover, 3/12 (25%) mentioned environmental problem, such as air pollution and noise; 3/12 (25%) mentioned privacy problems, and they thought users could thoroughly enjoy themselves when using this system without judgment from others.

Table 4. Demographic and personal data of the participants (N=12).

Participant	Gender	Chinese square dance frequency	Duration of square dance activity (years)	Other fitness activities
Younger participants (n=6)				
1	Female	2 times a week	N/A[a]	None
2	Female	None	N/A	Running
3	Female	None	N/A	None
4	Female	None	N/A	Street dancing
5	Female	None	N/A	None
6	Male	3-5 times a week	N/A	None
Older participants (n=6)				
7	Female	5 times a week	2	None
8	Female	6 times a week	2.5	None
9	Female	5 times a week	1	None
10	Female	5 times a week	2	None
11	Female	None	N/A	None
12	Male	None	N/A	Running

[a]Not applicable.

In response to question 3, “After using the somatosensory system, what would encourage or hinder your adoption of the system?”, 7/12 participants (58%) mentioned the score feature; after learning the Laban Elated Square Dance, assessing their progress created more interest and confidence for the majority of young participants. Of the 12 participants, 2 (16.7%) mentioned directional confusion; because the teacher in the film danced in the opposite direction from reality, they became confused and uncertain. Additionally, 1/12 participants (8.3%) indicated that the button color was too bright to see, 1 participant (8.3%) felt it was interesting to see herself in the video, and 2 participants (17%) thought that if they could watch the video in the system before becoming familiar with the movement patterns, they could better understand their movement accuracy.

In response to question 4, “How did your body change after the fitness training with the somatosensory system?”, 4/12 participants (33%) mentioned that the design and arrangement met their physical needs, while 4 participants (33%) mentioned the professional aspect of the dance; they felt more secure because the dance was taught by a rehabilitation therapist. Additionally, 4/12 participants (33%) considered that they did not exercise enough and did not take fitness training into consideration.

In response to question 5, “What is your overall rating of the square dance somatosensory system?”, 2/6 older participants (33%) indicated that the somatosensory system was novel, and 3/6 older participants (50%) who usually participated in square dance gave some recommendations, such as interface design and increased functionality. They expressed interest in learning more physical information through new technology. Moreover, 2/6 younger participants (33%) suggested adding different movement difficulties and music choices to increase the exercise options.

Statistical data analyzed from the three different sections of the satisfaction scale questionnaire are shown in Table 5.

The relaxation section received the highest scores of the three scales, indicating that the users were more than satisfied; “It can help me relax” had the highest evaluation (mean 4.58). “It can help me release stress” received the lowest score; however, the overall scores all indicated high satisfaction, which indicates that the 12 participants generally believed that the somatosensory square dance system is relaxing, satisfying, and pleasant. The psychological scale was the second highest (mean 3.83). The average score was higher than normal, which is close to satisfaction. “It makes me feel interested” was the most common response. This indicates that the system is a novel type of activity for middle-aged and young people. The lowest score was for the physiological scale (mean 3.64). “It keeps me healthy” was the most common response in the physical scale. Most of the participants believed that continuous use of this system would definitely be helpful for body function.

Table 5. Statistical analysis of the participant responses to the satisfaction scale questionnaire (1=”strongly disagree” to 5=“strongly agree”).

Questionnaire section and prompt	Scale score, mean (SD)
Psychological satisfaction	
It makes me feel interested.	4.16 (0.71)
It makes me feel confident.	3.83 (0.93)
It makes me feel a sense of accomplishment.	3.67 (0.88)
It makes me try different techniques.	3.67 (0.49)
Physiological satisfaction	
It challenges fitness.	3.67 (0.77)
It enhances physical ability.	3.58 (0.79)
It increases my interest in sports.	3.41 (0.66)
It keeps me healthy.	3.91 (0.79)
Relaxation satisfaction	
It can help me relax.	4.58 (0.51)
It can help me release stress.	4.33 (0.49)
It can make me joyful.	4.41 (0.51)
It can help my emotional health.	4.5 (0.52)

Discussion

Principal Findings

Based on Laban Movement Analysis (LMA) of previous Chinese square dance movements, in this study, we designed a Laban Elated Square Dance for middle-aged and older persons to enhance balance training. We developed an indoor somatosensory square dance system to address existing privacy, noise, and space shortage conflicts as well as to provide adequate training. In previous studies, dance-based aerobic exercise was proved to improve indices of falling risk and lower body function in older persons; it was also proved to provide psychological benefits [5,30,31].

The establishment of the Laban Elated Square Dance was in line with the previously mentioned aspects. The Laban Elated Square Dance was professionally choreographed for balance training of older persons, and it greatly addresses the problem of poor professional guidance. Most participants stated that the lack of square dance fitness guidance is one of the greatest deficits in square dancing, which was a hidden issue.

Square dance movement involves many different aspects, and the participants suggested that only the music beat should be considered in the movements while ignoring the physiological conditions of older people. Square dancing causes joint injuries; however, in previous studies, the square dance choreography was not optimized to prevent this. The Laban Elated Square Dance system meets the physical and psychological needs of participants, addresses current issues, and can be provided to any square dance group. Previous studies showed that video games can improve physical and psychological health and are beneficial to the quality of life of older people [32-36].

This study assessed the usability of a somatosensory square dance system based on the subjective experience of participants as described in interviews, a satisfaction scale questionnaire with psychological, physiological, and relaxation sections, and system design and acceptance by the participants. The results showed that the overall evaluation and acceptance of the somatosensory system was generally positive. The satisfaction scale scores showed that the overall evaluations of the three sections were close to satisfactory. Participants’ relaxation scores ranged between satisfied and very satisfied. The results were consistent with Beard’s interpretation of needs: participation in leisure activities can help people relax and can relieve their daily life pressure. This study also supported the ability of the Kinect-based somatosensory technology equipment mentioned in the literature review to improve rehabilitation and balance [26-28].

The results of the evaluation of the system were encouraging. The overall evaluation of the system was positive; however, for individuals with different exercise styles, the experiences of this system by the target user groups were different. Middle-aged and older people who continuously participated in traditional outdoor square dance repeatedly mentioned the words “exercise,” “chat,” “interact,” and “communicate;” they considered the Laban Elated Square Dance system to be an auxiliary tool. For those who do not understand or participate in outdoor square dance, this system may provide a platform for them to overcome shyness and fear of shame and to enjoy the exercise and entertainment functions of square dance in a private space.

Limitations

There are limitations of this study. The interaction interface designed in the somatosensory system could be enhanced and made more attractive for older people to use. The participants in the system verification experiment were all recruited from one university, which may result in geographical bias. The interview outline is specifically designed for the participants to provide feedback about their experience of the system, which is a potential limitation of this research.

Although a somatosensory system cannot completely replace square dance, this newly designed technology could help spread Chinese square dance culture; thus, this unique Chinese cultural experience may become international, and people in the Western World can experience Chinese square dance in a somatosensory way.

Conclusions

We developed a novel somatosensory square dance system as an indoor dancing and fitness training tool for older people that integrates the motivational attributes of video games with functional sensory tracking. Usability tests (interviews and a questionnaire) with a small sample of older and younger people demonstrated the evaluation, acceptance, and suggestions for improvement of the system. The results indicate that the system can be used as an indoor square dance fitness tool for exercise and practice in the future. It provides a platform for people to overcome shyness and fear of shame and to enjoy the exercise and entertainment functions of square dancing in a private space. With the professional guidance within the system, dancers can receive targeted training indoors and can communicate more with family members. Moreover, with the application of the system, competition for outdoor space and noise conflicts will be alleviated. Data from the motion-recorded video can be transmitted to physicians for motion analysis and disease prediction. Our goal was to produce more interactive and social functions for square dancers and contribute to family medical care. Different feature levels will be considered in the next stage, such as selection of exercises and difficulty level settings; users' social needs and a larger sample size will also be explored in subsequent stages. Alternative software, such as iClone Motion and FXhome Action Pro, can be used as to capture users' motion.

Acknowledgments

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Conflicts of Interest

None declared.

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Abbreviations

LMA: Laban Movement Analysis

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Review

Digital Gamification to Enhance Vaccine Knowledge and Uptake: Scoping Review

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Abstract

Background: Vaccine hesitancy is a growing threat to population health, and effective interventions are needed to reduce its frequency. Digital gamification is a promising new approach to tackle this public health issue.

Objective: The purpose of this scoping review was to assess the amount and quality of outcomes in studies evaluating gamified digital tools created to increase vaccine knowledge and uptake.

Methods: We searched for peer-reviewed articles published between July 2009 and August 2019 in PubMed, Google Scholar, Journal of Medical Internet Research, PsycINFO, PsycARTICLES, Psychology and Behavioral Sciences Collection, and SocINDEX. Studies were coded by author, year of publication, country, journal, research design, sample size and characteristics, type of vaccine, theory used, game content, game modality, gamification element(s), data analysis, type of outcomes, and mean quality score. Outcomes were synthesized through the textual narrative synthesis method.

Results: A total of 7 articles met the inclusion criteria and were critically reviewed. Game modalities and gamification elements were diverse, but role play and a reward system were present in all studies. These articles included a mixture of randomized controlled trials, quasi-experimental studies, and studies comprising quantitative and qualitative measures. The majority of the studies were theory-driven. All the identified gamified digital tools were highly appreciated for their usability and were effective in increasing awareness of vaccine benefits and motivation for vaccine uptake.

Conclusions: Despite the relative paucity of studies on this topic, this scoping review suggests that digital gamification has strong potential for increasing vaccination knowledge and, eventually, vaccination coverage.

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KEYWORDS

gamification; vaccination; vaccine hesitancy; digital tools; scoping review

Introduction

Vaccination is one of the most cost-effective methods of preventing the spread of infectious diseases. The rates of people receiving vaccinations have recently declined in developed countries. If vaccination coverage falls below the thresholds that are safe for the prevention of epidemic transmission, the incidence of vaccine-preventable diseases increases [1]. One of the most illustrative examples of this phenomenon is the measles outbreak that returned over the past 2 decades. In the first 6 months of 2019, reported measles cases were the highest they had been in any year since 2006, indicating a concerning and continuing upsurge in the overall measles burden worldwide [2].

Reasons why some people do not get vaccinated are as varied as they are complex and include a sense of complacency, difficulty in accessing vaccines, mistrust of health or medical authorities, spread of misinformation, underestimation of risks, and limited knowledge of the benefits of vaccination and how it works [3,4]. According to a 2019 World Health Organization report, "vaccine hesitancy" (ie, the reluctance or refusal to be vaccinated) is one of the top 10 threats to global health [5]. Interventions to address vaccine hesitancy are urgently needed in order to promote vaccine acceptance and uptake in developed countries.

Many researchers have explored different ways to deliver fair information on vaccine risks and benefits through ad hoc interventions addressing different targets, ranging from parents [6] to adolescents [7], and concerning different types of vaccines, ranging from human papilloma virus (HPV) vaccination [8] to measles, mumps, and rubella vaccination [9]. In order to better design and implement such interventions, Willis et al [10] proposed a classification of 7 important items to be used in immunization communication methods: inform or educate, remind or recall, teach skills, provide support, facilitate decision making, enable communication, and enhance community ownership.

Gamification is defined as the use of game design elements in non-game contexts [11]. It encompasses several features and dimensions like fun interfaces, immediate success or continuous progress feedback, reward systems (point scores, badges, levels), challenges and competitions, team playing, avatars, and quizzes. These features echo the 7 items described by Willis et al [10] for efficacious immunization communication. Previous studies have been conducted worldwide on the use of gamification as a means to increase the initiation and retention of desired health behaviors [12-14]. By using game-based mechanisms, gamification stimulates participants' involvement and facilitates their learning about health [15]. Serious games and mobile or tablet applications with game-based features are increasingly used to not only train health professionals but also deliver prevention and health promotion messages to the general population [16,17]. In detail, serious games are defined as full-blown digital games applied to train and educate players and are not predominantly or exclusively intended for entertainment purposes [18,19]. On the other hand, gamified digital tools (eg, apps) are not a full game experience but just contain gaming elements such as scoring of points, in-game rewards, or engaging in quests [20]. Thus, gamification is a broader concept including but not limited to serious games. A literature review of empirical studies on gamification [21] has provided evidence on the effectiveness of the game-based approach on the user, particularly on motivation and engagement.

Given its increasing use in the public health domain, gamification might be a useful approach for interventions aimed to sensitize populations to the relevance of vaccination acceptance. Including game-based features might improve vaccination campaign strategies by educating individuals, explaining the risks they face if they are not vaccinated and encouraging them to keep their vaccination records up to date. Interventions using fun and interactive approaches and leveraging digital technologies to deliver positive views on vaccination are increasingly requested [22]. A previous systematic review identified 16 serious games related to vaccination developed from 2003 to 2015 [23]. However, data on the effectiveness of these tools were not fully provided nor compared. Among the 16 serious games, only 2 games were formally evaluated [23,24]. Furthermore, other vaccination-related gamified digital tools, like mobile apps or quizzes, were not taken into account. A study on the evaluation of existing gamified digital tools for vaccination not limited to serious games would bridge this research gap.

The aim of this scoping review was to identify gamified digital tools that have been implemented and evaluated across diverse populations and types of vaccines in an effort to tackle issues of vaccine hesitancy. The effectiveness of identified tools in terms of impact on users' knowledge and behavior towards vaccination as well as their usability/acceptability were also synthetized. Thus, the overarching goal of this study was to respond to the need for information on evidence-based interventions that could help design and implement future gamified digital tools to address vaccination hesitancy.

Methods

Search Strategy

We conducted a scoping review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement as a more robust methodological approach [25]. The search was performed between July 2019 and August 2019.

Before starting the review, we manually checked for relevant articles in the authors' languages (ie, French, Italian, and Spanish) on the first 20 pages of Google Scholar. Since we did not find any article on "gamification" AND "vaccine" in corresponding languages, we confirmed our initial choice to restrict our search to English-language papers. The following search terms and related variations were used: all ("vaccine*" OR "vaccination" OR "immunization*") AND all ("serious game*" OR "video game*" OR "therapeutic game*" OR "online game*" OR "game*" OR "game app*" OR "mobile game*" OR "digital game*" OR "gamif*").

Studies were selected from a search of the following major electronic databases: PubMed, Google Scholar, Journal of Medical Internet Research, PsycINFO, PsycARTICLES, Psychology and Behavioral Sciences Collection, and SocINDEX via EBSCOhost. A supplementary manual search was performed to identify additional relevant publications by reviewing the reference lists of the included articles and using ResearchGate.

Selection Criteria

Only peer-reviewed studies written in English in the decade 2009-2019 were included, regardless of the location of the study, type of vaccination under study, and study population. All types of study designs were included (eg, quantitative, qualitative, and mixed-methods studies; systematic reviews; meta-analyses; randomized controlled trials; and other experimental studies like pretests and posttests). Posters, preprints, and conference proceedings were excluded. Studies were included only if they used a gamification technique or tool to deliver informative or educative messages on vaccination. All types of digital games or gamified elements were included, from serious games (content gamification) to gamified Web-based quizzes (structural gamification) [26]. Articles not presenting the description and evaluation of a concrete gamified digital tool were excluded (eg, articles reporting the results of a survey on users' needs and perspectives on games for vaccination).

Data Extraction and Quality Assessment

Records identified in the literature search were evaluated in a 3-step approach. First, all identified titles and abstracts were screened for eligibility and coded by one researcher according to the selection criteria. Second, relevant articles were retrieved, and full-text articles were read independently by the researcher in charge of coding and extracting all data and by a second researcher. Third, a final list of publications for full-text review was established and validated by the 2 researchers. Any discrepancies were reviewed by a third researcher and finally resolved through consensus.

The 2 researchers conducted a quality assessment using the quality assessment method presented by Connolly et al [27]. This method assesses the overall weight of empirical evidence for the positive impact and outcomes of games. Each final paper included in the review was given a score of 1 (low), 2 (medium), or 3 (high) across the following 5 criteria: (1) appropriateness of the research design, with a score of 3 for randomized controlled trials, 2 for quasi-experimental controlled studies, and 1 for case studies, single subject-experimental, pretest/posttest, and other types of quantitative and qualitative studies; (2) appropriateness of methods and analysis; (3) representativeness and generalizability of the findings; (4) relevance of the focus of the study; and (5) relevance of the findings and their discussion. The total score for each paper was calculated by adding the scores of all 5 dimensions, resulting in a range from 5 to 15 points. Following the studies by Connolly et al [27] and Johnson et al [13] using the same quality assessment method, we categorized articles with a score of ≤8 points as weaker evidence, articles with a rating >8 to 12 points as moderate evidence, and articles with a rating >12 points as stronger evidence. We calculated the average score for each study and measured the weighted Cohen's kappa coefficient to test interrater reliability.

Data were sorted in categories, including author, year of publication, country, journal, research design, sample size and characteristics, type of vaccine, theory used, game content, game modality, gamification element(s), data analysis, type of outcomes, and mean quality score. For game modality and gamification elements, we based our coding on the work by Hamari et al [21].

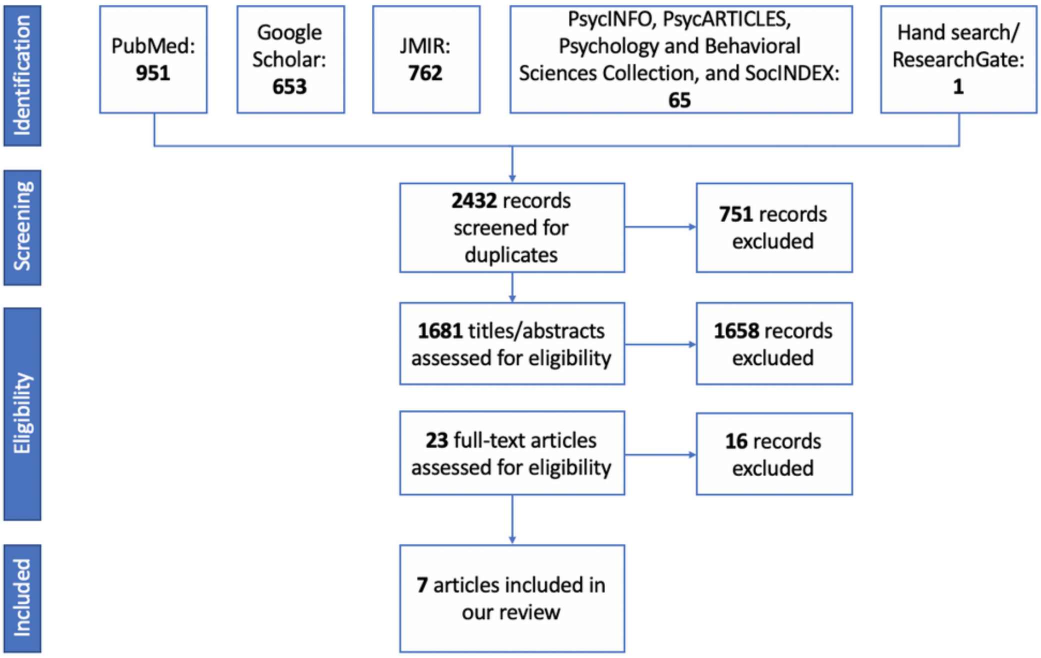
Outcome Measures

To assess the effectiveness of gamified digital tools for vaccination, we took into account 3 types of outcomes: behavior (eg, real actions like receiving a vaccination or intent to get vaccinated), cognition (eg, increased knowledge of the topic or vaccine literacy [28]), and usability/acceptability (eg, appreciation of the intervention). Furthermore, detailed outcomes of the evaluation of each game were individually reported.

Results

A total of 2432 records were identified through database searches. After duplicates were removed, remaining papers were assessed using the described selection criteria. The same tool was presented by 2 different papers [29,30], with similar results. We decided to select only the most recent study [30] since it provided more in-depth information, including qualitative data. As a result, 7 articles were finally included. Figure 1 shows the flowchart of the study selection process.

Figure 1. Flow diagram of the literature search according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.



General Description of the Studies

Each study presented 1 gamified digital tool, with the exception of 1 study that described and evaluated 2 tools: one on vaccination and one on antibiotics [31]. Only data concerning the vaccination game were taken into account for this scoping review.

The final 7 articles eligible for review were rated for the quality of the evidence: 2 articles were categorized as providing weaker evidence [24,32], 2 articles were categorized as providing moderate evidence [33,34], and 3 articles were categorized as providing stronger evidence [29,31,35]. The weighted Cohen's kappa coefficient was 0.71, suggesting good agreement between raters [36]. Concerning methodologies, 2 studies used a randomized controlled trial design [29,34], 1 study used a controlled experiment with posttest questionnaires [32], 1 study used only focus groups [33], and 1 study used only pretest and posttest questionnaires [24]. A mixed methods approach was used by 3 studies [30,31,35], balancing quantitative data from questionnaires with qualitative data from interviews or focus groups.

Game modalities and gamification elements were diverse (eg, avatars, challenges, informative feedback, points, levels, leaderboards, storytelling), but role play and reward systems were present in all studies. Of the 7 games, 4 were Web-based [24,31,32,34], whereas the other 3 were mobile apps [30,33,35]. One study [35] also used a social networking site. Of the 7 studies, 3 described tools that were cocreated by several stakeholders including health professionals, developers, and end users [24,33,35]. All gamified digital tools were promoted and funded through health authorities for public health purposes and universities for educational purposes. Of the 7 gamified digital tools, 5 were serious games [24,31,33-35], and the other 2 were implemented as a quiz [30] and website [32].

Infectious diseases were the specific focus of 6 studies: 3 studies addressed HPV [33-35], 2 studies addressed influenza [24,32], and 1 study addressed the combination of measles, mumps, and rubella [30]. The remaining study addressed vaccination in general [31].

Tools were mostly aimed at young players: 3 tools were developed for school-aged children [24,31,33], and 2 tools were developed for university students [32,34]. For 1 of the tools developed for children [33], evaluation data were collected also from parents. The remaining 2 tools were developed for the general population [30,35].

All studies but one [27] explicitly incorporated one or more behavioral theories: self-determination theory [33], health belief model [33,34], self-concept theory [34], theory of reasoned action and planned behavior [34], game theory [24,32], social value orientation [32], nudge theory [35], and empowerment model [30].

Positive effects of gamified interventions were reported in all 7 studies across at least one of the 3 outcomes we considered (ie, behavior, cognition, and usability/acceptability). For behavior, data were available for 5 studies [24,30-32,34]; for cognition, data were available for 3 studies [30,31,35]; and for usability/acceptability, data were available for 4 studies [30,31,33,35].

Table 1 outlines the characteristics of the 7 articles included in the review presented in chronological order. See Multimedia Appendix 1 for a description of the games and outcomes.

Table 1. Summary of the characteristics of the 7 studies.

Author(s) (year of publication)	Country	Journal	Research design	Sample size	Sample characteristics	Type of vaccine
Bertozzi et al (2013) [24]	United States	International Journal of Gaming and Computer-Mediated Simulations	Preplay and postplay assessments through face-to-face questionnaires	12	Lower-income, school-aged children	Influenza
Böhm et al (2014) [32]	Germany	Journal of Economic Behavior & Organization	Controlled laboratory experiment (8 sessions) with postexperiment quantitative data collected through questionnaires	180 (124 women)	College-aged social science students, mean age 23.37 years (SD 4.09 years)	Influenza
Ruiz-Lopez et al (2016) [35]	Norway	Journal of Medical Internet Research Serious Games	Mixed-methods with beta testing, focus groups (2 sessions), and self-administered questionnaires	40 for the beta testing, 6 women for the first focus group, 23 (10 girls) for the second focus group	First focus group age range 40-60 years, second focus group (high school students) age range 16-18 years	HPV[a]
Cates et al (2018) [33]	United States	Games for Health Journal	Focus group (5 sessions)	16 preteens (5 girls) and 9 parents (7 women)	11-12 years old (preteens)	HPV
Darville et al (2018) [34]	United States	Simulation & Gaming	Randomized controlled trial (2x2 fully crossed between subjects) with post-experimental quantitative data collected through questionnaires (eg, Likert scales)	108	College-aged male students (18-26 years old)	HPV
Fadda et al (2017) [30]	Italy	Journal of Medical Internet Research mHealth and uHealth	Mixed methods, including a randomized controlled trial, Web-based survey (including the Mobile App Rating Scale [37]), and qualitative telephonic interviews	140 (138 women) for the survey, 60 for the telephone interviews	Parents	MMR[b]
Eley et al (2019) [31]	United Kingdom	Journal of Medical Internet Research Serious Games	Mixed methods including pre- and post-experiment questionnaires, focus groups (26 sessions), and open-ended questions in the post-experiment questionnaire	473 (123 juniors and 350 seniors) for the questionnaire, 126 for the 26 focus groups	Students 7-16 years old	Infectious diseases

[a]HPV: human papillomavirus

[b]MMR: measles, mumps, and rubella

Description of the Evaluation Outcomes of Individual Games

Flu Busters!

The outcomes of this game [24] concerned behavior in terms of real action (ie, receiving vaccination). The game was deployed with 12 school-aged children in clinic waiting rooms before their appointments. A group of physician and midwives asked them to play the game and collected their feedback. Preliminary testing demonstrated that the game was reasonably successful in achieving its stated goal (ie, 10 of the 12 children were vaccinated for the flu after playing the game). Therefore, 92% of those who played the game agreed to be vaccinated compared to 42% (5/12) of a group of 12 clinic patients at the same premises who did not play the game. This demonstrates the real-world effectiveness of the game, despite the small sample size. Of the children, 27% (3/12) was able to answer how the vaccine worked after the game, while all of the children understood that germs invading the body and altering its cells were bad and that the vaccine could help. Children especially appreciated the animations of the protagonist *Vaccine Man* wrestling with the flu virus. Through feedback, the researchers also realized that the game was effective in communicating how prevalent the flu virus is in heavily populated environments.

I-Vax Game

Key findings of this game [32] concerned behavior. In fact, this was a game model to simulate vaccination behavior based on real-world vaccination decisions. *I-Vax* underwent a controlled laboratory experiment involving 4 sessions with 2 treatment groups each (n=96 total), 3 different sessions with 2 treatment groups each (n=84 total), and 1 session with 1 control group. Results showed that the reaction to the game varied by personality, but that the game could contribute to a better understanding of vaccination behavior and vaccine hesitancy. Those with a positive attitude were vaccinated more often and did not alter their vaccination behaviors, while those with a neutral attitude had higher switching rates (*P*<.001). Pro-socials were more likely to get vaccinated than pro-selfs (*P*<.001). Participants experiencing adverse effects after vaccination within the game were more likely to change their attitude towards vaccination (*P*<.001). Overall, participants reported an intent to change health behaviors after playing.

FightHPV

Outcomes of this game-based learning tool [35] reflected both cognition and usability/acceptability. Feedback was collected from 40 participants (employees of the Cancer Registry of Norway), a focus group of 6 participants aged 40-50 years (members of the Norwegian Women's Public Health Association), and a focus group of 23 high school students aged 16-18 years. HPV knowledge and cognition before and after playing the game was evaluated in the 22 participants from the second focus group who returned a questionnaire. Gameplay data from the beta testing study were collected using Google Analytics. Concerning cognition, after playing the game, concepts about HPV vaccination were better understood, and an increase in HPV knowledge was observed (*P*=.001). As for usability/acceptability, all those who returned the questionnaire stated that FightHPV was an appealing educational tool, 69% (18/26) reported that they liked the game, and 81% (21/26) stated that the game was challenging. Google Analytics showed that the game was easy to access and use but that players stopped the game when it became too hard.

Land of Secret Gardens

This interactive videogame [33] presented outcomes only on usability/acceptability. Data were collected qualitatively through 3 focus groups conducted with a total sample of 16 boys and girls aged 11-12 years distributed among the focus groups as well as 2 parallel focus groups with a total sample of 9 parents distributed among the focus groups. Input on game design and perspectives on the game concept were investigated. Land of Secret Gardens was considered acceptable by both the preteens and parents. Preteens especially liked the mixture of entertaining and instructional elements and the opportunity to earn tokens and advance levels. Parents also favored game levels that were contingent on correct answers to HPV knowledge questions. However, some parents expressed hesitancy around games as motivational tools. In general, the game was appreciated as an opportunity to enhance communication about HPV between preteens and parents.

VAX!

This study [34] studied outcomes on behavior only. This randomized control trial involved 24-29 students per condition group. The effects of avatar characters (assigned or customized) and perception of self (ideal or actual) on HPV risk perception, HPV vaccine self-efficacy, and behavioral intent to receive the HPV vaccine were tested. Outcomes of the evaluation were perception of self, self-efficacy, and HPV vaccine intention. Although results were not statistically significant (*P* values ranging from .581 to .001), data analysis indicated an increase in gain scores for risk perception, self-efficacy, and behavioral intention when participants were able to customize their avatar to look like their ideal or actual self. After playing the game, participants declared their intent to get vaccinated.

Morbiquiz

The outcomes of Morbiquiz [30] concerned behavior, cognition, and usability/acceptability. The game was evaluated through a randomized controlled trial and mixed-methods with a Web-based survey (n=140) and qualitative telephonic interviews (n=60) to explore participants' experiences with the app. Objective outcomes were measured using an adapted version of the Mobile App Rating Scale [37] corresponding to 4 objective qualities (engagement, functionality, aesthetics, and information quality) and 2 subjective qualities (star-rated question and possible recommendation of the app). In addition, 3 items were included to assess participants' perceived impact of the app on their knowledge, on their help seeking, and the perceived likelihood of an actual change in the target health behavior. Concerning behavior, players reported significantly higher intention to vaccinate (*P*=.03) and more confidence in the decision (*P*=.006). When compared with the control group (empowerment and knowledge intervention), those receiving the app intervention were more likely to actually change their behavior and look for health information to opt for vaccination. As for cognition, all experimental groups reported a significant increase in their vaccination knowledge compared with the control group (*P*<.001). Concerning usability/acceptability, functionality and aesthetics scored high. The results of the focus group were a general appreciation of the design and content of the app. Participants defined the app as useful, trustworthy, innovative, and engaging and described their experience as fun and pleasant. Most participants reported that MorbiQuiz was highly convenient, meaning that it is handy, quick, noninvasive, easily accessible, and functional, and stressed that the game invited users to seek information actively thanks to its gamified approach.

Stop the Spread

The outcomes of Stop the Spread [30] concerned behavior, cognition, and usability/acceptability. A total of 123 junior-aged students and 350 senior-aged students (age range, 7-16 years) from 5 UK educational provisions completed knowledge and evaluation questionnaires before and after using the game. Focus groups with 126 students were also conducted. As for behavior, in some focus groups, students reported an intent to change their health behavior. Concerning cognition, after playing, participants reported that their knowledge about sneezing behaviors and vaccinations increased significantly (*P*<.05) for both age groups.

Concerning usability/acceptability, the mean enjoyment score for Stop the Spread was 6.2/10 for juniors and 5.1/10 for seniors; participants found that Stop the Spread was fast-paced and challenging. Overall, many students reported positive perceptions of their user experience, with a few suggestions for improvement.

Discussion

Principal Findings

We identified 7 studies reporting data on the evaluation of the effectiveness of digital tools using gamification on the topic of vaccination. All 7 studies presented positive results in terms of pre-established outcomes (ie, behavior, cognition, and usability/acceptability) confirming that gamified digital tools can facilitate communication of vaccination-related messages and contribute to increased vaccination uptake. These results agree with those of previous studies demonstrating that gamification can contribute to changed behaviors and increased knowledge as well as be appreciated by users with regard to health-related topics [38]. When combining gamification and emerging technologies, results might be even more promising [39]. Digital tools have the advantage of being ubiquitous without time and space constraints [40], and the inclusion of gamified features might increase their appeal and acceptability, as reported in our study. Based on these assumptions, the design of future interventions should consider the use of both new technologies and gamification.

Previous research described existing serious games used for vaccination [23]. However, selected tools dated back to the year 2015 and were just listed and fully described without any appraisal of their effectiveness. Furthermore, only serious games were analyzed in this previous study [23], without considering other digital tools that were not full-blown games but used gamified features [20]. Through our review, we provide an update, through the year 2019, of existing digital games for vaccination and an evaluation of these games. Given the speed at which technology changes and improves, monitoring new digital tools is essential. Most importantly, to our knowledge, our study is the first scoping review synthesizing data on the evaluation of the effectiveness of different types of digital tools using gamification, not exclusively serious games.

We classified games per type of outcome. The 4 studies [24,30,32,34] reporting data on behavior showed a remarkable increase in the intent to get vaccinated and a positive attitude towards vaccination. Similar results on behavior change have been found in serious games for oral hygiene [41], asthma [42], and fruit and vegetable consumption [43]. Effectiveness in terms of behavior change might be explained by the fact that gamification tends to improve the involvement and motivation of users who feel more convinced of their decision after playing [44,45]. Games are thought to provide a good medium for increasing self-efficacy and changing behavior as they offer the opportunity for a new experience in a safe environment, without real-life consequences to making wrong decisions [46].

Positive findings on cognition were reported by 3 studies [30,31,35], corresponding to increased knowledge and literacy about vaccination. This agrees with a meta-analysis of serious digital games for healthy lifestyle promotion [46]. According to this previous scientific work, health knowledge is easier to influence than other outcomes, but the impact of a change in knowledge is not as strong as influencing a person's intent to change behavior. These positive results might be explained by the learning-by-doing approach used in gamified digital tools where players learn through exploration and experimentation.

In terms of usability/acceptability, results on this outcome were reported by 3 studies [30,31,35]. Effectiveness in terms of usability is potentially justified by the co-construction process. Including different stakeholders like health professionals and game developers is time-consuming but is useful for developing games that will appeal to the target audience [47]. One game promoting healthy eating in children [48] and one game to help young people quit smoking [49] underlined the advantages of using a co-construction approach to increase commitment to and acceptability of the games.

While all 7 gamified digital tools were effective across the 3 types of outcomes, they presented different characteristics (ie, game features, targeted audience, and targeted disease for vaccination). Among successful game features, role play or characterization, earning and losing tokens, and advancing levels were the 3 modalities that were the most used and accepted by users across all studies. As for role play or characterization, FightHPV [35] and Stop the Spread [31] were appreciated by users because they included a set of characters that were considered really amusing. In particular, the avatars in Vax! [34] allowed users to better appraise risk perception for infectious diseases as well as to increase one's intent to receive vaccination. Presenting a story with a character with which users could identify might be preferred because the character refers to one's doubts and knowledge and helps virtually measure the impact of one's decision. Character identification can improve risk perception and encourage vaccination uptake [50], since, within the game, the harms of nonvaccination can be virtually self-experimented. Furthermore, following a herd immunity approach [51], some of the games under study made users interact and confront with other imaginary characters to explain the collective dimension and community-level impact of vaccination. Immersive story telling could also have enhanced engagement and subsequent retention of key messages. As for earning and losing tokens, like in I-Vax [32], Land of Secret Gardens [33], and Morbiquiz [30], the presence of tokens in a game might encourage the players and maintain their motivation. The explanation can be found in behavioral theories: reinforcement and punishment contingencies are equally effective as long as they challenge the user [52]. Participants feel their role in the game is active, which makes them more engaged with the game. As for advancing levels, we know from the Stop the Spread game [31] that players enjoy the steady increase in difficulty as the game progresses. However, if games are too difficult, like the first version of FightHPV [35], users stop playing and cannot learn if they do not advance. Thus, it is important to design the game so that players feel challenged but not frustrated. Like earning and losing tokens, advancing levels maintains the interest and motivation of the player. Finally, results showed that using a serious game format, like in most of the studies [24,31,33-35], was not more effective than the other two formats (ie, quiz [30] and website [32]), thus confirming that using gamifying features might be as effective as a full-blown game. Future research including more studies is needed to validate this hypothesis.

As for the targeted audience, apart from 1 study involving parents who were a little skeptical about the trustworthiness of a gamified approach [33], all other studies targeted young people (children, students, young parents) who were attracted by digital gamified tools and represented the most captive audience. About 90% of teenagers play video games [53], and millennials are simultaneously technologically adept with and shaped by technology [54]. As future parents and adults making decisions about their health and the health of their relatives, young people represent a core target group for interventions addressing vaccination coverage.

As for the type of targeted vaccine, all games except Stop the Spread [31] targeted a specific vaccine. This might have been a good strategy to clearly explain one vaccine at a time without confusing the player. Targeting other vaccines like hepatitis, for instance, with new games might be interesting to have a complete spectrum of vaccines explained through gamified digital tools. On the other hand, the design of games seems to be independent from the type of vaccine. This means that the same game might be transferable to all types of vaccine. This could be the case of games like Morbiquiz [30], VAX! [34], and FightHPV [35], whose designs can be easily adapted to other vaccines or vaccine-related diseases.

Finally, the main findings of this review include the relevance of incorporating behavioral theories within the game conception. Almost all gamified digital tools under study were based on solid theories and proved to be effective in facilitating understanding and appraisal of information about vaccines and behavior change endpoints. As suggested by previous literature, theory-driven interventions are more efficacious than those that are not [55], which might further explain the positive outcomes of synthesized tools supported by the gamification approach.

Limitations of this review were the comparative paucity of included studies and the marked heterogeneity of their study design and contents. Publication bias should also be considered, as small studies with negative findings would likely not be published. Furthermore, the scores of some articles were low [33,34] for various reasons including a limited study focus, a research design that was not completely appropriate, nongeneralizable findings, or small sample sizes. Only 3 articles [30,31,34] presented a solid evaluation methodology relying on quantitative and qualitative pretest and posttest data. We also relied on the work of a single coder, which might have introduced systematic bias. However, by omitting a second coder, we wished to ensure consistency in the study selection. Finally, all 7 studies presented positive short-term outcomes, while no long-term impact assessment of the games was conducted.

Recommendations for the Design of Future Interventions

Based on our study, we can suggest how to improve the design of future interventions. Especially during this period of disinformation about vaccination circulating on the internet, gamified digital tools can help provide more accurate information, while being fun and engaging. These recommendations might ensure that produced games are attractive, validated, and effective, especially if they are produced with researchers and professionals in the vaccine domain.

First, the educational perspective is fundamental for all games, but it must be implicit. Interventions should be focused on increasing knowledge and influencing behavior about vaccination without clearly presenting their final aim. Users might unconsciously learn by playing without having the feeling that they are following a training class or didactic presentation. It is important to use a narrative approach with an appropriate story line to engage, motivate, and empower users throughout the learning process. However, the information provided must be factual and trustworthy.

Second, emotional engagement between the player and the environment should be created. Fun contributes to such engagement. Using characters and avatars is a good strategy to capture and maintain the attention of the players. Avatars can self-represent the player in a simulation or role-playing game so that players are immersed in the game; if users are active, their chances to learn increase. Emotional engagement is also reinforced with levels and tokens. Their use is highly recommended for future gamified digital tools. Provide a leaderboard for competition not only with other players but also with oneself as a personal challenge. However, game functions like recovery aids and the pace of the games should be adapted to the public, to avoid frustration with levels that are too difficult.

Third, a balance should be found between simplicity and attractiveness. Future games should pay attention to the design and aesthetics of the game. Using concise text might help with retention of information and knowledge about vaccination, while not stopping the flow of the game. Amusing characters and animations are necessary to make the game appealing.

Fourth, games should take into consideration their target audience. The best solution to achieve this is to co-construct the games with all concerned stakeholders, including end users, through a design-thinking approach [56]. In general, games addressing children and young adults (especially boys) have the advantage of targeting a population who is familiar with video games and computers in general. This might not be the case for older adults.

Finally, before designing a gamified digital intervention, it is important to consider its costs, which are usually very high (at least US $10,000).

Implications for Future Research

Our review suggests that there is a need to continue developing gamified digital tools but also to evaluate the impact of existing and future tools. Great enthusiasm for these games has led to many being produced with insufficient validation of their effectiveness. To better evaluate gamified digital tools in the short term, medium term, and long term, preferred study designs are randomized controlled trials or any other experimental design with a control group, combined with longitudinal data collection. Using a mixed methods design would also be beneficial to comprehensively capture users' opinions and satisfaction with the game. Like in our scoping review, the outcomes to measure might be behavioral indicators like individual vaccination records or intent to get vaccinated, cognitive indicators like an increase in knowledge or vaccine literacy, and indicators of usability/acceptability of the intervention. If possible, all 3 types of outcomes should be measured to better assess the overall qualities of the games. Instruments like the Mobile App Rating Scale [37] could be used for this purpose. These evaluation studies will eventually help us understand how gamified digital tools can change vaccination uptake and coverage.

Conclusions

Gamification is an innovative and promising option to consider when designing vaccination-related interventions addressed to the general public and young people in particular, especially for those who are hesitant about vaccination. Based on the findings of this review, health professionals, health promotion and prevention specialists, and developers are encouraged to use game-based features in interventions aimed to endorse vaccination uptake in order to increase their acceptability and consequent effectiveness. Theory-driven gamified digital tools are preferred.

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Conflicts of Interest

None declared.

Multimedia Appendix 1
Summary of the findings on gamified digital tools in the 7 studies.
[DOCX File , 16 KB - games_v8i2e16983_app1.docx]

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Abbreviations

HPV: human papillomavirus.
MMR: measles, mumps, and rubella.

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Original Paper

Age-Associated Capacity to Progress When Playing Cognitive Mobile Games: Ecological Retrospective Observational Study

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Abstract

Background: The decline of cognitive function is an important issue related to aging. Over the last few years, numerous mobile apps have been developed to challenge the brain with cognitive exercises; however, little is currently known about how age influences capacity for performance improvement when playing cognitive mobile games.

Objective: The objective of this study was to analyze the score data of cognitive mobile games over a period of 100 gaming sessions to determine age-related learning ability for new cognitive tasks by measuring the level of score improvement achieved by participants of different ages.

Methods: Scores from 9000 individuals of different ages for 7 cognitive mobile games over 100 gaming sessions were analyzed. Scores from the first session were compared between age groups using one-way analysis of variance. Mixed models were subsequently used to investigate the progression of scores over 100 sessions.

Results: Statistically significant differences were found between age groups for the initial scores of 6 of the 7 games (linear trend, $P<.001$). Cognitive mobile game scores increased for all participants ($P<.001$) suggesting that all participants were able to improve their performance. The rate of improvement was, however, strongly influenced by the age of the participant with slower progression for older participants ($P<.001$).

Conclusions: This study provides evidence to support two interesting insights—cognitive mobile game scores appear to be sensitive to the changes in cognitive ability that occur with advancing age; therefore, these games could be a convenient way to monitor cognitive function over long-term follow-up, and users who train with the cognitive mobile games improve regardless of age.

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KEYWORDS

cognitive performance; brain training; cognitive monitoring; mobile games; aging; serious games

Introduction

According to the World Health Organization, the proportion of the population aged 60 years and older will double by the year 2050 to an estimated 2 billion people [1]. The two major health-related problems that have been linked to increased life expectancy are an increased risk of falling due to age-related changes in musculoskeletal and neural systems [2] and cognitive decline due to age-related changes in the brain [3]. In the past decade, the use of video games in rehabilitation for various pathological conditions [4] and for improving balance in older adults [5] has become more and more popular.

While healthy aging is associated with some progressive decline in cognitive function, especially in processing speed and executive functions [6], pathological conditions related to aging may abnormally affect cognitive function leading to mild cognitive impairment or dementia. Globally, the number of people with dementia is estimated to be 50 million and with nearly 10 million new cases every year, represents a significant public health problem. The negative impact of cognitive disease on patients, relatives, and nations is a major public health problem which must be addressed [7,8].

Although aging has been shown to be associated with reduced brain plasticity due to structural and functional changes in the brain [9-11]; processing speed, executive function, and memory are the cognitive functions that are most affected by ageing [12]. Numerous cognitive intervention studies have documented that performance improvements during cognitive tasks are maintained until very late in life [13].

The use of video games that are specifically developed to train and challenge the brain (ie, cognitive games) have been popularized by games such as Dr. Kawashima's How Old Is Your Brain [14] and have attracted the interest of adults of different ages. Gamification of cognitive assessment and cognitive training have gained interest in the medical community [15] to increase patient participation and alleviate boredom. The potential of such cognitive mobile games to decelerate the cognitive decline associated with ageing has led to an increase in their use by patients and older adults [16].

In a systematic review [17] that analyzed the efficacy of computerized cognitive training in healthy older adults, it was concluded that this type of intervention was modestly effective at improving cognitive performance in healthy older adults, but also that efficacy varied across cognitive domains. Similarly, a recent Cochrane review [18] found low-quality evidence that suggested that, in healthy older adults, immediately after completion of 12 or more weeks of cognitive training using computerized solutions, small benefits may be seen for global cognitive function when compared with active controls and for episodic memory when compared with an inactive control. This absence of effect is not specific to cognitive mobile games; evidence supporting the benefits of cognitive training programs on functional abilities are sparse, thus warranting further research to identify effective interventions [19].

Mobile technology has spread rapidly around the globe. Today, it is estimated that more than 5 billion people own a mobile device, over half of which are smartphones [20]. As the use of mobile health apps and wearable sensors increases, the impact of digital health technology on patient care increases likewise. In 2017, the number of health-related mobile apps available to consumers surpassed 318,000—nearly double the number that was available just two years prior [21]. This significant increase in the use and availability of health-related devices and apps offers interesting prospects in the medical field, among others, for monitoring and training cognitive functions. Proof-of-concept studies have shown that smartphone-based cognitive testing seems promising for large-scale data collection in population studies [22].

Despite the gain in popularity of cognitive games in both young and older adults, age-related changes in performance with frequent use of cognitive mobile games in an ecological study environment have not yet been investigated.

The aim of this study was to evaluate if cognitive mobile games are useful for monitoring and training cognitive functions in subjects of different ages by (1) assessing if game scores are adequately able to differentiate between different age groups and (2) comparing the trajectories of scores over 100 game sessions to evaluate the extent that people of different ages can improve their cognitive performance.

Methods

Study Design and Participants

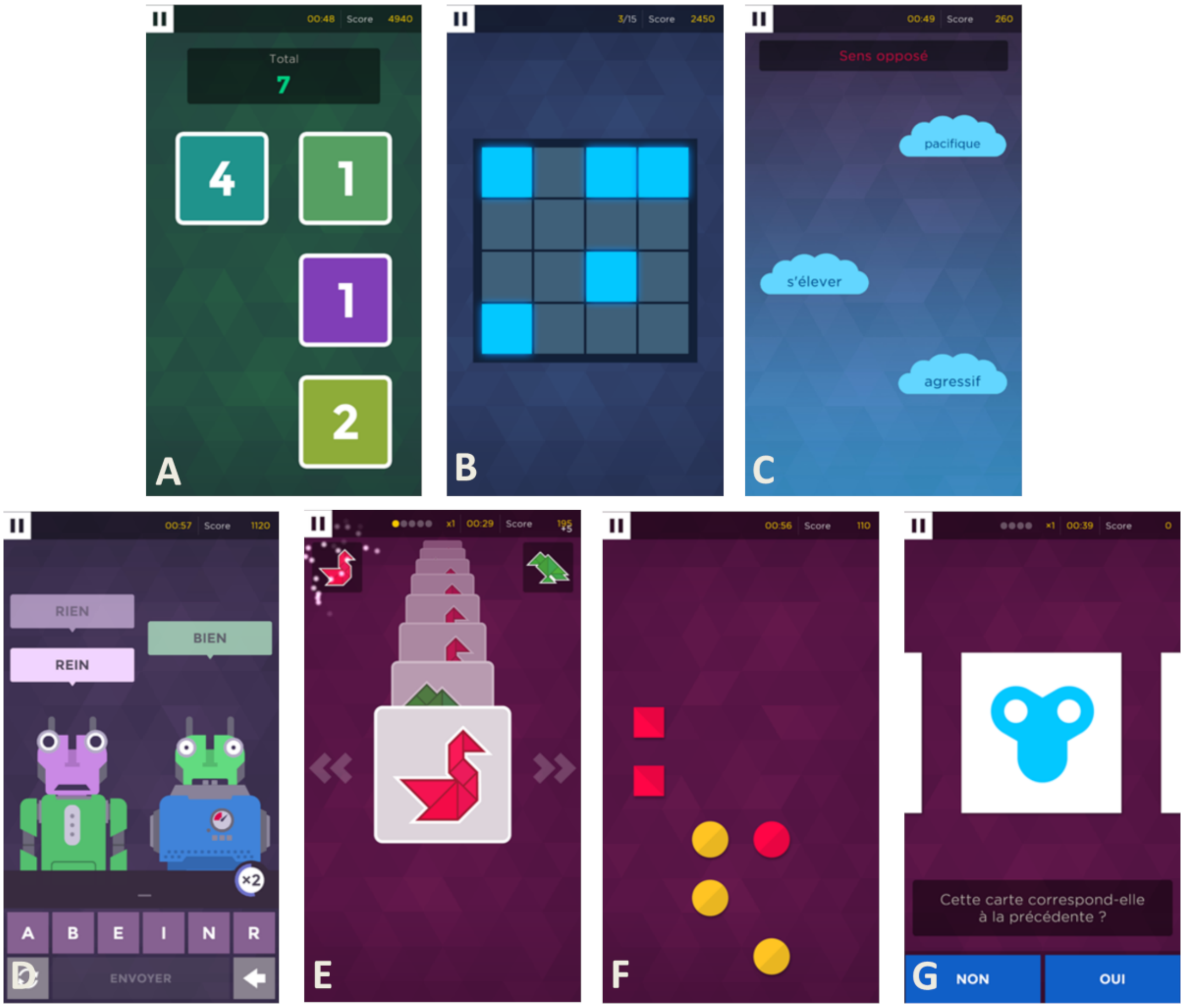
This study was a retrospective observational study which used the anonymized data of 9000 individuals. This study was approved by the Cambridge Psychology Research Ethics Committee (Pre.2020.28) and all participants had agreed that their data could be used for research purposes when installing the app. Data from individuals who met the inclusion criteria (having completed 100 sessions of training with 7 specific cognitive mobile games) were randomly selected from a database provided by Peak Brain Training [23]. Descriptions of the cognitive mobile games that are included in the Peak app are presented in Multimedia Appendix 1. To select the data, simple random sampling was used; 65,428 data sets met the criteria, but a subset of participant data were selected (N=9000) to have the same numbers of participants in each age group (n=1500 per group).

Anonymized scores from the cognitive mobile games which had been automatically recorded by the app were analyzed for each of the six groups: ages 18 to 24 years, mean 21.25 (SD 2.16) years; 25 to 34 years, mean 30.57 (SD 3.28) years; 35 to 44 years, mean 40.29 (SD 4.17) years; 45 to 54 years old, mean 49.42 (SD 3.31) years), 55 to 64 years, 59.66 (SD 3.49) years; and 65 years or older, mean 70.50 (SD 4.16) years. The time of the training was 13 hours (ie, time doing exercises which did not include the pauses between the different cognitive mobile games) and the median duration of the training was 204 (104-346) days with no significant differences between the age groups.

Procedures

Cognitive mobile games (Square Number, Memory Sweep, Word Pair, Babble Bot, Must Sort, Unique, and Rush Back) were used to evaluate the time course of game scores over 100 gaming sessions. The games were organized into categories based upon which main cognitive function they focused. The 7 cognitive mobile games were selected based on a previous study [24] that identified correlations between scores obtained for these 7 particular games and scores in two clinical cognitive assessments (Mini-Mental State Examination and Addenbrooke Cognitive Evaluation) in elderly subjects with and without cognitive impairments [24]. Screenshots of the 7 cognitive mobile games are presented in Figure 1. Full descriptions are presented in Multimedia Appendix 1. The cognitive mobile games could be played on a smartphone or tablet. The scores for 100 sessions were included in the analysis. One session was defined as the completion of one level in the cognitive mobile games. Descriptive session data (mean duration of one session and total training duration) are presented in Multimedia Appendix 2.

Figure 1. Screenshots of the 7 cognitive mobile games selected for this study from the Peak App. A) Square Numbers, B) Memory Sweep, C) Word Pair, D) Babble Bot, E) Must Sort, F) Unique, G) Rush Back.



Outcomes

The main outcome was the score obtained for each session for each of the 7 games for each age group. Each cognitive mobile games had its own scoring system which is described in Multimedia Appendix 1.

Statistical Analysis

For each game, scores from the first session were compared between age groups using one-way analysis of variance (ANOVA) to determine if age had an influence on initial score. Omega-square was used to estimate effect size [25]. Bonferroni tests were used to correct for multiple comparisons in posthoc analysis as well as to test for linear trends.

Then, for each cognitive mobile game, a mixed model with random intercept was used. The scores from each session were treated as repeated measures. The model equation is

where α and $\beta_{1, 2, 3}$ represent fixed effect; $\varepsilon_{i,t}$ represents random error, and α_i represents the measure of the random effect. Fixed effects of age group, session (1 to 100), and the interaction between age group and session were specified. The estimated baseline measures were constrained to be identical in every age groups by subtracting the mean values of each group's first session from all the sessions. This approach was equivalent to adjusting for baseline and permitting the relationship between baseline and follow-up scores to differ at each session. The fact that the explanatory variables were centered using the mean values allowed this effect to be directly interpreted as an intergroup effect [26].

Likelihood ratio tests were used to test the significance of the random effects model and the linear mixed model with interaction. Since we observed a large range in the duration to complete the 100 sessions, we also performed univariate linear regression to assess if the duration of the intervention had an influence on the outcome.

Statistical analyses were performed at an overall significance level of .05 and were carried out in RStudio (version 1.1.442) using R (version 3.4.4) and in STATA statistical software (release 13; StataCorp LLC).

Results

Initial Scores

First session scores differed significantly between age groups for each game (*P*<.001 for each; Square Number, Memory Sweep, Word Pair, Babble Bot, Must Sort, and Rush Back) with the exception of Unique ($F_{5, 8994}$=1.2, *P*=.29), a game which addressed visual attention and recognition. The results of the ANOVA are presented in Table 1. Differences between age groups and posthoc tests are presented in Multimedia Appendix 2. Interestingly, we observed a linear decrease in initial scores with increasing age for all cognitive mobile games except Word Pairs (*P*=.29). In Word Pairs (semantic access), the group aged 65 and older outperformed all other age groups; a linear trend in the opposite direction was identified (*P*<.001) indicating a lower score for younger participants.

Table 1. One-way ANOVA and effect size results for each cognitive mobile game.

Cognitive mobile games	*F* test (*df1*,*df2*)	*P* value	Effect size[a]
Square Number	15.4 (5, 8994)	<.001	0.08
Memory Sweep	534.6 (5, 8994)	<.001	0.23
Word Pair	14.1 (5, 8994)	<.001	0.01
Babble Bot	30.0 (5, 8994)	<.001	0.02
Must Sort	15.9 (5, 8994)	<.001	0.01
Unique	1.2 (5, 8994)	.29	N/A[b]
Rush Back	239.8 (5, 8994)	<.001	0.12

[a]small effect size was <0.01, medium effect size was >0.01 and <0.06, and large effect size was >0.14

[b]N/A: not applicable.

Changes in the Scores

The time course of scores over the 100 sessions are presented in Figure 2 and the results of the mixed model for the interaction between the session and age group are presented in Table 2. Complete results of the mixed model are presented in Multimedia Appendix 3. An important findings of this analysis was the interaction between training session and the age (*P*<.001). A linear trend was found for the interaction between age and session indicating that all age groups improved regardless of which cognitive mobile game was played, but that improvement progress was slower for older participants. To better visualize the influence of age on learning capacity over the course of playing the games, we plotted the normalized results of the 7 cognitive mobile games on separate plots in Figure 3.

No significant correlation was found between the duration of the period for 100 sessions and progress in the games for any of the age groups. Results of the linear regression for the mean progress of the 7 cognitive mobile games and duration of the total training period are presented in Figure 4.

Figure 2. Time courses of the normalized score through the 100 sessions for the different age groups. Grey bands indicate 95% confidence intervals.

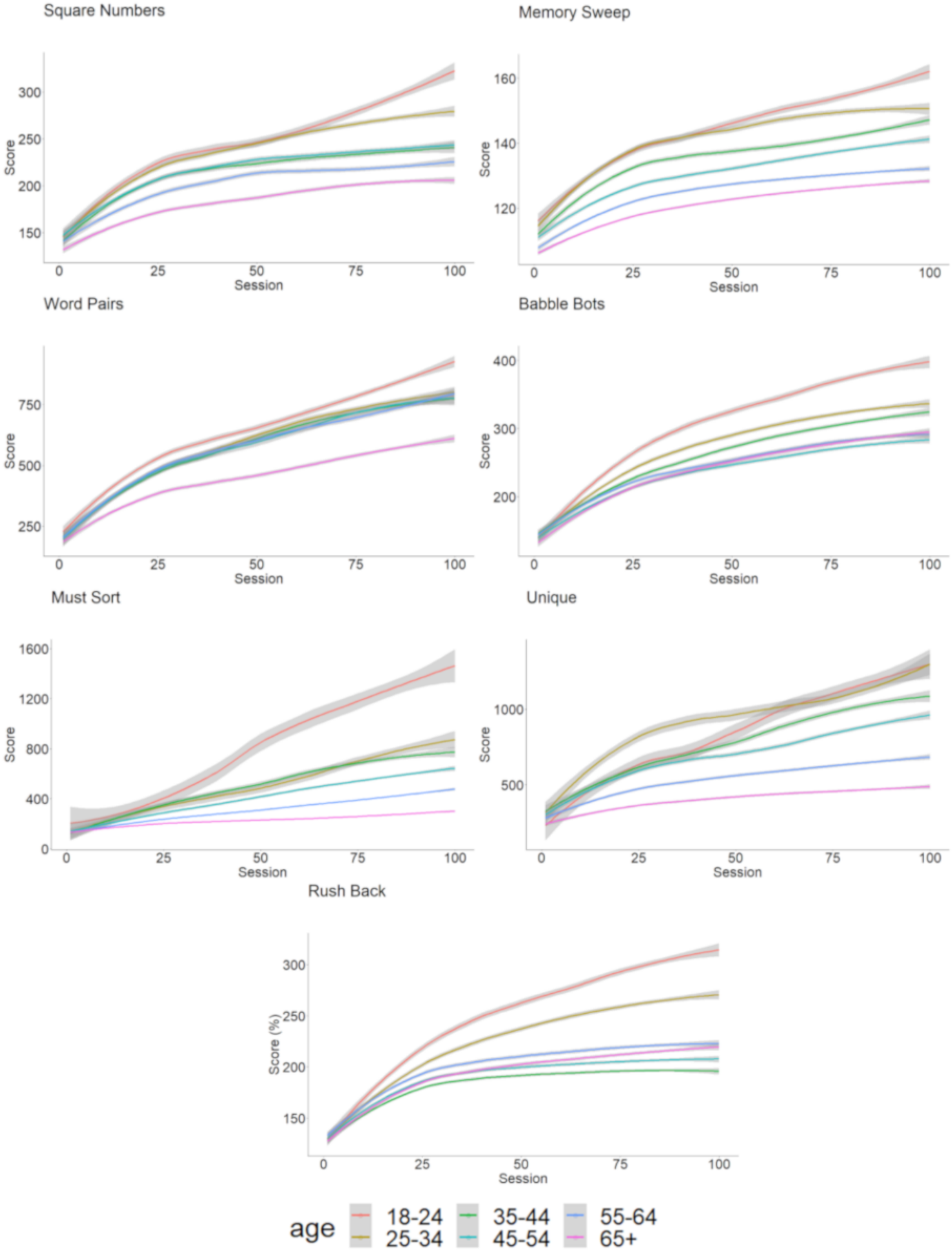


Table 2. Results of the mixed effect model analysis for the interaction between session and age group for each cognitive mobile game.

Cognitive mobile game	β_3 (95% CI)				
	25-34 years	35-44 years	45-54 years	55-64 years	≥ 65 years
Square Numbers	–84 (–93, –76)	–147 (–155, –139)	–191 (–199, –183)	–231 (–239, –223)	–274 (–281, –266)
Memory Sweep	–99 (–104, –94)	–158 (–163, –153)	–207 (–212, –202)	–241 (–245, –237)	–250 (–254, –245)
Word Pair	–6 (–12, 1)	–44 (–49, –39)	–84 (–89, –79)	–111 (–116, 107)	–147 (–152, 143)
Babble Bots	–47 (–50, –43)	–77 (–81, –73)	–102 (–106, –99)	–117 (–121, –113)	–124 (–128, –120)
Must Sort	–68 (–77, –59)	–305 (–314, –297)	–524 (–532, –516)	–683 (–690, –675)	–812 (–819, –804)
Unique	–79 (–84, –74)	–191 (–195, –186)	–270 (–275, –265)	–327 (–332, –322)	–392 (–397, –388)
Rush Back	–82 (–88, –76)	–280 (–285, –275)	–407 (–412, –401)	–478 (–482, –472)	–510 (–515, –505)

Figure 3. Mean normalized results of the 7 cognitive mobile games for the different age groups. $Normalized\ results_i = 100 + [(Results_i - Results_1/Results_1) \times 100]$. Grey bands indicate 95% confidence intervals.

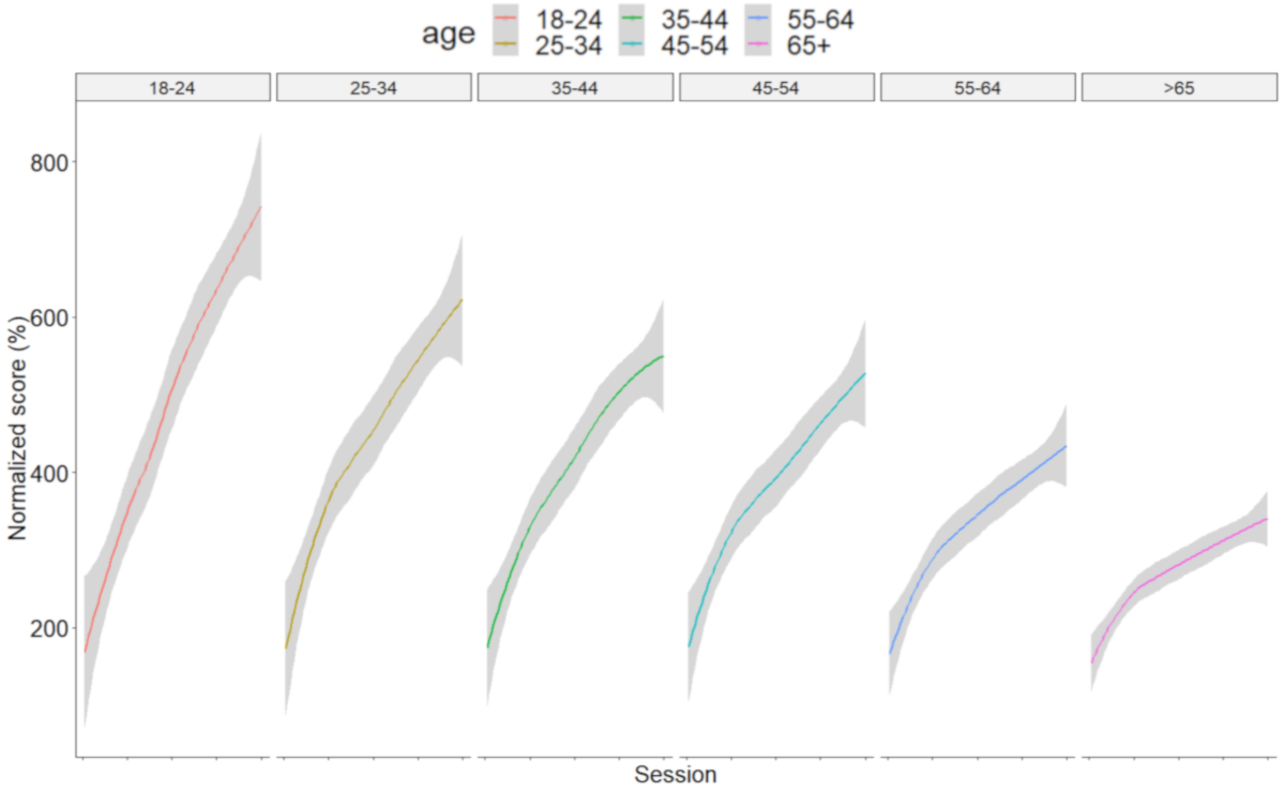
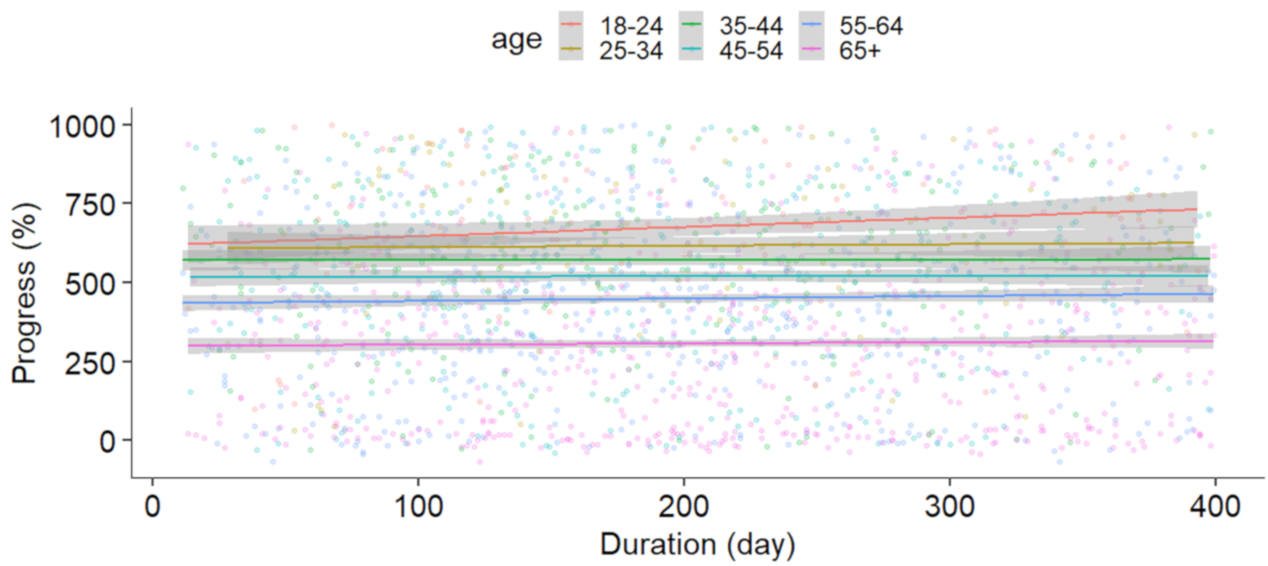


Figure 4. Linear regression between the duration of the period to perform the 100 sessions and the mean progress in the 7 cognitive mobile games for the different age groups (β = 0.02, SE = 0.06, *P*=.71).



Discussion

Principal Findings

This study, using a large sample in an ecological environment, found that lower scores are obtained during the first session in older age groups and that slower rates of progression were apparent in the cognitive mobile game scores of older age groups.

The lower initial score for 6 out of the 7 cognitive mobile games in the older groups is in agreement with the literature that suggests a decline of most cognitive functions—processing speed, memory, visuospatial skills, and executive functions—with advancing age [27]. In interpreting our results, the following considerations must, however, be taken into account. Age-related decline can affect other functions. It has been demonstrated that other processes such as slower reaction speed [28], poorer vision [29], and slower motion [30] with advancing age and could also affect performance in cognitive mobile games. In addition, familiarity with touchscreen tools is generally lower in the elderly population [31]. Therefore, the observed differences in initial cognitive mobile game scores between groups may not be due solely to the changes in cognitive function that occur with advancing age. This observation was supported by the nonsignificant effect of age on the first session score for the cognitive mobile game Unique. This game required visual attention and recognition skills, but was less dependent on reaction time, dexterity, and familiarity with mobile devices compared to the other cognitive mobile games.

Our findings, both for the initial scores and the evolution over time, are in agreement with those of a previous study [27] indicating that not all cognitive functions are affected by age in the same way; simple attention, semantic knowledge, vocabulary, and autobiographical remote memory appear to be more resistant to the regressive effects of aging [27]. A longitudinal study [32] showed that a decline in the ability to rapidly process information and to invoke executive processes occurs across the lifespan and is more pronounced after the age of 60. This is similar to what was observed for Must Sort and Rush Back. In contrast, semantic memory and short-term memory have shown remarkable preservation across most of the adult lifespan, with declines occurring only very late, and not systematically, in life [9]. On the other hand, some functions seem to improve with normal aging, such as semantic memory and richness of vocabulary [33] as well as verbal abilities [27], which is in line with the better scores that were observed for Word Pair in older age groups compared to those of the younger age groups but that were not observed in Babble Bot. Although both cognitive mobile games focus on verbal abilities, the nature of the task in each is quite different: Word Pair challenges semantic memory and understanding of the words to pair them, while Babble Bots required a good knowledge of word spelling to form words based on random letters. This observation is therefore in agreement with the literature showing that retrieval of the meaning of words and other semantic processes are preserved whereas written and spoken spelling abilities are affected by ageing [34].

While changes in the different cognitive abilities over the lifespan have been relatively well documented [3,35,36], there has been less evidence on the ability to learn new cognitive tasks across the lifetime [37,38]. Our findings showed that cognitive mobile game scores increased in all age groups demonstrating that, although the older population is generally considered to be less familiar with the use of touchscreen technology [30], adults aged 65 and older are nevertheless able to benefit from this mobile game training to improve their cognitive performance. Despite slower progress being evident in older age groups, the results demonstrated that cognitive function remains plastic across the lifespan [39]

Strengths and Limitations

The strengths of this study were the large sample size and that results were obtained in an ecological environment, which increases external validity.

The main limitation of this study was that only scores from the cognitive mobile games were used to assess the progression, and information about the cognitive health or the level of education of the participants were not collected, nor was the level of attention and concentration of the participants during the exercises known. Furthermore, due to the design of the study which used longitudinal analysis of the scores from cognitive mobile games performed by real users of the app, we did not have control groups. Since the results of the cognitive mobile games were used as the outcome to assess the participants, we indirectly evaluated a set of the two to three cognitive abilities used for each cognitive mobile game, rather than one specific cognitive function [40].

Also, due to the retrospective design of this study, we must acknowledge that most of the participants of this study were probably quite familiar with new technologies [41] and that our results may be not generalizable to the general older population.

Future Works

Little is currently known about whether cognitive skill improvements from playing cognitive mobile games are transferable to real-life, which represents a major challenge in this field of research [39]. Further studies should, therefore, try to elucidate the possibility of transfer between cognitive mobile games performance and activities of daily living.

One study [42], conducted over a 10-year period, suggested that the risk of dementia could be reduced in individuals who took part in a computerized cognitive training that aimed to improve speed of processing. This observation is encouraging, but more long-term longitudinal studies are needed to determine if cognitive mobile games can be used to slow or detect early signs of cognitive decline [43,44].

Further studies are also needed to evaluate how the scores obtained in the cognitive mobile games correlate with clinical neuropsychological assessments and cognitive functioning in everyday life in patients with various pathologies or dementia [45].

In general, the use of cognitive mobile games as digital biomarkers for real-life monitoring of cognitive functions in apparently healthy subjects and patients requires further investigation to evaluate its feasibility (as well as in subjects unfamiliar with smartphones technology) and to determine which outcomes are best correlated with cognitive decline [46].

Conclusions

Our results show that the initial scores of most of the cognitive mobile games were lower for older age groups, as expected from a physiological viewpoint. The rate of the cognitive performance progress, as measured by changes in the cognitive mobile game scores, is dependent on age, but participants of all ages were able to improve their performance.

These findings suggest that cognitive mobile game scores are sensitive to changes in the cognitive abilities that occur with advancing age and that all age groups can learn new skills using mobile technology. These encouraging results open up the possibility of using cognitive mobile games to simultaneously train and monitor cognitive functions, facilitating cheaper and more regular follow-up. With clinicians facing increasing financial and time constraints, and therefore, less time for face-to-face consultations with patients [43], this type of monitoring might be of particular benefit to detect early signs of cognitive decline and to offer more efficient preventive interventions. Additional research is required to test the validity and feasibility of this kind of approach before it can be applied to clinical practice.

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Authors' Contributions

BB performed the analysis and wrote the first draft of the manuscript. JCB and OVH co-wrote the manuscript. JL and SSh supervised data collection and co-wrote the manuscript. SSa, MK and FK-S supervised the analysis and co-wrote the manuscript.

Conflicts of Interest

SSh work for Peak Brain Training. The other authors declare no competing interests.

Multimedia Appendix 1
Instructions, cognitive abilities trained and scoring system of the CMG included in this study.
[DOCX File , 173 KB - games_v8i2e17121_app1.docx]

Multimedia Appendix 2
Time per session and total training time for each CMG.
[DOCX File , 12 KB - games_v8i2e17121_app2.docx]

Multimedia Appendix 3

Results of the one-way ANOVA and post-hoc analyses, ω2 is the measure of the effect size (ω2 < 0.01 = small, between 0.01 and 0.06 = medium, ω2 > 0.14 = large) – and scores differences [95% confidence interval] between age group (the youngest groups are taken as reference values).
[DOCX File , 18 KB - games_v8i2e17121_app3.docx]

Multimedia Appendix 4
Results of the mixed effect models analysis. ß coefficient [95% CI].
[DOCX File , 16 KB - games_v8i2e17121_app4.docx]

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Abbreviations

ANOVA: analysis of variance

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Review

Controlling for Placebo Effects in Computerized Cognitive Training Studies With Healthy Older Adults From 2016-2018: Systematic Review

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Abstract

Background: Computerized cognitive training has been proposed as a potential solution to age-related cognitive decline. However, published findings from evaluation studies of cognitive training games, including metastudies and systematic reviews, provide evidence both for and against transferability from trained tasks to untrained cognitive ability. There continues to be no consensus on this issue from the scientific community. Some researchers have proposed that the number of results supporting the efficacy of cognitive training may be inflated due to placebo effects. It has been suggested that placebo effects need to be better controlled by using an active control and measuring participant expectations for improvement in outcome measures.

Objective: This review examined placebo control methodology for recent evaluation studies of computerized cognitive training programs with older adult subjects, specifically looking for the use of an active control and measurement of expectations.

Methods: Data were extracted from PubMed. Evaluation studies of computerized cognitive training with older adult subjects (age ≥50 years) published between 2016 and 2018 were included. Methods sections of studies were searched for (1) control type (active or passive) and subtype (active: active-ingredient or similar-form; passive: no-contact or passive-task); (2) if expectations were measured, how were they measured, and whether they were used in analysis; and (3) whether researchers acknowledged a lack of active control and lack of expectation measurement as limitations (where appropriate).

Results: Of the 19 eligible studies, 4 (21%) measured expectations, and 9 (47%) included an active control condition, all of which were of the similar-form type. The majority of the studies (10/19, 53%) used only a passive control. Of the 9 studies that found results supporting the efficacy of cognitive training, 5 were for far transfer effects. Regarding the limitations, due to practical considerations, the search was limited to one source (PubMed) and to search results only. The search terms may have been too restrictive. Recruitment methods were not analyzed, although this aspect of research may play a critical role in systematically forming groups with different expectations for improvement. The population was limited to healthy older adults, while evaluation studies include other populations and cognitive training types, which may exhibit better or worse placebo control than the studies examined in this review.

Conclusions: Poor placebo control was present in 47% (9/19) of the reviewed studies; however, the studies still published results supporting the effectiveness of cognitive training programs. Of these positive results, 5 were for far transfer effects, which form the basis for broad claims by cognitive training game makers about the scientific validity of their product. For a minimum level of placebo control, future evaluation studies should use a similar-form active control and administer a questionnaire to participants at the end of the training period about their own perceptions of improvement. Researchers are encouraged to think of more methods for the valid measure of expectations at other time points in the training.

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KEYWORDS

computerized cognitive training; brain training; placebo; active control; elderly; older adults

Introduction

Cognitive Training as a Solution for Age-Related Cognitive Decline

As the many of the world's nations face increasingly older populations, much attention has been given to how to limit the deleterious effects of aging on cognitive functioning, which are marked by a decrease in performance on a number of cognitive tests in the domains of memory, speed of processing, executive functioning, attention, and visual perception [1-4]. One proposed solution is computerized cognitive training, which has shown some promise in slowing age-related cognitive decline [5-7]. However, evaluation studies of computerized cognitive training have shown that it is still unclear whether success at training transfers to improved cognitive ability (see the following section for an explanation of transfer effects). Two opposing scientific consensus statements on this matter, signed by hundreds of scientists each, were published in 2014 [8,9]. Various studies have found significant effects of cognitive training on far transfer tests (indicating effects on broader categories of cognitive functioning) [5,6,10] or that cognitive training does little more than to improve abilities on near transfer tests (indicating effects on tasks similar to the training), with no indication of far transfer [11-13]. With such discrepancy in the field, some researchers have turned to analysis of the methodology used in cognitive training studies and identified, among other issues, a failure to properly control for placebo effects [12,14,15], which are systematic factors related to, but separate from, the training itself that may have been a causal component of observed effects [16] (see the "What Is the Placebo Effect" section for a more detailed explanation).

Transfer Effects: Near and Far

The term "transfer effect" indicates a significant, positive change on an outcome measure that is separate from the training itself and observed after completion of the training. The level of ecological validity for a transfer effect is denoted by the preceding word "near," "far," and sometimes "real-world" or "daily life." This review is concerned with claims of near and far transfer. If an outcome measure is very similar to the tasks in the training, this is considered a measure of near transfer. For example, a training game might have a gamified version of an n-back task, with slight variations; this would make an n-back test one of near transfer for this game. Other tests of specific elements of working memory might also be considered tests of near transfer. Far transfer is assessed by tests of broad cognitive domains, such as memory, processing speed, or cognitive control. More comprehensive tests of working memory or a conglomeration of tests of different working memory elements would be considered tests of far transfer. I am not aware of any official methods to determine whether a particular outcome measure is one of near or far transfer. Rather, the aforementioned general guidelines are used in this review to categorize studies as reporting near or far transfer in the event that they do not label their own findings as such. Any result indicating either near or far transfer effects will be referred to in this review as having a positive result.

What Is the Placebo Effect?

The placebo effect has been studied for over 100 years [17] and is well-known in pharmaceutical research, especially research involving pain [18-20] and mood disorders [21-23]. In such studies, a sham treatment is administered in order to ensure that any positive response of the treatment is not due to the "symbols, rituals, and behaviors embedded in the clinical encounter" [24], such as the patient's own expectations for improvement or social interactions with the clinician. Placebo effects do not necessarily replace an effect of the treatment; they can also occur alongside and interact with an effective treatment. For instance, a warm and caring demeanor on the part of the clinician administering medication may interact with the chemical components of the medication itself to produce an even stronger reduction in the patient's subjective experience of pain [25]. The problem occurs when this effect systematically occurs differently in one experimental condition than in the other. If this phenomenon occurs without being detected by researchers, it could appear to be an effect caused by the experimentally manipulated variable (the medication). When properly controlled for, a control condition should elicit an equal placebo response to the experimental condition, strengthening evidence that any effect found was due to the treatment itself.

Controlling for the Placebo Effect in Cognitive Training Studies: Active and Passive Controls

Pharmaceutical research uses double-blinding, random assignment, and utilization of a placebo treatment to minimize differences in possible placebo effects between control and experimental conditions. Two proposed solutions in cognitive training are the use of a carefully designed active control condition and the measurement of participant expectations for improvement [14]. In the following two sections, I give definitions of active controls and passive controls as well as two subtypes for each type of control that describe common methods for their implementation.

Active Controls: Active-Ingredient and Similar-Form Types

An active control game is meant to generate the same expectations for improvement on a cognitive assessment as the experimental training game, without providing the essential elements of the training that drive the effect on cognition. An ideal active control game, then, might be identical to the experimental game in every respect except for one, the hypothesized "active ingredient" that drives the effect of the game on cognitive performance [14,26]. For the purposes of this review, this will be referred to as the active-ingredient type of active control. In one example, in a multitasking game created to improve interference resolution (believed to be a component of executive control), Mishra et al [26] created a nearly identical game to serve as the active control but focused the challenge on the attention element of the game, rather than the interference element. In the second example, in a cognitive training game targeting multitasking ability, Anguera et al [27] created a single-tasking version of the game for the active control condition.

A similar-form type of active control mimics the training game in form but differs in details of the gameplay in more than one way. For instance, Cujek and Vranic [28] tested a computerized version of a challenging card game as cognitive training and used a computerized dice game as an active control. Between the conditions, the constants were the time spent playing a game at a computer and interaction with the experimenter. Ideally, participants would be unable to figure out from the gameplay if they were in the experimental or control condition, and expectations for improvement between conditions would remain constant. While perhaps less powerful than an active-ingredient type at generating similar expectations to the experimental training, the similar-form type is less demanding on study resources and is better suited to control for expectations than a passive control.

Passive Controls: No-Contact and Passive-Task Types

A common practice in cognitive training studies is to use a passive control game [12]. This review uses the term no-contact passive control to refer to studies where control subjects do not engage in any training and take only the pretest and posttest of cognition, often not speaking to researchers in between. This review uses the term passive-task passive control to refer to studies that have control subjects engage in an activity that shares little similarity with the experimental training program, such as watching educational DVDs or reading about cognitive training literature, and would be very unlikely to generate the same sorts of expectations (though expectation data could theoretically contradict this proposition).

Evidence for Poor Placebo Control in Computerized Cognitive Training Studies

In a paper published in 2013, Boot et al [14] suggested that differences in expectations for improvement between groups could be responsible for some or all of the published positive results in the cognitive training literature. In several studies of the effects of video games on cognition [29,30], fast-paced action video games were tested as potential cognitive enhancers, with slower-paced video games as the control condition. Boot and colleagues [14] surveyed a sample uninvolved in other video game studies for general expectations regarding the video games tested in those studies. The results of the survey predicted the observed results found by those studies of video game play on cognition, supporting the claim by Boot et al [14] that placebo effects could not be ruled out as a driver of some or all of the observed effects. In 2016, a large-scale systematic review of cognitive training literature by Simons et al [12] concluded that, among other methodological issues, many studies still lacked an active control group and were therefore, at best, weak evidence for the effectiveness of the cognitive training games tested.

Study Groups May Systematically Form Expectations That Impact Results

There is evidence that self-selection bias may be systematically contaminating results of cognitive training studies. Simply changing the method of recruitment created groups that would perform differently on outcome measures, despite being matched in nearly every other way. Overtly advertising the opportunity to participate in a cognitive training study (eg, “Brain Training & Cognitive Enhancement”) recruited a sample that achieved higher on tests of cognition after training, compared to a sample that was recruited via a neutral advertisement (eg, “Email Today & Participate in a Study”) [15]. Groups were matched for intelligence and motivation, and the groups performed equally well on the training tasks. The only measurable difference, other than performance on outcome measures, was that questionnaire data indicated the overtly recruited group had a stronger belief that intelligence is malleable rather than a fixed property of genetics. This study provides evidence that overt recruitment methods alone can create samples biased towards belief in the effectiveness of cognitive training, which can interact with the experimental condition to generate an improvement on outcome measures.

There are signs that overt methods are a common method of recruitment. Foroughi et al [15] checked recruitment methods for studies in a meta-analysis by another author [31] and found that 17 of the 19 studies had used overt recruitment methods. In this review, recruitment methods were not assessed; however, it is notable that the majority of studies may be unintentionally and systematically recruiting subjects that hold optimistic beliefs about the power of cognitive training.

Other Evidence of Optimism About the Effectiveness of Cognitive Training

People generally believe that cognitive training is effective [32]. Furthermore, participants indicated higher or lower optimism for the effectiveness of cognitive training after the researchers showed them brief statements about the topic. The majority of elderly participants in one cognitive training study believed they had improved, even though no significant improvement had been found at the group level. Goghari and Lawlor-Savage [33] provided an analysis of expectation data; for actual cognitive training data, see the 2017 article by Goghari and Lawlor-Savage [34]. This indicates there may be a general optimism in elderly populations that cognitive training is effective.

Placebo Effect Versus a Motivation Effect

There is another way to consider expectation effects: For cognitive training to be effective, a person needs to believe in it in order to approach the training in a motivated way. When is it a placebo effect, and when is it an interaction between the training program and motivation? I will differ on this question here. The question underlying this review was not the mechanism of how expectations may influence observed effects or even if expectations influence observed effects, but rather, in light of evidence that expectations may impact performance on outcome measures in cognitive training studies, are recent studies measuring and properly controlling for expectations between groups?

Why Is it Imperative to Control for a Placebo Effect in Cognitive Training Research?

Unsupported claims about cognitive training carrying the blessing of scientific research can have direct consequences for society. Such claims may encourage people to spend time or money on cognitive training games, especially older adults that may be experiencing age-related cognitive decline and are therefore vulnerable to the marketing tactics of game makers. One example of such a claim about cognitive training studies is "What they show is that for the average person, our exercises truly speed up and sharpen the brain" [35]. Studies, such as that by Grönholm-Nyman et al [11], and meta-analyses, such as that by Sala and Gobet [36], have provided evidence against the existence of far transfer from cognitive training studies, but enough positive results exist [5,10] that the debate continues.

Population: Healthy Older Adults

Cognitive ability may begin to decline due to age starting as early as 25 years old [37], resulting in a decrease in functionality for functions such as memory, speed of processing, executive functioning, attention, and visual perception [1-4]. Rather than viewing the new arrival of computerized cognitive training with fear or distrust, there are signs that older adults are generally optimistic about the effectiveness of such training [32,33]. There is some evidence that cognitive training may result in improvement on cognitive tests and effectively slow age-related cognitive decline in older adults [5-7], especially for narrow transfer effects [12,38]. However, there is an opportunity cost: If cognitive training is not effective at improving cognition or slowing decline, older adults could be wasting valuable time that could be spent exercising, socializing, or engaging in other activities for which there is stronger evidence of a benefit to cognition [12,39].

Objective and Scope of This Review

In light of the diverging results in the cognitive training literature, evidence for potential widespread placebo effects in cognitive training studies should be taken seriously. If studies are not controlling for placebo effects, the possibility cannot be ruled out that this is a systematic methodological problem, falsely inflating the number of positive results. This review examined cognitive training literature from the previous 2 years (2016-2018) in studies of healthy older adults, specifically to determine the proportion of current studies focused on this population that properly controlled for potential placebo effects. Placebo control was assessed primarily by whether participant expectations for improvement were measured (in any form) and whether the study included an active control condition. Special attention was paid to studies that report far transfer effects. Studies with poor placebo control that find positive results for far transfer effects form the basis for the most extreme and potentially most egregious claims in the cognitive training game industry.

Methods

Registration

This review was not pre-registered. However, it was structured based on the PRISMA guidelines [40]. This review was conducted to fulfill a paper assignment for the Master's Program at the Berlin School of Mind and Brain at Humboldt-Universität zu Berlin.

Eligibility Criteria

Inclusion criteria were as follows: randomized controlled trials (including exploratory studies); participants ≥50 years old; participants not diagnosed with any cognitive disorder, including mild cognitive impairment; administration of the experimental cognitive training in electronic form, such as on a computer or tablet; outcomes were assessments of cognitive ability; and studies published between 2016 and 2018.

Exclusion criteria were as follows: training interventions of which the target was motor ability, such as gait; an experimental variable in a form other than that of computerized cognitive training, such as transcranial direct current stimulation (tDCS) dosage, exercise, or viewing instructional videos; reviews, metastudies, and other nonrandomized controlled trials; participants younger than the minimum age or with diagnosed cognitive impairment or neurodegenerative disease; studies published before 2016; and studies unavailable in an English translation.

The criteria were established to be able to make a generalization about current placebo control practices in studies that fit the aforementioned criteria. Motor activity as a target of cognitive training involves different enough sorts of training and tests than ones used for measurement of other cognitive abilities that it would widen the scope of the review too much. The time range was limited to the past 2 years so that the review can serve as a measurement of current standards of placebo control in cognitive training research. A healthy population was chosen because methods for recruitment, training, and testing of impaired populations may vary widely from those of healthy populations. Methodological practices in healthy populations of this age group may also be more easily comparable to those of healthy populations in other age groups. The definition of an older adult varies between studies, but the age was set to ≥50 years to be more inclusive.

Information Sources

Studies were identified via a search of PubMed Online performed on December 1, 2018 by the study author. Each item that appeared in the search result was evaluated according to the inclusion and exclusion criteria.

Search

The formula of search terms entered into PubMed was: ("2016/01/01"[Date - Publication] : "3000"[Date - Publication]) AND (cognitive[Title/Abstract]) AND (training[Title/Abstract]) AND ((game[Title/Abstract]) OR (computer[Title/Abstract])) AND ((older adult*[Title/Abstract]) OR (elderly[Title/Abstract])) NOT ((physical[Title]) OR (motor[Title/Abstract]) OR (exercise[Title]) OR (movement[Title]) OR (walking[Title/Abstract]) OR (gait[Title/Abstract]) OR (MCI[Title/Abstract]) OR (mild cognitive impairment[Title/Abstract]) OR (Alzheimer*[Title/Abstract])).

Study Selection

Eligibility was assessed according to the previously described inclusion and exclusion criteria. Following the search, titles and abstracts of each returned result were reviewed for search criteria. If eligibility could not be determined in this way for a given paper, the methods section was inspected more closely. Eligibility was possible to determine for all studies using this method.

Data Collection Process

The aforementioned search query was constructed by trial and error until most of the undesired study types (eg, motor ability as an outcome measure) were not returned in search results and many results for the desired study types (cognitive training game evaluations) were. A printout of results for the official search was saved. Each study on the list was then systematically checked for inclusion and exclusion criteria, first by looking at the title and abstract, then in the Methods section if needed. Data items of interest (see next section) were recorded in an Excel document for each included study.

Data Items

The following data items were coded for each study. First, the measurement of expectations was coded as yes or no. If "yes" was determined for expectations measured, then how they were measured and if the expectation measurements were used in the analysis of the cognitive training results were recorded. Second, the control type (active or passive) was recorded. If the control type was active, the subtype (active-ingredient or similar-form) was recorded. If the control type was passive, the subtype (no-contact or passive-task) was recorded. Third, positive results were defined as a significantly higher score on the outcome measures for the experimental group. If positive results were found, the type (near transfer, far transfer, or both) was recorded. Fourth, if expectations were not measured, whether the authors mentioned this as a limitation in the discussion section (yes or no) was recorded. Fifth, if an active control was not used, whether the authors mentioned this as a limitation in the discussion section (yes or no) was recorded.

The reason for coding for positive results was to calculate the proportion of studies that found positive results that were performed without good placebo control (as defined by this review) compared to the overall number of included studies. This number was used as a metric of the proportion of cognitive training studies with methodology that may be biasing results and therefore, consensus in favor of efficacy.

Near and far transfer were determined based on whether the authors claimed their results reflected near or far transfer and on an investigation of the description of the outcome measure by the reviewer to see if these outcome measures were meant to reflect more general measures of cognition (far transfer) or specific tests of subcategories (near transfer).

Effect sizes were not recorded as this is review was meant as an inquiry into methodology, not as a synthesis of results.

Summary Measures and Synthesis of Results

A summary of the data collected for the listed items is presented in the Results section. Conclusions were drawn about whether cognitive training studies are properly controlling for placebo, based on the proportion of studies measuring expectations and of those using an active control.

Results

Study Selection

The initial search of PubMed returned 38 results. Of these, 19 met the eligibility criteria, and 19 were excluded. Studies were excluded if: they were preregistered trials that had not yet returned results (3 articles), they were not evaluation studies of cognitive training on cognitive performance (15 articles), or were focused on subjects' perceptions of the benefits of playing these games (1 article). The 15 articles excluded for being nonevaluation studies were comprised of: 2 correlational studies, 1 usability study, 1 survey of preferences (not expectations), 1 study with "flow" as an outcome measure (a measure of player absorption into a game), 1 evaluation study of tDCS on cognitive ability, 1 that used electroencephalogram gamma activity as an outcome measure, 1 that included a cohort of younger adults, and 6 studies that fell into one of the following categories: metastudy, review, conference proceedings, or opinion essay. Another paper was excluded because, although it stemmed from a cognitive training evaluation study, its focus was on subjects' perceptions of the benefits of playing these games [33].

While it was not a study of a training game, 1 paper that was a study of general iPad training in improving cognition was included [41] because it was computerized training (via tablet) and followed the clinical evaluation format. Although it used several arcade-style games as the cognitive training and had other signs of methodological problems with reporting and possibly English translation issues (ie, used a dementia screening examination as a test of global cognition), 1 study [42] was included because it presented itself as an evaluation of "electronic cognitive training games" in its title; it was returned in the search results and had the potential to affect general perceptions of cognitive training game effectiveness.

Study Characteristics

Studies That Measured Expectations

Of the 19 included studies, only 4 (21%) studies made any attempt to measure expectations to improve their experimental and control interventions (Table 1). Of those 4 studies, 3 used the expectation data in the interpretation of results. Of the 4 studies, 2 used an active control of the similar-form type, while 2 used a no-contact, passive control group (see next section for results on the use of active controls). Of the 4 studies that measured expectations, 2 found positive results for near transfer effects, and none found positive results for far transfer. Of the 15 studies that did not measure expectations, 5 mentioned this as a potential limitation of their study, while 10 did not, which suggests that the authors were either not aware of this as or did not believe this to be a potential confounding factor.

Table 1. Studies that measured expectations.

Search result #	Study	Control type	Control subtype	How were expectations measured?	Used in analysis of results?	Positive result?	Transfer
6	Souders et al (2017) [38]	Active	Similar-form	Expectation for improvement in various cognitive modalities measured at end of intervention	Yes	Yes	Near
14	Hynes (2016) [43]	Passive	No-contact	One question on questionnaire following training: "How much do you think you benefited from the training?" Rating: 2.62 of 4 (SD 0.67)	Yes	No	—[a]
21	Guye and von Bastian (2017) [44]	Active	Similar-form	Three questions after the post-assessment: improvement in trained tasks, in untrained tasks, and in everyday life tasks	Yes	No	—[a]
30	Yeo et al (2018) [45]	Passive	No-contact	One question after assessment: did your memory improve?	No	Yes	Near

[a]Positive results were not reported.

Active Control

Of the 19 included studies, 9 (47%) included an active control in the study design. None of these utilized an active-ingredient type game, such as that suggested by Mishra et al [46], where the control game mirrors the experimental in every way except for one factor hypothesized to drive the effect of training on cognitive ability. All 9 used a similar-form type of active control, where both groups play a game presented in a similar form for a similar amount of time, although details of the games themselves may vary (eg, the puzzle game suite, administered on a tablet, that served as the active control for the tablet-based training game suite used by Souders et al [38]). Of these studies, 3 also included a passive control group. Of the 9 studies using an active control, 7 found positive results: 6 for near transfer and 1 for far transfer.

Passive Control

Of the 19 included studies, 10 used a passive control and no active control group. Of these 10 studies, 5 used passive-task control groups, which completed simple tasks such as meeting the experimenter or reading information pamphlets about cognitive training. The other 5 studies used no-contact control groups that simply took the cognitive assessment tests before and after the experimental group had completed its training. Of the 10 studies that did not use an active control, 9 (90%) reported a significant positive effect of training, when compared with the control; 1 of these studies measured expectations but in a limited capacity and did not include this measurement in analysis of results. Of these 9 positive results, 5 were for near transfer effects, 2 were for far transfer effects, and 2 were for both near transfer and far transfer effects. Of the 10 studies that used only a passive control, only 4 mentioned this as a limitation to their study results, suggesting a potential lack of awareness on the part of the authors of the remaining 6 studies. Of these 6 studies that did not mention this limitation, 2 wrongly claimed to have included an "active placebo" condition (both studies had the same principle author; see the Discussion for more information).

Far Transfer

A significant, positive effect of training on tests of far transfer were reported by 6 studies. None of the studies measured expectations. Only 1 included an active control [28], 4 used passive-task controls, and 1 used a no-contact passive control.

Results of Included Studies

Table 2 presents the results of the included studies.

Table 2. Results of included studies.

Search result #	Study	Control type	Control subtype	Description of conditions	Expectations measured?	Known limitation: expectations?	Known limitation: active control?	Positive result?	Transfer	Description of result
4	Cujzek & Vranic (2017) [28]	Active	Similar-form	Experimental: challenging computerized card game; active control: computerized dice-rolling game	No	No	__[a]	Yes	Far	Reasoning test (D-48) was different enough from skills required for the card game for authors to conclude that this was evidence of far transfer. Effect was maintained at 4-month follow up.
6	Souders et al (2017) [38]	Active	Similar-form	Experimental: Mind Frontiers suite; active control: puzzle game suite	Yes	__[b]	__[a]	Yes	Near	Corsi block tapping test (memory) was similar to game task. However, expectations for improvement may actually have MASKED observed improvement.
7	Kühn et al (2017) [47]	Both	Active: similar-form; passive: no-contact	Experimental: Inhibition training game on a tablet; active control: general-purpose cognitive training platform; passive: pretests and posttests only	No	No	__[a]	Yes	Near	Experimental group showed significant improvement on inhibition task while other groups did not.
8	Ballesteros et al (2017) [48]	Active	Similar-form	Experimental: Luminosity games; active control: The Sims or SimCity Build	No	No	__[a]	No	__[c]	Nonsignificant trend on n-back task for training; significant effect for group on oddball task in favor of active control
10	Pereira-Morales et al (2018) [49]	Passive	Passive-task	2 experimental groups: computerized training and computerized + pen and paper training; control: read brochure about cognitive training	No	No	No	Yes	Far	Experimental groups improved on cognitive tests more than passive control group. Experimental groups could not be considered active controls for each other because they were the same training, although one had additional training.
12	Lussier et al (2017) [50]	Passive	Passive-task	2 experimental groups: VPT[d] vs FPT[e]; passive control: computer classes	No	No	No	Yes	Both	VPT had larger effect than FPT for near transfer and smaller effect for far transfer.

Search result #	Study	Control type	Control subtype	Description of conditions	Expectations measured?	Known limitation: expectations?	Known limitation: active control?	Positive result?	Transfer	Description of result
13	Toril et al (2016) [51]	Passive	Passive-task	Experimental: Luminosity, 15 1-hr training sessions; control: met with experimenter once a month	No	Yes	Yes	Yes	Both	Jigsaw puzzle task, digit forward (short-term memory), and Faces I and Faces II (episodic memory), Corsi Blocks; also maintained after 3 months (except for Corsi blocks)
14	Hynes (2016) [43]	Passive	No-contact	Experimental: watched videos about cognitive training and played adaptive online training games; control: took pretests and posttests	Yes	__[b]	No	No	__[c]	No difference found; therefore, no evidence of transfer effects (but: exploratory study)
15	Vaportzis et al (2017) [52]	Passive	No-contact	Experimental: learned how to use regular apps on a tablet; passive control: only took pretests and posttests	No	No	Yes	Yes	Near	Improved processing speed compared to control group
17	Lussier et al (2017) [53]	Passive	Passive-task	2 experimental conditions: heterogeneous training context and homogeneous training context; control: computer lessons	No	No	No	Yes	Near	Training groups both had significantly better scores on near transfer tests than control. Heterogeneous training led to steeper improvement of dual-task coordination learning curve.
18	Grönholm-Nyman et al (2017) [11]	Active	Similar-form	Experimental: task-switching training games; control: fun games (Tetris, Angry Birds, and Bejeweled)	No	Yes	__[a]	Yes	Near	Very limited: only one near-transfer effect found: overall accuracy on a rule-based part. Training group also improved on the training tasks (very near transfer).
21	Guye and von Bastian (2017) [44]	Active	Similar-form	Experimental: WM[f] training games; control: visual search training games	Yes	__[b]	__[a]	No	__[c]	Bayesian analysis supported evidence for the null hypothesis. Expectation data went in opposite direction of observed result.
22	Chan et al (2016) [41]	Passive	Passive-task	Experimental: learned how to use a tablet; 2 control groups: games and radio programs at home, social groups met to discuss topics (to control for social interaction of training but limit new learning)	No	No	No	Yes	Far	iPad training improved processing speed and episodic memory compared with controls.

Search result #	Study	Control type	Control subtype	Description of conditions	Expectations measured?	Known limitation: expectations?	Known limitation: active control?	Positive result?	Transfer	Description of result
24	Perrot et al (2018) [54]	Both	Active: similar-for; passive: no-contact	Experimental: Kawashima Brain Training; active control: Super Mario Brothers; passive control: only pretests and posttests	No	Yes	__[a]	Yes	Near	Experimental training led to higher Stroop score than active control; both experimental training and active control had higher matrix reasoning scores than passive control; active control was significantly better at Corsi block test, spatial relations test, and number comparison test.
25	Nouchi et al (2016) [55]	Active	Similar-form	Experimental: processing-speed training game; active control: knowledge quiz training game	No	No	__[a]	Yes	Near	Improvements in processing speed, inhibition, and mood (depression scale) compared to active control
27	Belchior et al (2018) [56]	Both	Active control: similar-form; passive control: no-contact	Experimental: PositScience Insight (visual attention and processing speed); active control: Crazy Taxi; passive control: took pre and post-tests	No	Yes	__[a]	Yes	Near	Cognitive training improved visual attention and processing speed.
30	Yeo et al (2018) [45]	Passive	No-contact	Experimental: BrainFit software, which was controlled via BCI/dry EEG[g] headband; passive control: took pretests and posttests	Yes	__[b]	Yes	Yes	Near	Men in intervention group outperformed men in control group on RBANS[h] total score and subscore of Delayed Memory and Language.
31	Ordonez et al (2017) [42]	Passive	No-contact	Experimental: Actively Station cognitive training game suite, a series of games, many involving physical movement; passive control: took pretests and posttests	No	No	Yes	Yes	Far	Training group improved on global cognition, verbal fluency, memory complaints, and mood compared with control. Reported a significant result for language, which is contradicted by the data table, unless what was truly meant was verbal fluency. Other methodological problem: ACE-R[i] is a dementia screening test.

Search result #	Study	Control type	Control subtype	Description of conditions	Expectations measured?	Known limitation: expectations?	Known limitation: active control?	Positive result?	Transfer	Description of result
34	Sosa and Lagana (2018) [57]	Passive	No-contact	Experimental: Brain Age; passive control: pretests and posttests	No	Yes	Yes	Yes	Near	Training group scored higher in brief syllable count and arithmetic assessments.

[a]The study included active control (not a limitation).

[b]The study controlled for expectations (not a limitation).

[c]The study reported no transfer effects.

[d]VPT: variable priority training.

[e]FPT: fixed priority training.

[f]WM: working memory.

[g]EEG: electroencephalogram.

[h]RBANS: Repeatable Battery for the Assessment of Neuropsychological Status.

[i]ACE-R: Addenbrooke's Cognitive Examination Revised.

Synthesis of Results

The summary of the control for expectations is shown in Table 3. The first two columns report the proportion of included studies that took methodological steps identified in this review to control the influence of expectations: measuring expectations and including an active control condition. The third and fourth columns show the proportion of studies whose results may be misleading due to concerns raised in this review: those that did not include an active control, yet found a significant effect for their intervention, and those that additionally found a far transfer effect.

Table 3. Summary of expectation control (n=19).

Studies	Measured expectations, n (%)	Used active control (all similar-form), n (%)	No active control + positive result, n (%)	No active control + far transfer results, n (%)
Studies that fit the criteria	4 (21)	9 (47)	9 (47)	5 (26)

Discussion

Summary of Evidence

This review found that 4 of 19 studies (21%) measured expectations; therefore, the majority of studies (15/19, 79%) did not find it necessary to measure expectations for improvement. Of these 15 studies that did not measure expectations, 9 studies also did not mention this as a limitation of the study. A smaller majority of studies (10/19, 53%) did not include an active control condition, 6 of which did not mention this as a limitation. Perhaps most troubling is that 9 of 10 of the studies that did not include an active control also found a positive result; therefore, 9 of the 19 studies included here (47%) have published results reporting positive effects and did not properly control for placebo effects.

Studies That Measured Expectations: Further Analysis

Expectations were measured in some form in 4 studies. Of these, 2 found positive results, 1 found null results, and 1 found evidence supporting the null hypothesis using Bayesian analysis.

Souders et al [38] provided the strongest evidence for a positive result that was not due to undetected placebo effects. They used an active control and administered a detailed expectation questionnaire. They found that the experimental group improved more than the active control group on the Corsi Block Tapping test, a test of memory similar to the training game task and therefore a near transfer result. The expectation data suggest that their subjects expected more improvement from the puzzle games (the active control) than from the intervention games, strengthening the claim that this was not a placebo effect. The authors suggest that expectation effects may even have gone in the opposite direction, potentially masking a bona fide effect from the training on cognition.

Guye and von Bastian [44] provide strong, expectation-supported data against the effectiveness of working memory training. Using Bayesian analysis, they found evidence in favor of the null hypothesis, suggesting that the computerized working memory training regimen they used had no greater effect than the active control condition on cognitive ability. To gather data on expectations, they asked whether their subjects believed they had improved in three areas: on training tasks, on untrained tests of cognition, and on real-life tasks. The expectation data suggest that participants believed that they had improved as a result of the training. The results of this study support other research [13,58], suggesting that working memory training in general may not confer any near or far transfer effects on cognition in healthy subjects.

In an exploratory study with a small sample, Hynes [43] found no effect for a computerized cognitive training program on a battery of cognitive tests, including a reasoning test correlated with fluid intelligence and a test of general intelligence. Responses to a question gauging participant expectations suggest that participants had moderate expectations for improvement, at least following the training period (mean 2.62/4, SD 0.67). The study used a no-contact passive control design, which provides weak control of potential placebo effects; however, it may strengthen a null result, under the assumption that expectations for improvement would be higher for the training group than the no-contact group. A potential rebuttal to this assumption is that the training program could discourage participants and lower expectations for improvement. In this case, however, participants indicated on a single expectation question, administered at the end of outcome testing, that they believed they had improved. More expectation questions could have potentially helped to better understand participant expectations.

Yeo et al [45] found a sex-dependent, near transfer effect for cognitive training on scores of the Repeatable Battery for the Assessment of Neuropsychological Status, which tests a number of cognitive domains including language, memory, attention, and visuospatial construction. Expectation data were collected in the form of one question presented after the outcome measures, asking participants if they believed their memory had improved as a result of the training; the data suggest that they did believe that it had. While the authors interpreted this as a subjective marker of cognitive improvement, it also could mean that their positive results are weakened by the expectation data, as they cannot rule out the possibility that positive expectations were responsible for the sex-dependent increase in performance. Their design used a no-contact control; thus, the expectation question was only administered to the cognitive training group. It cannot therefore be known whether expectations for improvement differed between conditions.

False Definition of Active Control

Two studies, both with Lussier as the first author, claimed to include an "active placebo" condition [50,53]; however, an examination of the methods indicated that both studies used a passive control condition of the passive-task type, according to the definitions in this review. This distinction is important because a passive control provides weaker control for potential placebo effects than an active control. The training conditions in both studies were variations on group-administered, computer-based cognitive training; the control condition in both studies was computer classes, teaching how to use software such as Microsoft Excel. While the participants engaged in learning in both conditions, expectations for improvement on cognitive assessments could be very different for a training program that exists for the purpose of improving cognition, rather than to simply teach particular skills. Expectations were not measured, so there is no reason to believe that expectations for improvement were held constant across conditions. There is an argument to be made that the two experimental conditions in each study served as active control conditions for each other; however, the authors did not present nor analyze their data in this way [50,53].

Recommendations for Researchers of Cognitive Training Games

Measuring expectations can add to the practical workload of conducting a study. However, as demonstrated by some of the studies in this review, there are ways to measure expectations without significantly adding to the burden of data collection. All studies that collected expectation data that were reviewed here did so in the form of a questionnaire administered after the outcome measures. While potentially problematic because it cannot indicate what expectations were before or during training, it provides at least some insight into what expectations subjects held by the end of the training. This post hoc expectation data, while limited, can still be used in analysis of the observed results from the outcome tests. The study by Souders et al [38] serves as a model of expected data collection using a variety of expectation questions at the end of the training (note: Walter R. Boot, of Boot et al [14], was an author on this study and presented analysis of expectations towards the experimental and control games in a separate paper [59]). This study is also commendable for its use of an active control, of the similar-form type. Their experimental design strongly supports their claim that observed results were not likely to be placebo effects.

Using a variety of expectation questions can help elucidate whether participants formed expectations for improvement in specific cognitive modalities. Two of the studies reviewed here [43,45] used only one question to assess expectations and accordingly lacked a detailed understanding of participant expectations. The study by Hynes [43] was exploratory, so a fully placebo-controlled design may not have been practically feasible; however, it serves as an example of how simply administering more questions could help to clarify participant expectations. The mean score for responses to this study's expectation question implied participants thought they had improved due to the training; further questions could clarify whether they found the training discouraging, for instance, or if they believed they had improved on one specific modality, such as memory, but not another. The study by Yeo et al [45] could have also benefited from additional expectation questions, as their expectation data reveal very limited information about participant expectations.

An active control provides all of the same benefits as a passive control, plus other benefits, such as expectation control. Beyond practical feasibility, there is no compelling methodological reason to forego use of an active control in favor of a passive control. No-contact passive controls offer some insight into the effects of repeated testing, but no control for any other placebo-related factors [16]. Passive-task control conditions can control for social interaction effects, but likely do not control for expectation effects, as participants can likely determine if they are in the control or training condition and form expectations for improvement accordingly.

More work can be done to find ways to measure expectations, both for the conditions used in specific studies and for general expectations regarding various types of cognitive training. Boot et al [14] used a separate sample to measure expectations; Rabipour et al [32] surveyed people about expectations for cognitive training in general. Foroughi et al [15] examined the effects of recruitment methods on performance after training and measured belief in the ability to improve one's own intelligence. There are, perhaps, creative new ways in which researchers could assess expectations before and during cognitive training or to gain insight into other placebo-related factors [16], such as social interaction, that may be impacting performance.

Limitations

This review was necessarily limited in its scope: Only one researcher was available, and it was conducted as one assignment to fill a paper requirement for a Master's program. Only one search site was used (PubMed), the Works Cited sections of included papers were not screened for potential additions that matched the review criteria, and this review was not preregistered.

The search terms may have been too restrictive by only returning results that contained the terms "game" or "computer" in the title or abstract. One study of cognitive training, by Goghari and Lawlor-Savage [34] was not found by this search query. This study measured expectations and reported a null result. It would have slightly changed the results of this review by increasing the number of studies that attempted to measure expectations from 4/19 to 5/20.

Recruitment methods were not assessed in this review. Recruitment methods may play an important role in controlling for placebo effects [15] and would be a good consideration for future methodological reviews.

Other types of studies that fell outside the scope of this review should be reviewed for placebo control methodology, as they are also potentially subject to placebo effects. Studies involving populations of unhealthy older adults, for instance, are numerous and should be considered; cognitive training may or may not be an effective way to mitigate degeneration and related symptoms due to neurodegenerative disorders such as Alzheimer's disease or even for less severe conditions such as mild cognitive impairment. Combined studies of neurostimulation, such as tDCS, with cognitive training may yield effects not present with tDCS or cognitive training alone. Such studies form a recent area of cognitive training research and should be examined for placebo-control methodology as well.

Conclusions

In summary, this review found that the majority of computerized cognitive training studies with older adult samples from the past 2 years, which were included in this systematic review, have not measured expectations or properly controlled for potential placebo effects by including an active control. Methodologically speaking, only one study here [28] found placebo-controlled evidence for far transfer effects of cognitive training, although some that used an active control found evidence for near transfer effects. Studies that did measure expectations did so by administering an expectation questionnaire at the end of the training period. Cognitive training evaluation studies should, at a minimum, include a similar-form active control and measure expectations at the end of the training period. Ideally, future evaluation studies will include an active-ingredient type of active control and find creative new ways to measure expectations and control for other unintended types of placebo effects.

If cognitive training can truly be effective, scientists have just as much of a duty to find evidence for this possibility as they do to find evidence against it. Well-controlled studies that rule out placebo as the reason for any observed effects strengthen the result, whether as evidence for or against the effectiveness of cognitive training.

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Conflicts of Interest

The author does contract work for a company called neomento, which creates virtual reality exposure therapy solutions for therapists (eg, for anxiety disorders) but is currently not involved with cognitive training. There are no other potential conflicts of interest to declare.

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Abbreviations

ACE-R: Addenbrooke's Cognitive Examination Revised
EEG: electroencephalogram
FPT: fixed priority training
RBANS: Repeatable Battery for the Assessment of Neuropsychological Status
tDCS: transcranial direct current stimulation
VPT: variable priority training
WM: working memory

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Original Paper

Construct Validity of a Serious Game for Laparoscopic Skills Training: Validation Study

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Abstract

Background: Surgical residents underutilize opportunities for traditional laparoscopic simulation training. Serious gaming may increase residents' motivation to practice laparoscopic skills. However, little is known about the effectiveness of serious gaming for laparoscopic skills training.

Objective: The aim of this study was to establish construct validity for the laparoscopic serious game *Underground*.

Methods: All study participants completed 2 levels of *Underground*. Performance for 2 novel variables (time and error) was compared between novices (n=65, prior experience <10 laparoscopic procedures), intermediates (n=26, prior experience 10-100 laparoscopic procedures), and experts (n=20, prior experience >100 laparoscopic procedures) using analysis of covariance. We corrected for gender and video game experience.

Results: Controlling for gender and video game experience, the effects of prior laparoscopic experience on the time variable differed significantly ($F_{2,106}$=4.77, P=.01). Both experts and intermediates outperformed novices in terms of task completion speed; experts did not outperform intermediates. A similar trend was seen for the rate of gameplay errors. Both gender ($F_{1,106}$=14.42, P<.001 in favor of men) and prior video game experience ($F_{1,106}$=5.20, P=.03 in favor of experienced gamers) modulated the time variable.

Conclusions: We established construct validity for the laparoscopic serious game *Underground*. Serious gaming may aid laparoscopic skills development. Previous gaming experience and gender also influenced *Underground* performance. The in-game performance metrics were not suitable for statistical evaluation. To unlock the full potential of serious gaming for training, a more formal approach to performance metric development is needed.

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KEYWORDS

laparoscopy; surgery; training; education; serious game; resident training; skills development; psychomotor skills; simulation center

Introduction

Simulation has been proven to be effective for laparoscopic skills training [1]. However, due to scheduling constraints and motivational issues, simulation training opportunities for residents remain underutilized [2,3]. Consequently, the burden of the surgical learning curve continues to fall on the patient [4-6]. Serious gaming can address these issues by providing a training modality that is fun, challenging, easy to implement, and inexpensive compared to current laparoscopic simulators [7]. Serious gaming refers to the application or adaptation of computer games for nonrecreational purposes, such as learning, training, or therapy [8]. This can lead to "stealth learning" [9], where the trainee is enjoying the training so much that they fail to notice improvements in key education outcomes [10,11]. Due to these attributes, serious gaming is a good candidate to alleviate motivational issues. Serious games are also easy to implement in a home environment, which can address the issue of scheduling constraints at work.

Serious gaming for psychomotor skills training is a new concept in surgery; however, it has been demonstrated to be successful in several other fields, including rehabilitation clinics and the aviation industry [12-15]. In these games, movements necessary to engage in gameplay are modeled on relevant motor tasks as they occur in reality in order to impart the requisite motor skills. This approach was adopted for laparoscopic skills training by ten Cate Hoedemaker and Grendel Games [16], who developed the serious game *Underground* for the Nintendo Wii U platform. In this game, medical content is replaced by a narrative that focuses on saving robots from a system of abandoned mineshafts. The psychomotor skills necessary to complete in-game tasks are closely modeled on laparoscopic movements and are performed using gaming controllers that resemble laparoscopic hardware. If effective, serious gaming can contribute to laparoscopic skills development by increasing training volume in the guise of a leisure activity.

In a previous study, we established concurrent validity by demonstrating skill transfer between *Underground* and the LapSim virtual reality trainer [17,18]. Limited evidence of construct validity has been offered by Jalink et al [18], who compared the performance of laparoscopic experts and internists playing *Underground*. However, this study compared groups who may differ in their innate abilities to perform psychomotor tasks [19]; also, it used a prototype of the game instead of the final product.

To assess the potential of *Underground* as a surgical training tool, validity criteria must be met, including construct validity [20]. Construct validity is the degree to which a test truly measures what it intends to measure; in this instance, it refers to the degree to which a serious game measures differences in the skills it is designed to evaluate. Therefore, the aim of this study was to establish construct validity for the laparoscopic serious game *Underground*. We compared the gaming performance of surgical novices, surgical house officers, surgical residents, and laparoscopic surgeons based on their self-reported laparoscopic experience. We hypothesized that more real-world laparoscopic experience would translate to better *Underground* gaming performance.

Methods

Participants

Study participants were selected from 4 different groups: fourth year medical students preparing for their surgical internships (surgical novices), surgical house officers, surgical residents, and staff laparoscopic surgeons from the departments of Colorectal and Hepatobiliary Surgery, Urology, and Gynecology. All participants were recruited at the Radboud University Medical Center, Nijmegen, the Netherlands. No IRB approval was needed for this study under Dutch law [21].

Performance data for the surgical novices were collected during a mandatory basic laparoscopic skills training course. The participants were informed about our study, and each participant voluntarily signed an informed consent form to allow us to use their anonymized performance data for research purposes. Participants were made aware that declining to sign this form did not impact their course participation or the assessment of their internship. Surgical house officers, surgical residents, and staff surgeons were recruited via emails, posters in the hospital, and in-person interactions. Participation was voluntary and did not result in compensation. All subjects were divided into 3 groups based on their self-reported laparoscopic experience: novices, who had performed fewer than 10 laparoscopic procedures (typically surgical novices and surgical house officers), intermediates, who had performed between 10 and 100 laparoscopic procedures (typically surgical residents), and experts, who had performed more than 100 laparoscopic procedures (typically laparoscopic surgeons) [22].

Study Design

An instructor was present throughout the session to observe the participants, provide instructions, and troubleshoot the game when necessary. After completing the informed consent form, the participants played the first 2 levels of the laparoscopic serious game *Underground* to familiarize themselves with the software and hardware of the system. Next, they played through the fourth and fifth levels of *Underground* while being timed and scored for error by the instructor. The fourth and fifth levels were selected as the basis of the assessment because of the more challenging nature of these levels, in which all basic laparoscopic skills were tested (eg, inverted movements, hand-eye coordination, depth perception, and ambidexterity). Participants subsequently completed a demographic questionnaire that included sections on prior laparoscopic experience and prior video game experience. Each complete session took an average of 30 minutes per individual.

Gaming sessions took place in a quiet working space located within the Department of Surgery (Figure 1). Fluorescent lights and sources of infrared light were turned off in the gaming area, as they are known to interfere with the Nintendo Wii-U system used in this study [23].

Figure 1. Laparoscopic interface of the serious game *Underground*.

Apparatus

We utilized *Underground* Version 1.1 with a dedicated laparoscopic interface for this study (Grendel Games). The serious game was played on a Nintendo Wii U video gaming system connected to a 21” HD LCD screen (LG Corporation). The game instrument sensitivity was set at maximum [24,25].

Data Preparation

Currently, *Underground* contains no formal embedded performance metrics relevant to laparoscopic skills training. Thus, in order to analyze game performance as it relates to surgical activities, we created 2 measured variables: time and error. Time was the measurement of how quickly the player was able to complete all game tasks; it was defined as the elapsed time between the start and finish of each level as measured with a stopwatch. The total play times for each level were summed to generate the final time measurement. Error was defined as the total sum of occurrences of 3 key player mistakes: orb drops, roadblocks, and robot deaths.

Video game experience was measured by asking all participants to estimate their average number of weekly gaming hours across several age-bands (1-6 years, 7-12 years, 13-18 years, 19-25 years, 26-45 years, and ≥46 years) [26]. We then calculated each participant’s total prior lifetime gaming experience by multiplying the average number of gaming hours per week by the number of weeks in the selected age bands. Since the resulting total gaming hours variable was not normally distributed, we ranked these data to render them suitable for non-parametric statistical analyses.

Data Analysis

Sample size was calculated using α=.05, a power of .95, a large effect size of 0.40, and 3 groups [18,27]. This resulted in a desired total sample size of 102. Normality for the variable time was confirmed using the Shapiro-Wilk test, allowing for parametric testing. We performed analysis of covariance (ANCOVA) to assess the effects of laparoscopic experience on the “time” performance variable, controlling for prior video game experience and gender. After performing ANCOVA on all groups together, planned contrasts were used to assess differences in performance for paired groups [28]. The incidence of error was not normally distributed for the novice or expert groups, as assessed by the Shapiro-Wilk test. We therefore used Mann-Whitney U tests to compare the number of errors between groups. α was set at .05. Power analyses were conducted in G*Power version 3.1.9.2. Statistical analyses were performed with SPSS version 25.0 (IBM Corporation).

Results

Participants

A total of 120 participants were enrolled in this study. Data for 9 participants (2 surgical novices, 4 surgical residents, 1 surgical house officer, and 2 laparoscopic surgeons) were excluded from the analyses because these participants were unable to complete the study due to hardware failure or urgent patient care activities. Data for 65 novice, 26 intermediate, and 20 expert participants were used. Gender proportions varied between experience groups (Table 1). Men had more video game experience than women in the novice group (t_{63}=4.94, P<.001) and intermediate group (t_{24}=3.00, P=.01). No gender-based difference for video game experience was found in the expert group.

Table 1. Demographics of the participant groups.

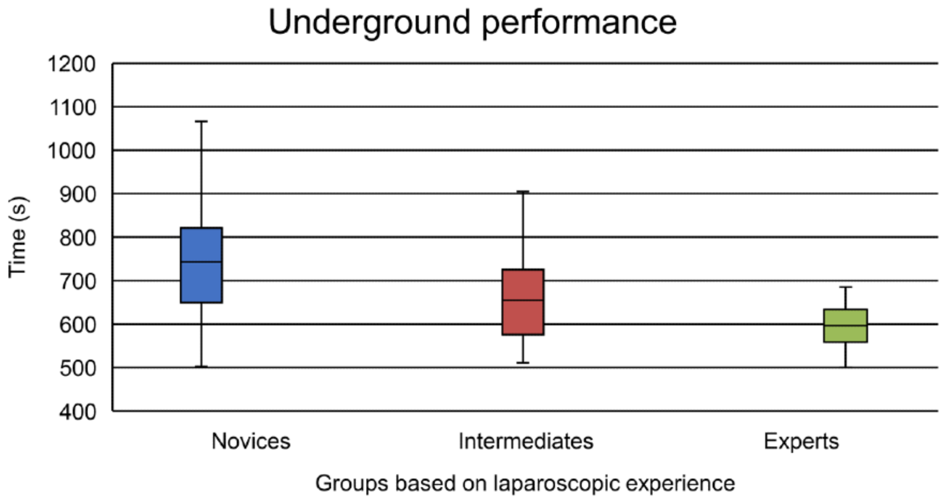
Characteristic	Novice (n=65)	Intermediate (n=26)	Expert (n=20)
Age (years), mean (SD)	24 (3)	31 (2)	44 (6)
Male gender, n (%)	20 (31)	16 (62)	17 (85)
Right-hand dominance, n (%)	57 (87)	23 (89)	20 (100)
Video game experience, mean rank	56	60	50
Professional status, n (%)			
Surgical novice	54 (83)	N/A[a]	N/A
Surgical house officer	11 (17)	N/A	N/A
Surgical resident	N/A	26 (100)	N/A
Laparoscopic surgeon	N/A	N/A	20 (100)
Department, n (%)			
No department (surgical novice)	54 (83)	N/A	N/A
Surgery	11 (17)	18 (69)	14 (70)
Urology	N/A	3 (12)	2 (10)
Gynecology	N/A	5 (19)	4 (20)

[a]Not applicable.

Time Performance Variable

After controlling for gender and prior video game experience by including them as covariates in ANCOVA, the participants' game completion times differed significantly depending on their laparoscopic experience ($F_{2,106}$=4.77, P=.01). Planned contrasts revealed that experts (mean difference –88 seconds, 95% CI –146 to –30, P=.002) and intermediates (mean difference –43 seconds, 95% CI –92 to 5, P=.04) performed faster than novices. Experts did not outperform intermediates (mean difference –45 seconds, 95% CI –106 to –17, P=.08). The performance distribution of each group is shown in Figure 2.

Figure 2. Box plots showing the performance distribution for time between groups. The assessment time is the sum of the time scores for levels 4 and 5 of the serious game *Underground*.

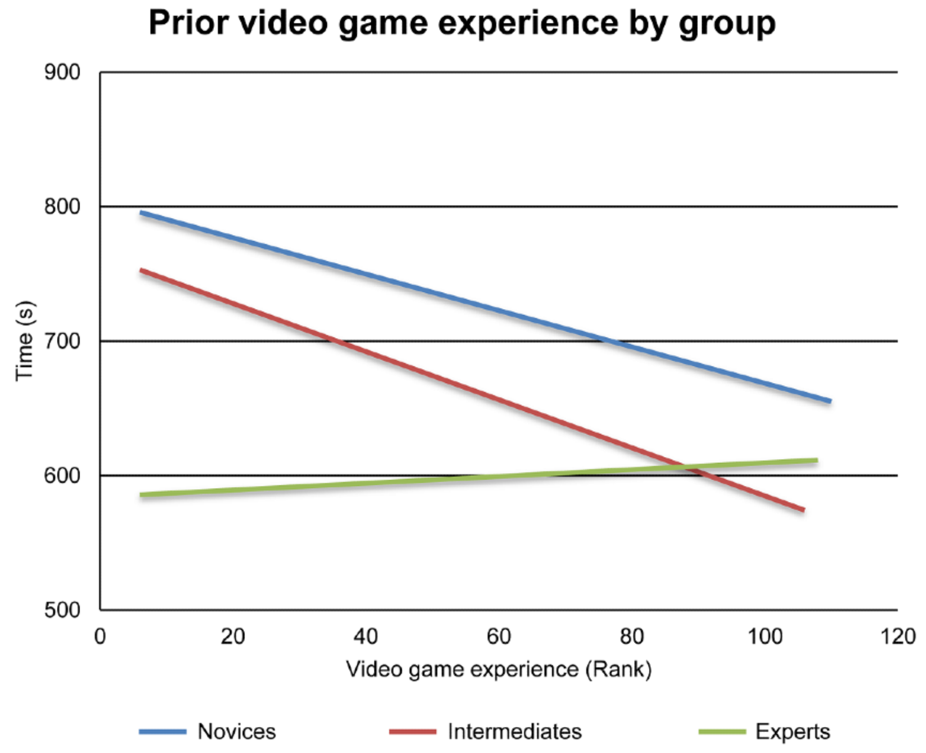


Performance for the time variable differed significantly depending on the participants' gender ($F_{1,106}$=14.42, P<.001). This effect was caused by men outperforming women in the novice group (t_{63}=–4.68, P<.001). No significant differences in performance for gender were found in the other groups.

Video game experience was also significantly related to the time performance variable ($F_{1,106}$=5.20, P=.03). A correlation between video game experience and game completion time was observed for both novices and intermediates but not for experts. The linear trend lines for the video game experience of each group are shown in Figure 3.

We were not able to establish independence of the gender and prior video game experience variables.

Figure 3. Linear trend lines showing the correlation between video game experience and the performance variable of time for each group.



The Error Performance Variable

In all groups, the subjects made few errors, and data were only normally distributed within the intermediate group. The differences in error performance between the experience groups were qualitatively similar to the differences in time performance but did not reach statistical significance. A floor effect and a limited range of errors were observed, ranging from 0-6 (Table 2).

Table 2. Numbers of participants who made 0, 1-3, and 4-6 errors in each group.

Errors, n	Group, n (%)		
	Novice (n=65)	Intermediate (n=26)	Expert (n=20)
0	3 (5)	3 (12)	4 (20)
1-3	38 (58)	18 (69)	16 (80)
4-6	24 (37)	5 (19)	0 (0)

Discussion

Principal Findings

In this study, we demonstrated construct validity for the laparoscopic serious game *Underground*. The completion times for the investigated game levels differed between 2 pairs of the 3 paired groups; the novices were outperformed by both other groups, but there was no difference between the intermediates and experts. The lack of performance difference between the intermediate and expert groups is likely because *Underground* was developed to provide *basic* laparoscopic skills training, a skill level that is already mastered by intermediates and experts. After previous studies established face validity, concurrent validity, and partial construct validity, we now provide additional construct validity [16-18]. *Underground* is a welcome addition to the existing laparoscopic simulation landscape.

Measurement of the error variable was not sufficiently sensitive for a full statistical analysis. Since *Underground* was not developed with the intent to provide formal laparoscopic performance assessments, we created custom time and error variables as described in the Methods section. Although our results for the error variable did not demonstrate significance, we have included them here because there were trends toward differences in error performance between the experience groups; also, we feel it is important that surgical performance assessment include variables beyond the speed of task completion, as speed in itself is not informative of the quality of the performance [6,29].

On its own, *Underground* has very limited built-in capabilities to measure performance. This lack of reliable performance metrics is one of its biggest limitations at present [20,24]. In the course of conducting our pilot study, it became clear that the game-supplied variables (number of robots saved and number of bonus items collected) did not discriminate between laparoscopic experience, as nearly all pilot study participants achieved the maximum score regardless of laparoscopic experience. Well-developed in-game performance metrics would improve the usefulness of *Underground* for basic laparoscopic skills training.

Future developments in the area of serious gaming for laparoscopic skills development would benefit from a more formal approach to the development of in-game metrics. Delphi method-based rounds that include students, experts from the video game industry, content experts (eg, surgeons), and educational psychologists may help unlock the full potential of serious gaming by combining insights from each of these complementary professional groups. With regard to *Underground* specifically, continued support of its developers could overcome the current lack of informative parameters in the game by providing a game update via a patch, as is commonplace for contemporary video games. The low cost and small form factor of *Underground* facilitate its installation in non-skills lab settings such as residents' homes or offices. This flexibility may increase residents' training volumes.

Given that *Underground* is a game-based educational tool, and given that gaming has increasingly become an integral part of residents' and surgeons' daily lives [30], we additionally assessed the effect of the subjects' prior video game experience on their *Underground* gaming performance. A greater amount of prior gaming experience was found to be associated with faster performance in the novice and intermediate groups. These results are consistent with previous studies, where video game experience has been shown to improve baseline performance on simulators [31,32]. Interestingly, prior video game experience did not result in better *Underground* performance within the expert group. This finding can be explained by a generational difference in the subject groups, since the novices and intermediates generally had more video game experience than the experts. Alternatively, it is possible that experts' video game experience made a negligible contribution to their performance compared with the impact of their professional experience. The literature is divided as to whether video game experience positively impacts operating room performance, with some studies finding a positive effect and others finding no impact [30,33-38].

Adopting *Underground* in our training curricula corresponds well with the current interest in multimodality training, which in the context of surgical training refers to the use of different simulations to train specific surgical skills [39]. Several studies have shown that junior residents particularly benefit from multimodality training for mastering basic laparoscopic skills [39-41]. This training provides the trainee with a fresh perspective each time a new modality is used, which enhances their learning [39]. It would be beneficial to residents to broaden this approach even further by including games such as Touch Surgery for training the procedural aspects of surgical procedures in addition to basic psychomotor skills [42-45].

Limitations

Our experience groups comprised different gender ratios, reflecting the increase in the number of women enrolling in medical school. As a result, our novice group had a greater proportion of female participants than the intermediate and expert groups. However, gender only impacted the results in the novice group. Since female participants in this group also showed a difference in gaming experience, we were not able to independently assess the effect of gender. Given the lack of impact of gender on the other 2 groups, we think the gender effects in the novice group are caused by differences in gaming experience rather than gender differences per se.

Methods for validity testing are changing. Currently, 2 main frameworks are used in the literature: the classic validity framework, which includes validity sources such as face, content, construct and concurrent validity, and the modern framework proposed by Messick et al [46], which is a unified model in which different sources of validity are explored. In our studies of serious gaming, we opted to use the older framework so that our results would be comparable with those of other literature reports in this area (eg, Jalink et al [18]). This provides a better benchmark regarding the potential of *Underground* as a serious game for laparoscopic training. In the more current Messick framework, our study would support "relations to other variables" as sources of validity [46,47].

Future Research

Understanding which specific aspects of the serious game *Underground* are responsible for laparoscopic skills transfer would aid its adoption in the surgical skills curriculum [48,49]. It is possible that the specialized laparoscopic gaming interface, compared to the original Wii U GamePad, is a critical component influencing laparoscopic skills transfer; this effect should be investigated further. In addition, if skill transfer to the operating room can be established, the potential value of serious games such as *Underground* will be heightened both for future laparoscopic skills training and for use as a preoperative warmup tool [50].

Conclusion

This study establishes construct validity for the laparoscopic serious game *Underground*. Serious gaming may aid laparoscopic skill development. Gaming experience had an independent, positive effect on *Underground* performance compared to laparoscopic experience. The in-game performance metrics were not suitable for statistical evaluation. To unlock the full potential of serious gaming for training, a more formal approach to the development of performance metrics is needed.

Conflicts of Interest

None declared.

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Abbreviations

ANCOVA: analysis of covariance

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Original Paper

Teaching Adequate Prehospital Use of Personal Protective Equipment During the COVID-19 Pandemic: Development of a Gamified e-Learning Module

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Abstract

Background: The coronavirus disease (COVID-19) pandemic has led to increased use of personal protective equipment (PPE). Adequate use of this equipment is more critical than ever because the risk of shortages must be balanced against the need to effectively protect health care workers, including prehospital personnel. Specific training is therefore necessary; however, the need for social distancing has markedly disrupted the delivery of continuing education courses. Electronic learning (e-learning) may provide significant advantages because it requires neither the physical presence of learners nor the repetitive use of equipment for demonstration.

Objective: Inclusion of game mechanics, or "gamification," has been shown to increase knowledge and skill acquisition. The objective of this research was to develop a gamified e-learning module to interactively deliver concepts and information regarding the correct choice and handling of PPE.

Methods: The SERES framework was used to define and describe the development process, including scientific and design foundations. After we defined the target audience and learning objectives by interviewing the stakeholders, we searched the scientific literature to establish relevant theoretical bases. The learning contents were validated by infection control and prehospital experts. Learning mechanics were then determined according to the learning objectives, and the content that could benefit from the inclusion of game mechanics was identified.

Results: The literature search resulted in the selection and inclusion of 12 articles. In addition to gamification, pretesting, feedback, avoiding content skipping, and demonstrations using embedded videos were used as learning mechanics. Gamification was used to enhance the interactivity of the PPE donning and doffing sequences, which presented the greatest learning challenges. The module was developed with Articulate Storyline 3 to ensure that it would be compatible with a wide array of devices, as this software generates HTML5-compatible output that can be accessed on smartphones, tablets, and regular computers as long as a recent browser is available.

Conclusions: A gamified e-learning module designed to promote better knowledge and understanding of PPE use among prehospital health care workers was created by following the SERES framework. The impact of this module should now be assessed by means of a randomized controlled trial.

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KEYWORDS

personal protective equipment; electronic learning; gamification; prehospital; COVID-19

Introduction

Background and Importance

Acquisition and regular updating of specific knowledge and skills are paramount in the context of an evolving major health crisis. However, the need for social distancing due to the coronavirus disease (COVID-19) pandemic has markedly disrupted continuing medical education [1]. Adequate supply and use of personal protective equipment (PPE) is more critical than ever because the risk of shortages must be balanced against the need to efficiently protect health care workers, including prehospital personnel [2,3]. Indeed, contamination of these professionals may lead to further dissemination of the disease, including among frail patients being transported in the closed cell space of an ambulance, and it can affect human resources if paramedics and prehospital emergency physicians are also infected [4-6]. This in turn may decrease the ability of emergency medical services (EMS) to fulfill their mission.

In this challenging context, electronic learning (e-learning) may provide significant advantages because it requires neither the physical presence of learners nor the repetitive use of equipment for demonstration, as can be the case during live simulations [7,8]. The term e-learning is generic and refers to a host of different methods and materials [9-11]. Acquisition of knowledge and skills increases with interactivity, and this increase is even greater with the inclusion of game mechanics, or "gamification" [12,13].

Objective

A gamified e-learning module may enhance the knowledge and skills of prehospital personnel regarding the correct choice and handling of PPE. The objective of this research was to develop an evidence-based, gamified e-learning module addressing these aspects.

Methods

General Design

The SERES framework was used to define and describe the development process of this gamified e-learning module, including scientific and design foundations [14].

Scientific Foundations

Target Audience

To identify all the categories of health care professionals who may be expected to don PPE in the prehospital setting, the module developers interviewed chief ambulance officers, chief medical officers, paramedics, and emergency physicians working in Swiss EMS.

Learning Objectives

Given the general objective and the target audience, we performed individual interviews to assess specific learning objectives that the gamified e-learning module needed to fulfill. At this stage, specialists from the Geneva University Hospitals infection control program were included in the discussion.

Theoretical Basis

Use of game mechanics should not be a goal per se but a means to ensure that the intended learning objectives are met. We therefore searched the scientific literature using the PubMed engine with combinations (using the Boolean operator "AND") of the medical subject headings (MeSH) keywords *serious games*, *prehospital*, and *infection control* and the non-MeSH keywords *gamification*, *e-learning*, and *electronic learning*. Potentially relevant articles were retrieved based on their titles and abstracts. References from the most authoritative and relevant articles were manually screened to identify papers our initial search may have overlooked. Articles that were not written in English or French were excluded.

Factors contributing to learner engagement as well as to skill and knowledge acquisition were collected before being individually assessed according to their potential impact. As game mechanics may not apply to all aspects of knowledge acquisition, it was necessary to identify specific elements that could benefit from the use of such mechanics. Specialists from the infection control program as well as chief ambulance and medical officers were again consulted at this stage.

Content Validation

Infection control specialists were included early in the design phase of the module to validate the learning content and its coherence with local COVID-19 control guidelines. Due to the rapid and incessant growth of knowledge regarding COVID-19 and the need to preserve PPE, the advice of these specialists was essential.

Design Foundations

General Design

The gamified e-learning module was designed according to the scientific foundations established in the previous stage.

Learning Mechanics and Game Mechanics

To apply game mechanics to the learning objectives that could most benefit from this method, the learning mechanics-game mechanics (LM-GM) model proposed by Arnab [15] in 2015 was used. In this model, learning mechanics are determined according to learning objectives and are then transformed into game mechanics to achieve the intended goal. The scientific foundations for the module were therefore first translated into learning mechanics and then, when appropriate, into game mechanics.

Design Requirements

When making design decisions, it was necessary to consider the particular context of the COVID-19 pandemic along with the specific target population. The time taken to complete the whole module and the type of media included in the module were assessed in this regard. Ease of access to the module, including the platforms and support that could be used, was also considered.

Module Development

This stage required the integration of all the data collected during the scientific foundation and design foundation stages. The learning objectives were reviewed, and learning mechanics were decided according to theoretical basis. Decisions regarding gamification of specific sections of the e-learning module were reassessed. An iterative approach to the construction of the module was used, incorporating regular feedback from the different previously identified stakeholders (infection prevention and control consultants, chief ambulance officers, chief medical officers, paramedics, and emergency physicians).

Tool Evaluation

During the iterative development loops and at the end of the development process, the module was tested for usability according to theoretical bases acquired during the scientific foundations stage.

Results

Scientific Foundations

Target Audience

Five categories of health care professionals working in the prehospital setting were identified: emergency physicians, paramedics, emergency medical technicians, nurses, and ambulance drivers [16,17]. Although they are not strictly health care professionals, ambulance drivers are trained in providing basic life support measures and may encounter situations that require them to don PPE. Therefore, we considered a vast array of professionals who present important variability regarding both medical knowledge and technical skills.

Learning Objectives

The frequent guideline updates consecutive to the general increase in knowledge and understanding regarding severe acute respiratory coronavirus 2 (SARS-CoV-2), the virus that causes COVID-19, and its mode of transmission prompted the definition of specific objectives (Table 1).

Theoretical Basis

A literature search resulted in the selection and inclusion of 12 articles [8,9,12-15,18-22]. Based on these results, the module developers, along with the stakeholders, decided which learning mechanics would be used to fulfill the different learning objectives (Table 1).

A pretesting strategy was used for one of the learning objectives (incubation time), as this method has been shown to improve knowledge retention [19] (Figures 1-4). Following this type of interaction, providing the correct answer seems to be insufficient, and more detailed feedback has been shown to yield better results regarding knowledge acquisition [18].

One important aspect was to prevent learners from skipping content, which would cause them to miss parts of the learning material [21] (Figures 5 and 6). In addition to setting triggers designed to restrict further access without engaging with the interactive content, the content was segmented in multiple slides and slide layers to keep the learner engaged [20].

As some skills are better demonstrated and some related knowledge is more readily acquired through video [9], a movie demonstrating the correct PPE donning and doffing sequences was recorded. Portions of this video were then embedded in the module, particularly in its gamified portion (Figures 7 and 8) [23].

Table 1. Learning objectives, learning mechanics with references, and related implementation examples.

Learning objective	Learning mechanic	Implementation
Incubation time	Pretesting and feedback [18,19]	Figures 1-4: The virus must be placed in a spot on the timeline before the "Validate My Answer" button can be successfully clicked.
Knowledge of specific definitions, virus transmission, and disease symptoms	Avoiding content skipping [20,21]	Figures 5 and 6: All three images displaying patients (healthy, somewhat ill, and very ill) must be clicked before the learner is allowed to move forward. A different layer of information is displayed depending on the image clicked.
Definition of virtual zones	Avoiding content skipping, embedded videos [9,20]	Figures 7 and 8: Buttons linking to information regarding the contaminated and noncontaminated zones are displayed. A new button is displayed with the explanation for each zone. When the button is clicked, a video sequence describing each zone is shown.
PPE items, with donning and doffing sequences	Gamification, embedded videos [9,13]	Figures 9-11: Screenshots of the gamified PPE donning sequence (see the Gamified Sequences section).

Figure 1. Use of pretesting to promote acquisition of knowledge regarding incubation time. The virus must be placed on the timeline before the *Valider* (Validate My Answer) button can be successfully used.

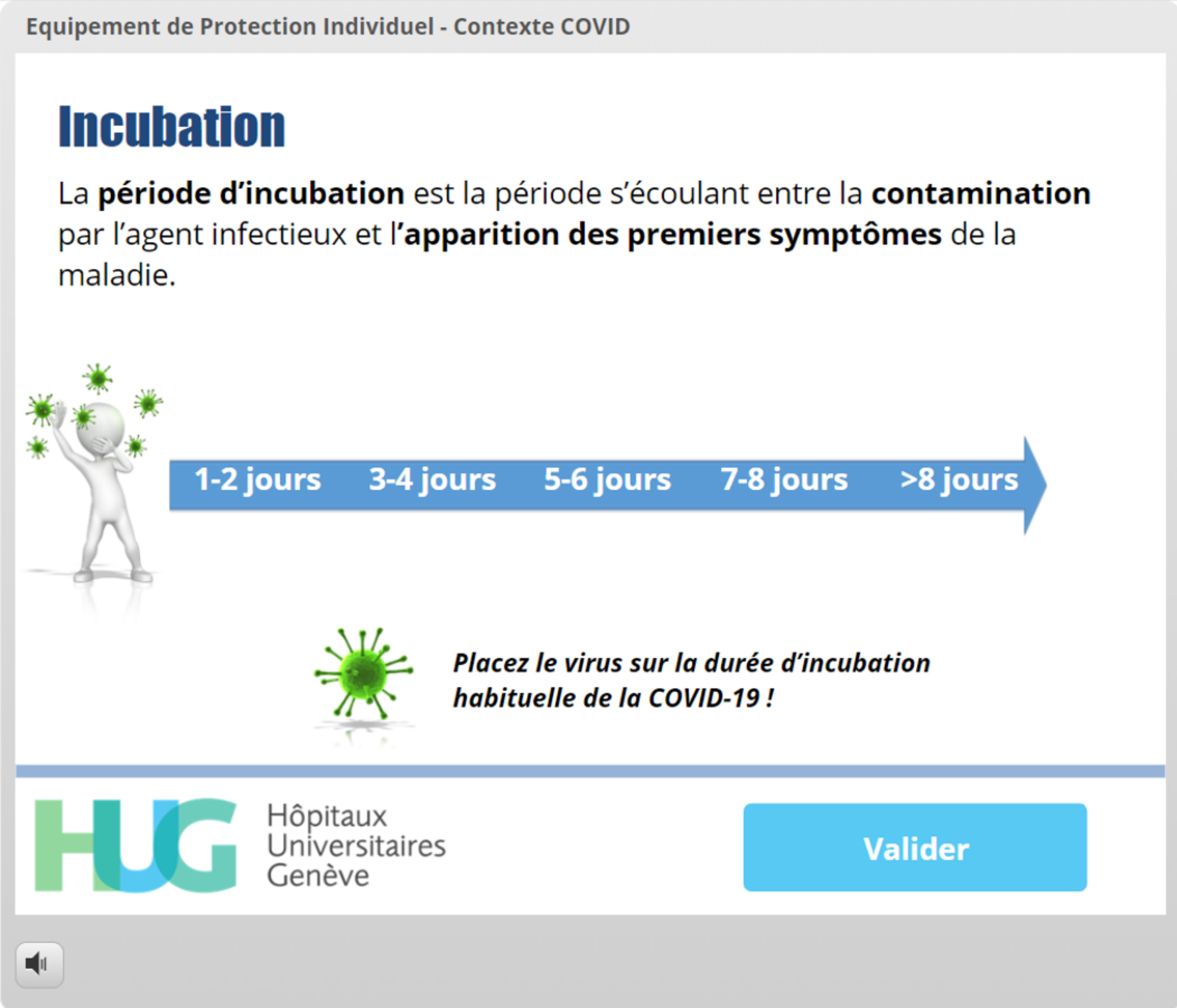


Figure 2. Mechanism preventing users from moving forward without completing the interaction. The learner clicked the *Valider* (Validate My Answer) button but could not proceed further because the virus had not been placed on the timeline.

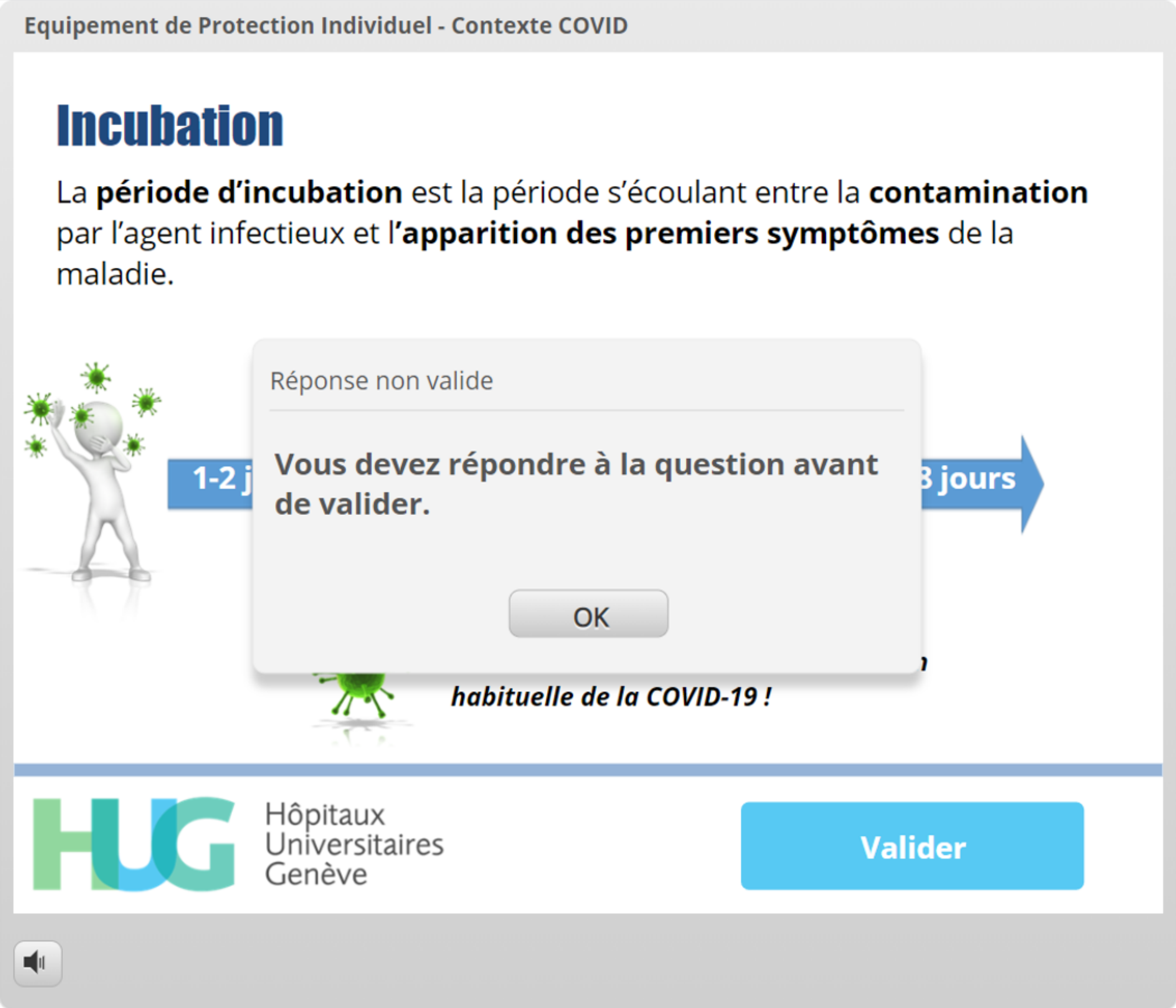


Figure 3. The learner has provided the wrong answer and is given the opportunity to retry. In this interaction, learners are allowed one more attempt if their first attempt fails.

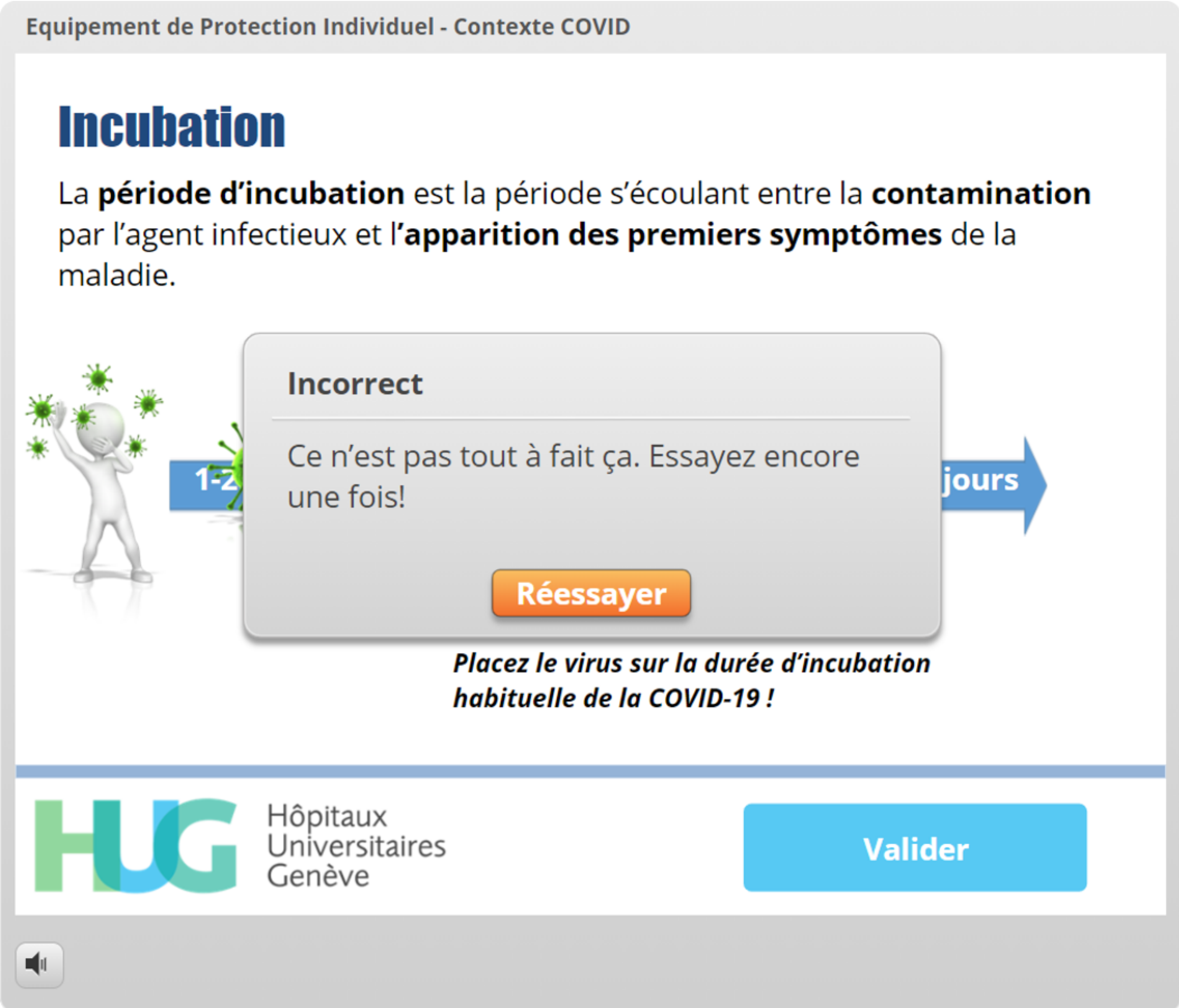


Figure 4. Response when the second answer attempt is also unsuccessful. Immediate feedback is provided, showing the right answer and other relevant information. The learner can now click on *Continuer* (Continue) to move forward.

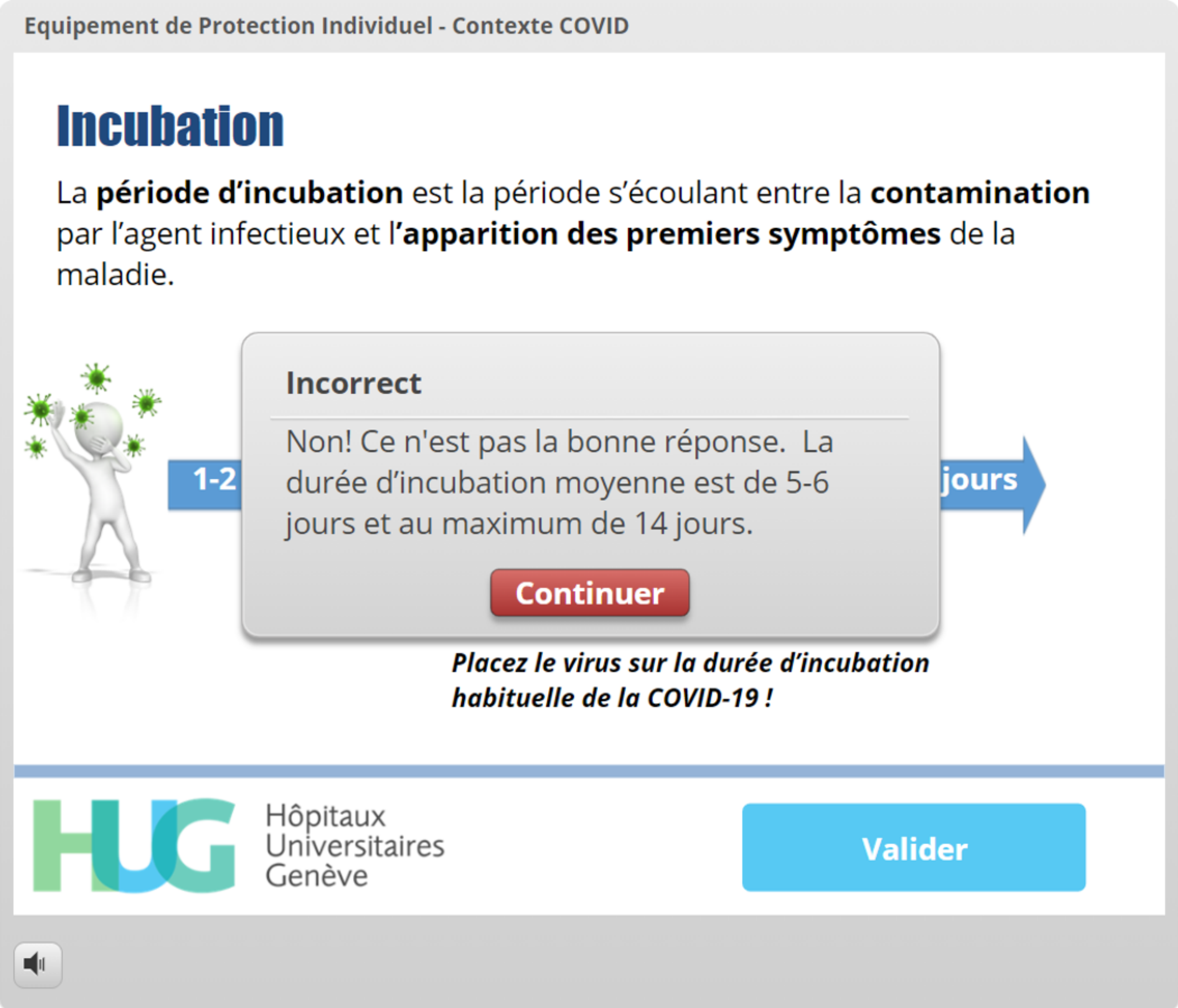


Figure 5. Use of triggers to avoid content skipping. The “very ill” patient on the rightmost side of the slide has been clicked and is therefore highlighted. The learning content related to this presentation is displayed; however, the *Continuer* (Continue) button does not appear because the learner must click at least one of the other patients.

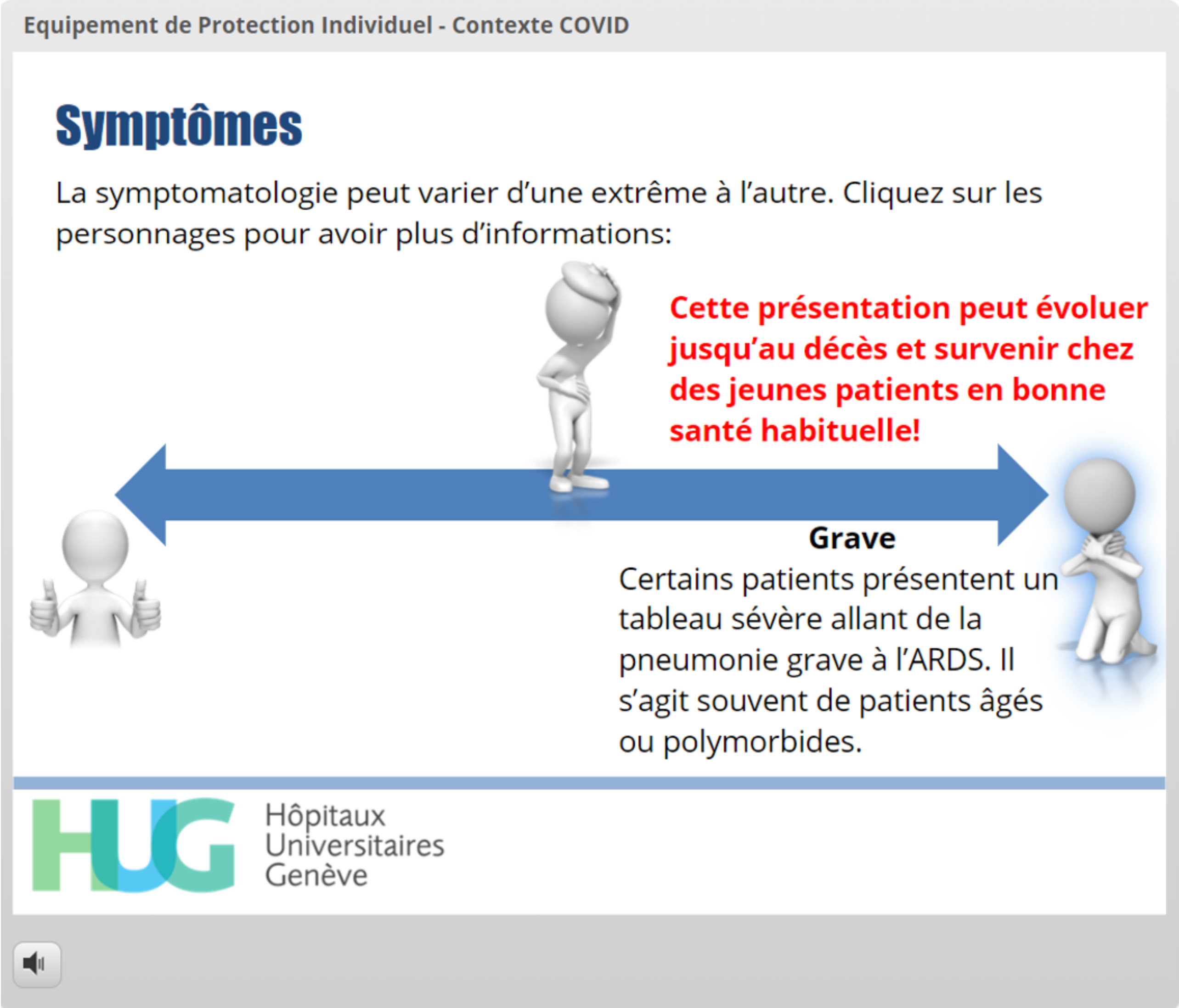


Figure 6. The learner has now clicked on all three patients, and the *Continuer* (Continue) button is therefore displayed, allowing the learner to move forward.

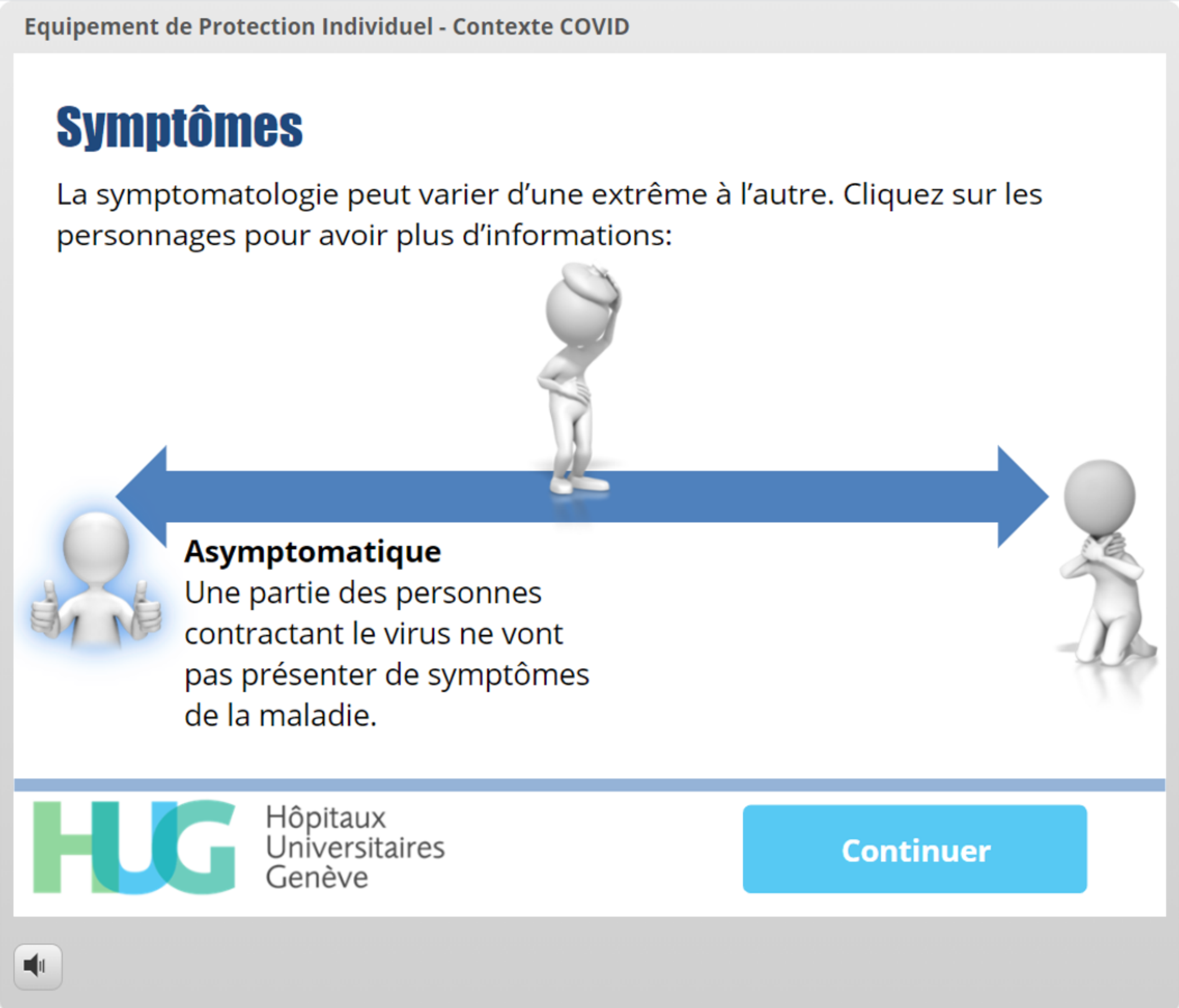


Figure 7. The learner has clicked on the button *Zone non contaminée* (Uncontaminated Zone). A new button, *Vidéo zone non contaminée* (Uncontaminated Zone Video), has now appeared. The *Continuer* (Continue) button is not displayed because the learner has not yet viewed all the learning material in this sequence.

Figure 8. Use of embedded videos to display virtual zones. The learner has clicked on the *Vidéo zone non contaminée* (Uncontaminated Zone Video) button, and the slide containing the video is lightboxed.

Finally, as health care personnel spend increasing amounts of time on their smartphones or tablets, and as these devices use many different and sometimes incompatible operating systems, the module was developed to be accessible on as many platforms as possible [22,24].

Module Development

A movie including the complete PPE donning and doffing sequences was recorded according to the latest prevention guidelines. To obtain realistic media to create the gamified donning and doffing sequences, a photo shoot was performed in front of a green screen, and the background was removed using chroma key technology [25]. Graphics such as stick figures were obtained from PresenterMedia (Eclipse Digital Imaging Inc).

The module was developed using Storyline 3 (Articulate Global), which enables publication in the HTML5 markup language; therefore, the module is compatible with most devices, including tablets and smartphones.

Gamified Sequences

Based on our prior decisions, game mechanics were applied to the donning and doffing sequences, which presented the greatest learning challenges. According to Bloom's revised taxonomy, three thinking skills matched this learning objective: applying, understanding, and retention [26]. The applying skill was linked to the action/task learning mechanic, which was translated into the "selecting/collecting" and "movement" game mechanics. Understanding was promoted by questions and answers and by instantaneous feedback, which are part of both learning mechanics and game mechanics. Retention was included using the "discover," "explore," and "repetition" learning mechanics and the "cutscenes/story" game mechanic.

Highly interactive sequences using photographs and embedded videos were created for three different COVID-19 risk settings: no suspicion of COVID-19, suspected or confirmed COVID-19 with no need to perform a high-risk procedure, and need to perform a high-risk procedure regardless of COVID-19 status. For each donning sequence, the learner was given the same six choices, including five different PPE options and a hand hygiene procedure option. Each option was represented by a photograph of the material that would be used and the name or abbreviation given to this material, all of which were grouped within circles (Figures 9-11). Learners made their choices by dragging one of the options onto the photograph of the EMS provider. Immediate written feedback was provided at the top of the screen (Figures 9-11).

Figure 9. Use of gamification to facilitate acquisition of the correct sequence of donning PPE before high-risk procedures such as endotracheal intubation. The user has already correctly used the FFP2 respiratory mask and protective goggles and has proceeded with hand hygiene. The feedback is displayed at the top of the screen (*"Vos mains sont maintenant propres. Quelle est la prochaine étape?" which means "Your hands are now clean. What should the next step be?"*).

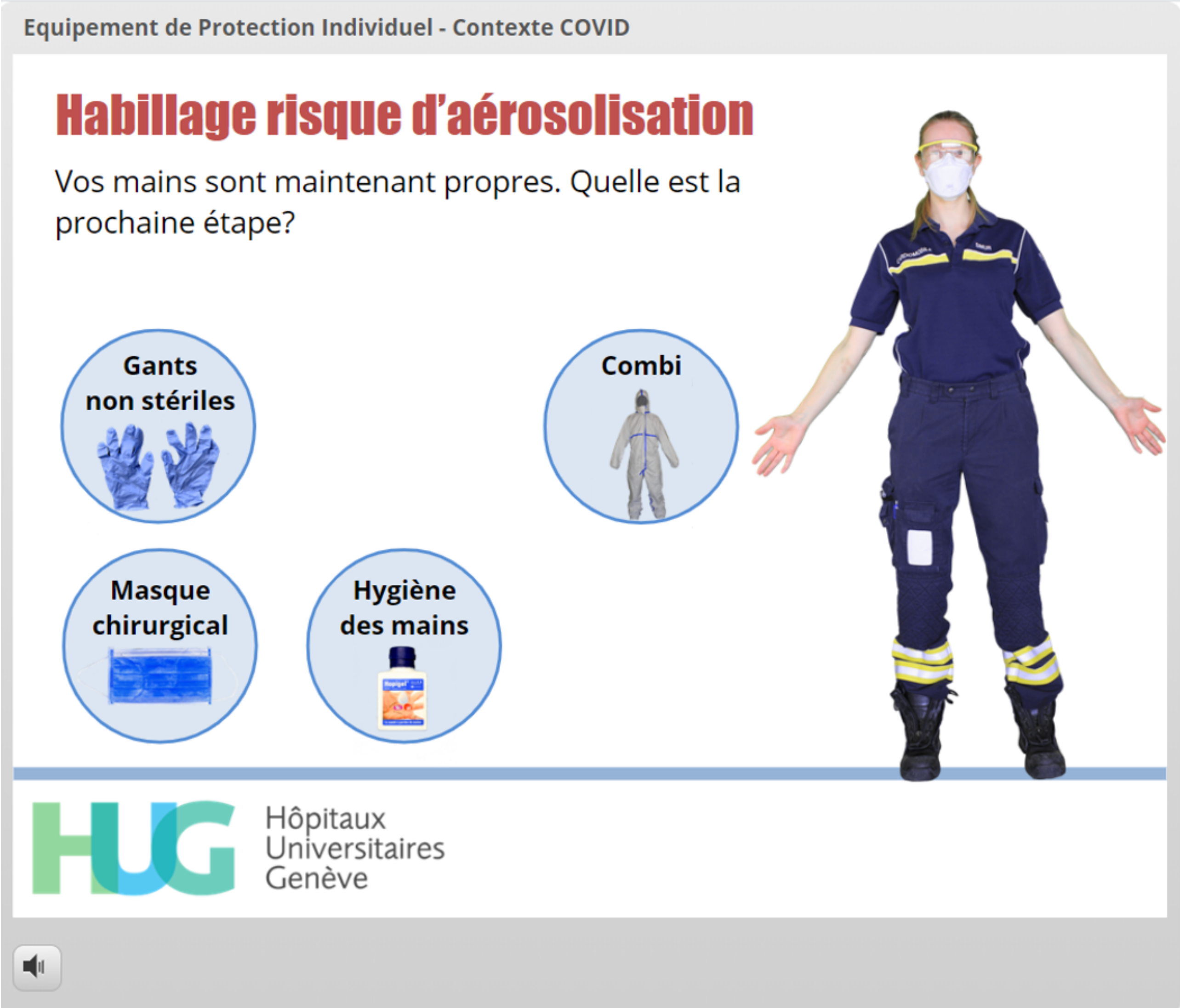


Figure 10. The learner has elected to try to put on gloves at this stage but is advised to try something else first without being given negative feedback (*"Cela semble être une bonne idée mais ne faudrait-il pas faire autre chose en premier?" which means "This looks like a good idea, but shouldn't you do something else first?"*).

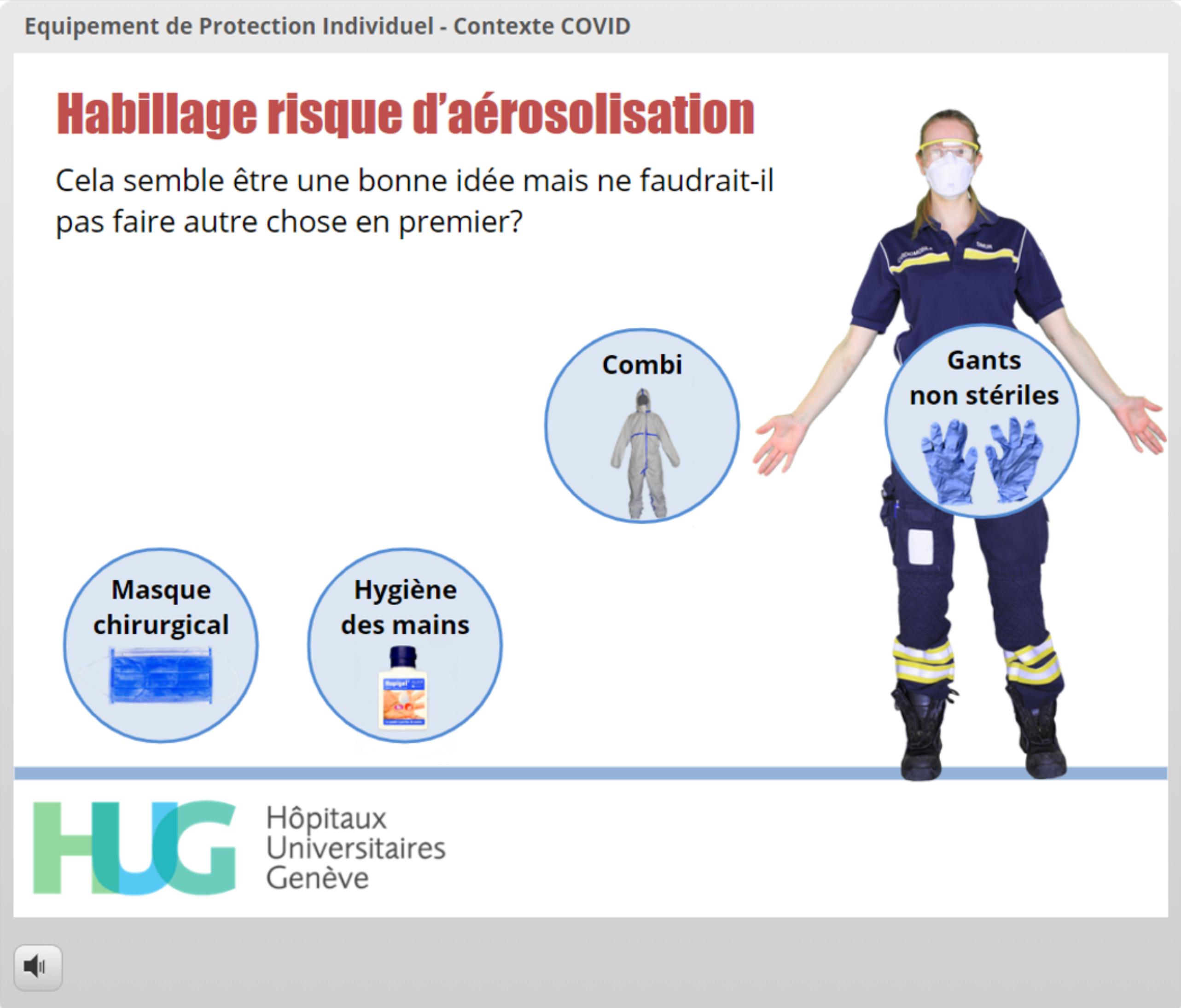
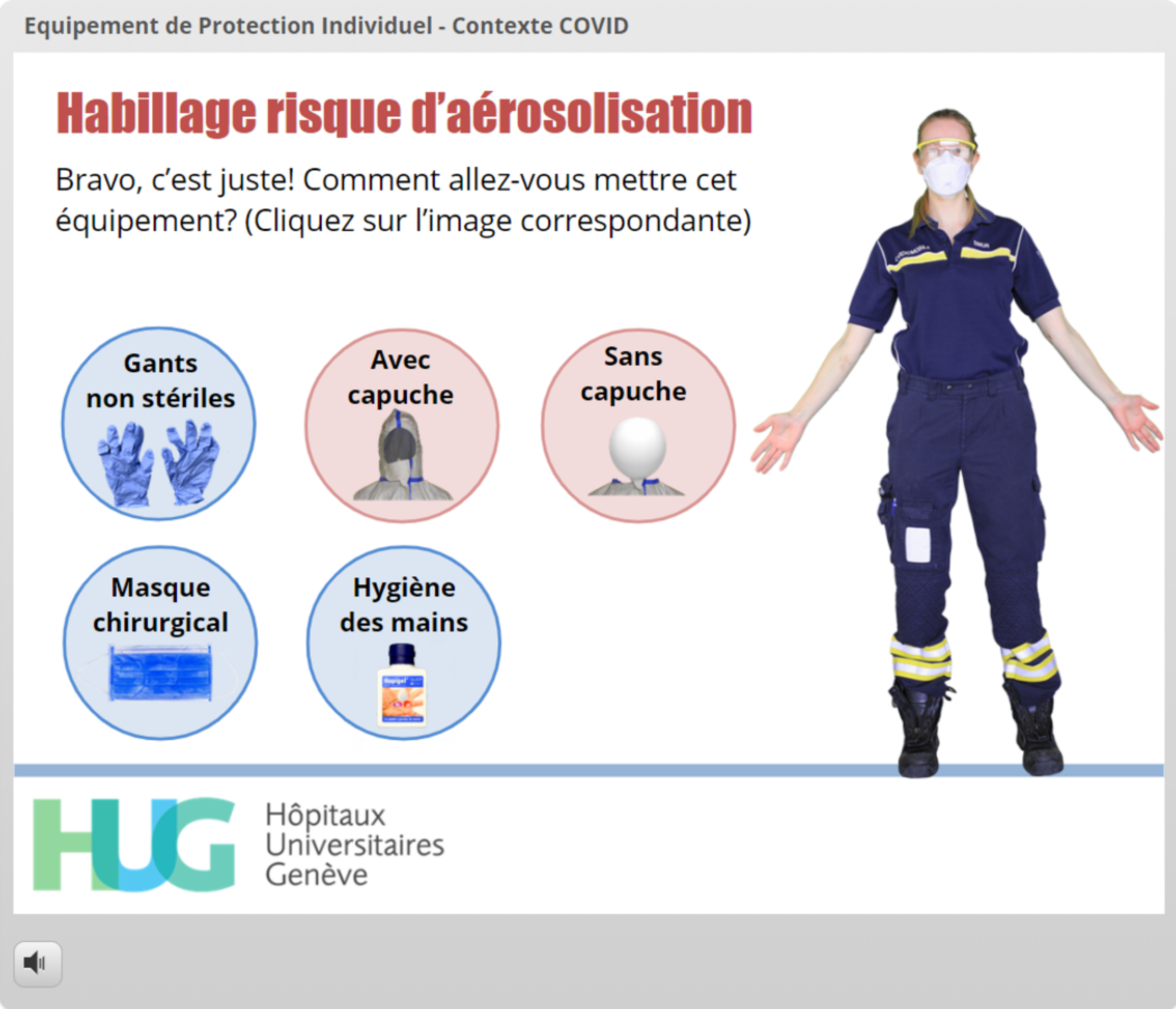


Figure 11. The learner has now decided to put on the overalls, which is the right answer at this stage. The positive feedback is displayed at the top of the screen (*"Bravo, c'est juste" which means "Congratulations, you're right!"*), and two options (with or without hood) have appeared.



When the choices were related to complex sequences, videos were launched automatically in lightbox slides (Figure 12). Once the correct PPE was chosen, the appearance of the EMS provider immediately changed to acknowledge the correct answer, thereby giving direct and visual feedback to the learner (Figure 13). Donning sequences were completed by slides repeating the correct donning sequences for the lead EMS provider (Figure 14) and by displaying the adequate PPE the EMS teammate and the patient should wear. The doffing sequences followed the same design, but in reverse: at the start of the sequence, the EMS provider wore PPE according to the risk setting. The circles containing PPE options were next to the provider, sometimes overlapping the photograph (Figure 15), and the learner was required to drag them away both in the right sequence and into the correct disposal bag (either a regular bin or a bag that could be stored to allow equipment decontamination and reuse). Specific PPE-related questions were asked using true/false interactions (Figure 16).

Figure 12. Automatic launch of a video in a lightbox upon selection of the correct PPE option. The video illustrates complex donning or doffing sequences.

Figure 13. Change in the appearance of the prehospital provider to acknowledge the learner's correct choice of PPE.

Figure 14. Repetition of the correct donning sequence for the lead prehospital provider in the context of a suspected or confirmed COVID-19 case with need for high-risk procedures.

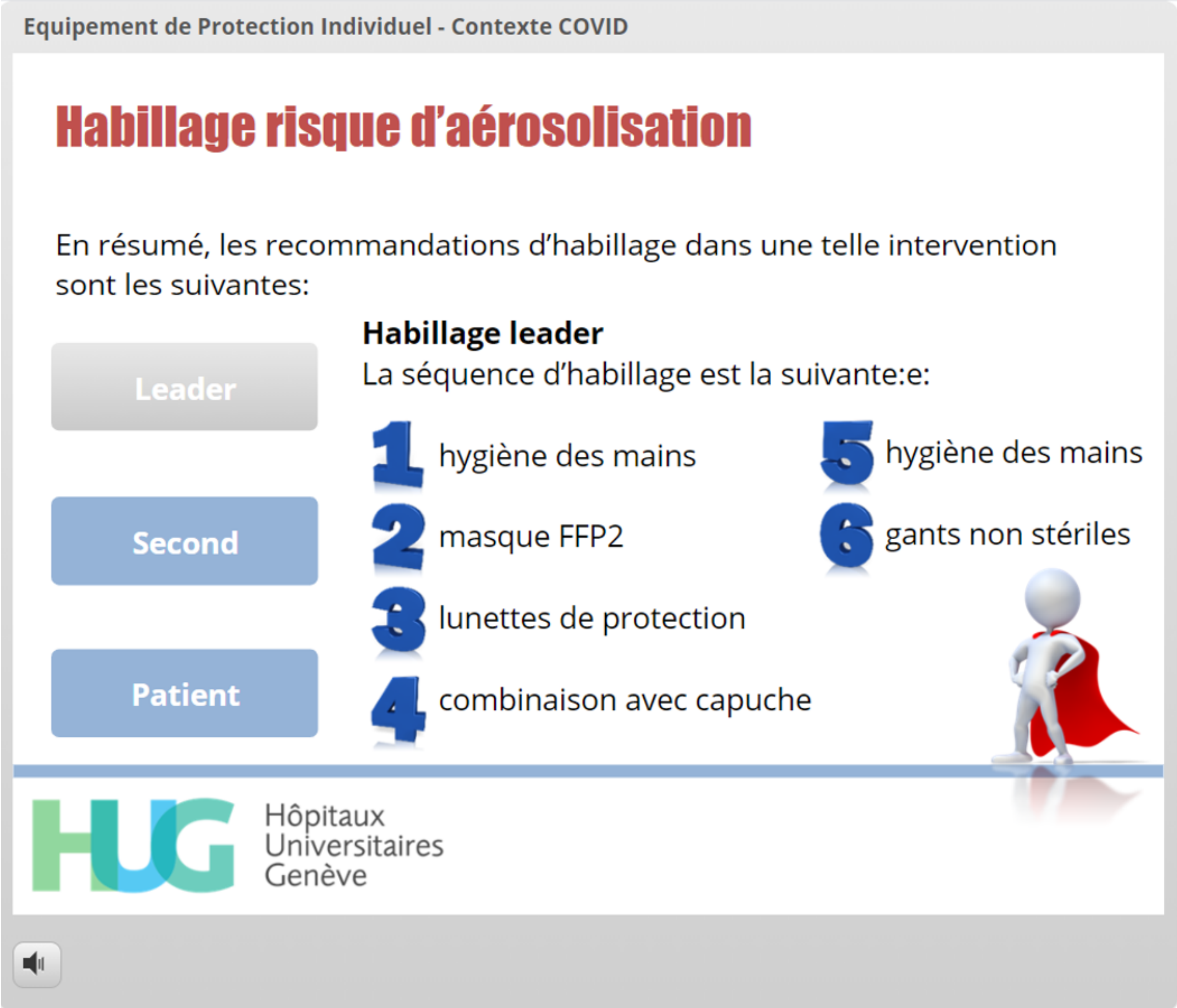


Figure 15. Gamification of the PPE doffing sequence. PPE worn by the prehospital provider must be dragged either to a biohazard trash bag (bottom right) or to a bag designed to hold reusable materials, such as protective goggles (bottom left).

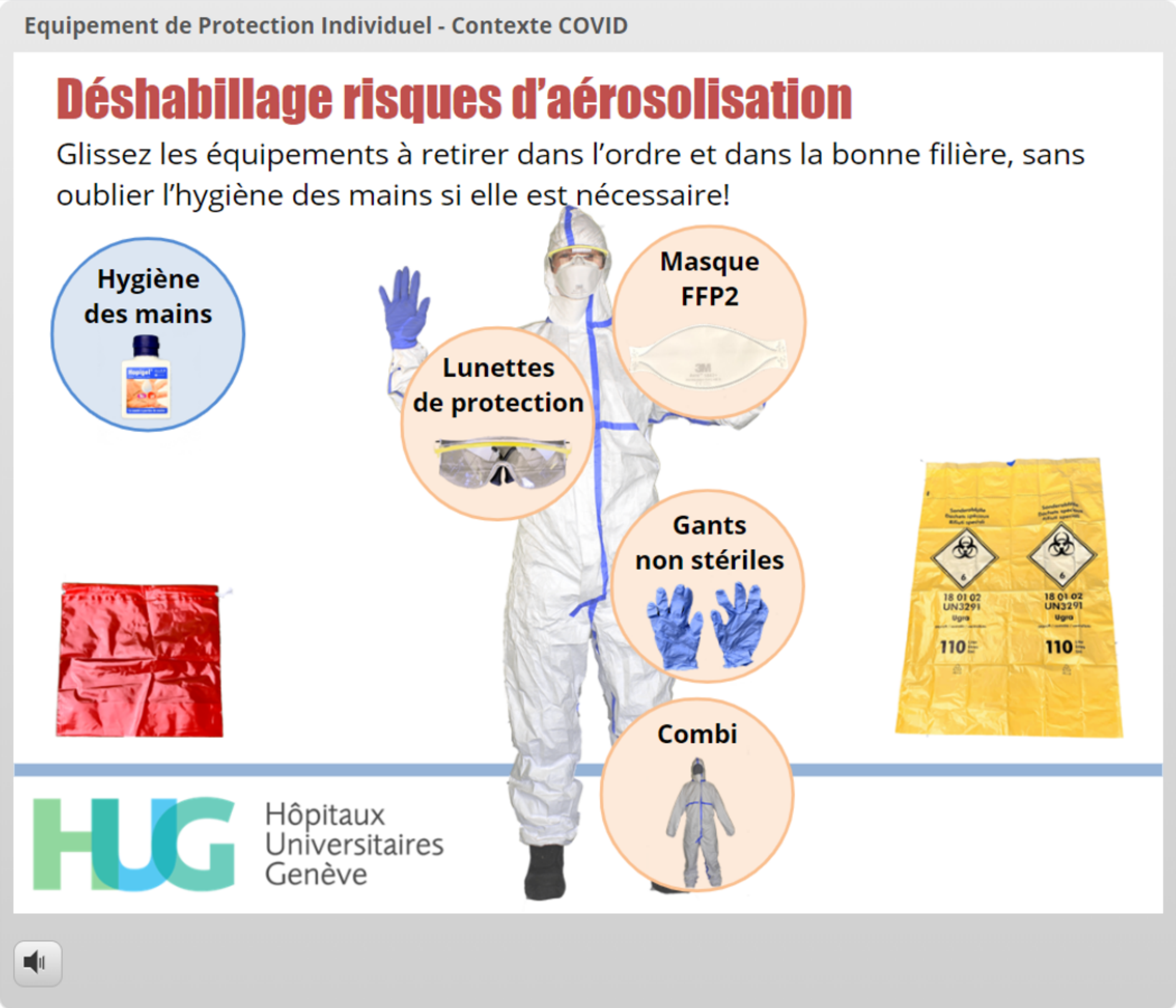
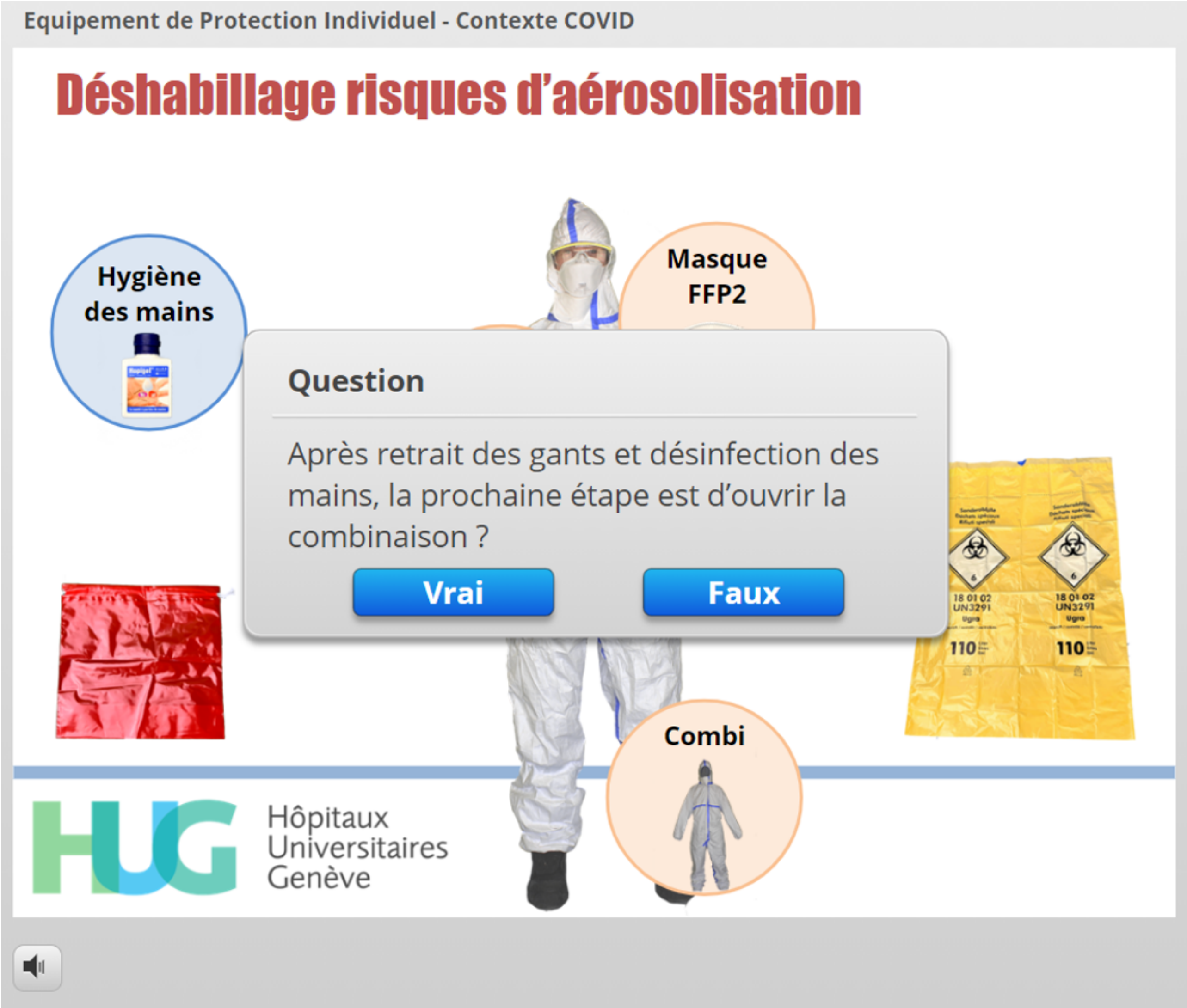


Figure 16. Use of a true/false interaction to assess the learner's knowledge during particular steps in the doffing sequence.



Module Validation

Once created, each sequence was thoroughly tested by all the other authors, who systematically provided feedback on each successive iteration. Usability issues were screened using the Davids heuristic evaluation procedure [27]. One major feature was added as a result of this procedure, namely the creation of a menu at the end of the module. This menu allowed learners to directly access any section of the module so they could review any specific element at will. Once all feedback was taken into account and the module was thoroughly debugged, a final version was validated by all the authors, among whom are chief ambulance and medical officers as well as infection prevention and control specialists who also act as consultants for the World Health Organization (WHO).

Module Availability

The gamified e-learning module can be accessed directly on the internet [23]. It can also be directly and freely downloaded from the website as a SCORM package or as a standalone web package, both of which are archived in independent ZIP files. The module can be reused freely under the Creative Commons 4.0 BY-NC-SA (Attribution-NonCommercial-ShareAlike) license [28].

Discussion

Principal Findings

A multiplatform gamified e-learning module designed using the SERES framework was created to help prehospital providers acquire knowledge regarding choice and use of PPE in the context of the COVID-19 pandemic [14]. The application of this framework to the development of a serious game has previously been described [29], and a pilot randomized controlled trial has shown promising results [30]. Although this framework was initially designed to help develop serious games, this study shows that it can also be used to create gamified content within materials that do not qualify as full-fledged games, and Deterding [31] indeed considers that gamification does not mandatorily imply the creation of a game but rather refers to "the use of game design elements in non-game contexts." The main purposes of using gamification techniques are to create more engaging material and to improve user experience to achieve a particular goal. In this instance, one of the main goals was to enhance acquisition of knowledge and skills regarding PPE donning and doffing sequences.

The theoretical bases on which this module was built were not only taken from medical literature. Indeed, data related to the way health care workers or health care students absorb learning content is still scarce, and the model used to create this gamified module was partly derived from other fields, such as electronic engineering [20] and computer science [21]. The medical literature nevertheless provided some useful insights, among which are the potential shortcomings associated with the lack of video demonstration, which were identified in a previous trial [9]. The use of short videos targeting specific learning goals has been shown to enhance knowledge acquisition and retention and has demonstrated the ability to transfer information in many different fields; therefore, cutscenes were included in the e-learning module [32].

As Bloom's revised taxonomy was used to define the target thinking skills, specific game mechanics were chosen to fit the learning objectives [15]. Although game mechanics based on rewards and action points are often used in gamification as well as in serious games, there is little data to suggest that their use enhances knowledge acquisition or retention. As these game mechanics are linked to the evaluating thinking skill, which was not elected during the design process, and as their inclusion in a serious game is not mandatory, we chose not to include them. In a similar way, badges, which are often used to keep learners engaged if multiple modules must be completed or if the course spans long periods of time, were not considered, as this was a single module that learners would be able to complete in a relatively short amount of time [33,34]. Moreover, rewards such as badges or action points may not yield the desired result, as learners may engage in the learning to obtain these rewards rather than to acquire specific skills or knowledge [35].

Integration of infection prevention experts early in the design of the module greatly helped us to gather the necessary media and ensure that the correct guidelines would be used during development. Validation of the content by these specialists, who also act as consultants for WHO, ensured the soundness of the elements taught in the module.

Limitations

Despite the use of a solid scientific rationale and of the SERES framework during the entire development process, the main limitation of this paper is that this module has not yet been tested and its contribution as a learning tool cannot currently be assessed. A protocol for a randomized controlled trial has therefore been submitted to our regional ethics committee (Req-2020-00374). As this project does not involve patient data or participation, this committee has already issued a "declaration of no objection," as such trials are not within the scope of Swiss federal law on human research [36].

Given the context of the COVID-19 pandemic and the need to quickly provide this gamified e-learning module to prehospital personnel, some of its features remain to be perfected. Indeed, more game design elements could be included to increase gamefulness. Key and selected elements from the RECIPE (Reflection-Engagement-Choice-Information-Play-Engagement) mnemonic for meaningful gamification developed by Scott Nicholson [35] could also serve as a building ground for development of further modules or even of a more comprehensive PPE course. However, some of these elements may not be relevant to this type of module, as they may imply too high a degree of freedom. Indeed, due to the need to achieve specific learning objectives, it is almost impossible to allow the learner to freely choose whether to engage in a specific and potentially crucial learning activity.

Other limitations must also be acknowledged. Indeed, although we strived to adhere to the most recent infection control guidelines, PPE type and use probably differs between EMS, and the contents of the module may not be compatible with some systems. Moreover, although we sought to enhance knowledge acquisition of PPE donning and doffing sequences through the use of game mechanics, these procedures may prove too complex to acquire without directly manipulating the PPE elements. This gamified e-learning module may therefore be better suited for a flipped classroom design [37,38]. However, the current need for social distancing prevents the organization of live training sessions, and this module may therefore be an acceptable surrogate until such training can be resumed.

Another limitation is that the module is currently only available in French. However, as this material is available under a Creative Commons license, it can now be used by many different institutions, ambulance companies, and hospitals. This may not only help spread knowledge regarding use of PPE but may also facilitate further research in the field. Last but not least, opportunities of distance teaching using gamified content may prove even more valuable than before, as social distancing may continue for many more months.

Conclusion

A gamified e-learning module designed to promote knowledge and understanding of PPE use among prehospital health care workers during the COVID-19 pandemic was developed by following the SERES framework. The impact of this module should now be assessed by a randomized controlled trial.

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Conflicts of Interest

None declared.

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Abbreviations

COVID-19: coronavirus disease
EMS: emergency medical services
LM-GM: learning mechanics-game mechanics
MeSH: medical subject headings
PPE: personal protective equipment
SARS-CoV-2: severe acute respiratory syndrome coronavirus 2
WHO: World Health Organization

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Original Paper

Exploring Features of the Pervasive Game Pokémon GO That Enable Behavior Change: Qualitative Study

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Abstract

Background: Digital gaming is one of the most popular forms of entertainment in the world. While prior literature concluded that digital games can enable changes in players' behaviors, there is limited knowledge about different types of behavior changes and the game features driving them. Understanding behavior changes and the game features behind them is important because digital games can motivate players to change their behavior for the better (or worse).

Objective: This study investigates the types of behavior changes and their underlying game features within the context of the popular pervasive game Pokémon GO.

Methods: We collected data from 262 respondents with a critical incident technique (CIT) questionnaire. We analyzed the responses with applied thematic analysis with ATLAS.ti (ATLAS.ti Scientific Software Development GmbH) software.

Results: We discovered 8 types of behavior changes and 13 game features relevant to those behavior changes. The behavior changes included added activity in life, enhancing routines, exploration, increased physical activity, strengthening social bonds, lowering social barriers, increased positive emotional expression and self-treatment. The game features included reaching a higher level, catching new Pokémon, evolving new Pokémon, visiting PokéStops, exploring PokéStops, hatching eggs, fighting in gyms, collaborative fighting, exploiting special events, finding specific Pokémon, using items, Pokémon theme, and game location tied to physical location. The behavior changes were connected to specific game features, with game location tied to physical location and catching new Pokémon being the most common and connected to all behavior changes.

Conclusions: Our findings indicate that the surveyed players changed their behaviors while or after playing Pokémon GO. The respondents reported being more social, expressed more positive emotions, found more meaningfulness in their routines, and had increased motivation to explore their surroundings.

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KEYWORDS

Pokémon GO; digital gaming; behavior change; pervasive games; augmented reality games; location-based games; exergames; behavior change support system

Introduction

Background

Digital gaming has become one of the most popular forms of entertainment in the world [1]. As individuals engage with digital games, they are receptive to potential changes in their behavior [2]. This is the case especially of pervasive games, which refers to games played in physical locations [3].

The characteristics and popularity of digital games make them a strong potential platform for behavior change, or the modification of human activities and routines. More specifically, digital games can offer new ways to motivate individuals to change their behavior for the better and play a part in combating contemporary problems such as a sedentary lifestyle and social isolation [4,5]. This is in line with the recent notion of gamification, which refers to implementing game elements to human activities [6] with the aim of motivating people to behave in favorable ways through more gameful and enjoyable user experiences [7].

Literature on digital games and other potential behavior change support systems (BCSSs) has provided valuable first insights on the link between games and behavior change [8-10]. However, we could not locate any studies that (1) explore the various behavior change types digital games enable or (2) identify the game features driving different types of behavior change. We aim to address this research gap by focusing on the context of pervasive games because of their potential for inducing a wide range of behavior changes. Our research question is: What kinds of pervasive game features drive different types of behavior change?

This study uses a qualitative research approach given its usefulness in tapping into individuals' real-life behaviors and exploring new areas of investigation [11,12]. We desire to extend the prior literature by exploring pervasive games as BCSSs and uncovering insights about specific game features and their relation to behavior change types. As for practical implications, our findings can help game designers and public sector parties identify game features that influence people's behavior for the better.

Theoretical Background

Pokémon GO

Pokémon GO [13] was launched in July 2016 and gained tremendous success around the globe [14,15]. As is typical for mobile games, after its success peaked, the number of downloads and players of Pokémon GO declined [16,17]. Nevertheless, in early 2019 the game still had a large player community and made exceptional profits, with an estimated revenue of $795 million worldwide in 2018 alone [18]. There are several aspects that drive Pokémon GO's popularity and success compared with earlier location-based and pervasive games (eg, franchise and fandom [19], game enjoyment, ease of use, challenge, nostalgia [20], a critical mass of players, social play, game mechanics, and the combination of outdoor play and physical activity [21]). The findings from Kari et al [22] suggest that perceived positive behavior changes are also one reason behind playing Pokémon GO.

The game itself is a location-based mobile game based on augmented reality mechanics. Since its publication, Pokémon GO has undergone several updates and received new content and features [23]. Yet the basic idea remains the same: The player navigates physical world settings, and the player's avatar follows on an in-game map based on real street maps. The in-game map includes some central places concerning gameplay, such as PokéStops (locations where players can collect game items) and gyms (locations where the players can battle others with their Pokémon). When the game is played as intended, it requires moving around physical world places, thus requiring physical activity [24]; as such, the game has an exergaming character [25]. The physical world locations of Pokémon GO are widely based on Niantic's earlier location-based game Ingress [13,26,27].

Academic interest in different aspects of Pokémon GO is extensive [28,29]. Several studies concerning Pokémon GO have reported on the game's positive influence on physical activity behavior [29-35]. However, other studies have questioned the sustainability of this increased physical activity [29,33]. Yet other studies have concluded that Pokémon GO can support people in changing their sedentary screen time and indoor activities to outdoor activities [35-37]. Pokémon GO also seems to have a strong social element. Research suggests the game can change people's social behavior [29] and aid with social withdrawal issues [38,39]. However, beyond these many reported positive side effects and benefits, there have also been reports of hazards connected to playing Pokémon GO [29,32,40], such as accidents, injuries [41], trespassing [42], and potential geographically linked safety risks [43]. Hence, the game could also change behavior in negative ways, which, of course, is important to prevent.

There are several motivations to play Pokémon GO (eg, exercise, fun, escapism, nostalgia, friendship maintenance, relationship initiation, and achievement [44]). The chief motivation to play seems to be fun [34,45,46], although combined fun and exercise is also popular [45].

All in all, a scoping review by Baranowski and Lyons [29] shows that Pokémon GO–related research has focused on numerous different aspects of the game. Still, there are limited studies on multifaceted behavior change types and game features driving them within Pokémon GO and other pervasive games. Additional research on how games can be designed to change behavior is thus necessary [29].

Behavior Change Support Systems

Digital games and other information technology (IT) can influence people's attitudes and behaviors [47]. This impact can be intended or unintended (eg, a side effect due to design). IT applications can be developed to induce behavioral changes both positive (eg, supporting a desired behavior change) and negative (eg, deception or coercion) [47]. The concept of BCSSs is defined as a "sociotechnical information system with psychological and behavioral outcomes designed to form, alter, or reinforce attitudes, behaviors, or an act of complying without using coercion or deception" [47]. Hence, BCSSs emphasize the voluntariness of behavior change. BCSSs can function in 3 ways [47]: formation, alteration, and reinforcement outcomes. The formation outcome means "formulation of a pattern for a situation where one did not exist beforehand," alteration outcome involves "changes in a person's response to an issue," and reinforcement outcome refers to "the reinforcement of current attitudes or behaviors, making them more resistant to change."

Further, Oinas-Kukkonen [47] divided changes into 3 categories: attitudes, behaviors, and the act of complying. The goal with systems supporting changes to attitude is to "influence the end users' attitudes rather than behavior only," with systems supporting changes in behavior, it is to "elicit a more enduring change than simple compliance once or a few times," and with systems supporting change in an act of complying, it is “simply to make sure that the end user complies with the request of the system” [47].

With BCSSs, there are 3 types of stakeholders with the intention of influencing someone’s attitudes or behaviors: those who create or produce the BCSS, those who distribute or grant access to the systems, and the individual users of the systems [47,48]. The focus of this study is on the users, but it also conveys implications for the other 2 stakeholders.

There are various ways that digital games can act as BCSSs. For example, by playing digital games, players are exposed to different kinds of game experiences that can function as stimulants for the players’ future behaviors [49]. According to Oinas-Kukkonen [47], ideal BCSSs persuade users to adopt intended behaviors voluntarily; however, changes in behavior can also be unintentional. For further reading about behavior change in general and related techniques, we refer the reader to research conducted by Connolly et al [49], Michie et al [50,51], and Davis et al [52].

Pervasive Games

While most digital games are played inside and on stationary devices, there is a tradition of games that are not tied to one location. These are referred to as pervasive games [53] and include diverse types of games from alternative reality games to those played on mobile devices. Games are identified as pervasive when they expand the spatial, social, or temporal limits of play beyond what is typical to them [3].

For example, I Love Bees [54] was an alternative reality game created as part of a viral marketing campaign for Halo 2 [55]. I Love Bees required players to collaborate in a wide geographical area. Another game that used mobile technology is BotFighters [56], in which players fought each other’s robots by sending text messages. Further, games like Momentum [57] removed players from their ordinary lives and gave them a fictional framework in which to participate.

Pervasive games blur different contexts and mindsets, requiring a variety of activities and approaches [53]. However, location-awareness technology and casual games have paved the way for less intensive approaches to pervasiveness. Presumably these also affect player behavior, but previous research has not explored possible behavior changes in depth. We investigate one such example, Pokémon GO.

Methods

Data Collection

We employed a qualitative approach in our study due to its benefits in exploring new areas and examining users’ real-life behaviors [12,58]. More specifically, we used the critical incident technique (CIT) [59], which focuses on acquiring individuals’ descriptions of their actual behavior. CIT has been widely used in studying individuals’ experiences and behaviors related to products and services [60], with the term critical incident referring to a single experience that a person perceives as unusually positive or negative [61]. CIT has several advantages: it focuses only on meaningful incidents that are typically influential for human behavior; respondents use their own words instead of research terminology; critical incidents are easy to remember and describe; and the incident descriptions tend to reflect detailed accounts of activities and behaviors [59,60,62,63]. In summary, CIT is considered an established technique for collecting data and exploring human behavior [60,64].

We collected data by conducting an online questionnaire in English for an international audience. We collected the data right after Pokémon GO was released, from mid-July to mid-November 2016. In seeking a broad range of respondents, we distributed the questionnaire via different kinds of online forums (eg, related to gaming, Pokémon GO, lifestyle, wellness, culture, cooking, sports, cuisine) and social networking services (Facebook, Twitter, and Reddit). There were no rewards offered for responding to the questionnaire. To elicit descriptions of outstanding incidents, we adapted wordings from recognized CIT studies [64,65] such as, “Think of a time when you had an outstandingly positive or negative experience [with Pokémon GO].” To acquire further details about the given incident, we asked a series of open-ended questions, including “Explain what you were doing and what happened.” “What exactly caused the positivity/negativity of the experience?” “Why do you consider this to be an outstanding experience for you?” and “How did you perceive the game and/or the gaming situation before and after the experience?” Each respondent of the CIT questions was required to have experience playing Pokémon GO. This was ensured by asking the respondents, “Have you played Pokémon GO?” Additionally, the questionnaire included questions for another study. The full question items are available from the authors by request. More details on the questionnaire can be found in the Checklist for Reporting Results of Internet E-Surveys (CHERRIES) [66] in Multimedia Appendix 1.

Data Analysis

We used applied thematic analysis [67] and the software ATLAS.ti (ATLAS.ti Scientific Software Development GmbH) to qualitatively analyze the data. During the analysis, we took suggestions from Charmaz [68] into account. To ensure the quality of the empirical evidence, we followed guidelines suggested by Gremler [60] and Bitner et al [65] and set these criteria for the reported incidents to be included in the analysis: it was required to be a single incident concerning a specific playing session of Pokémon GO with sufficient incident description. Altogether, we received 270 complete responses, of which 262 met the inclusion criteria.

In the first phase, the 262 CIT responses were free-coded by one of the authors. All responses were read through twice, after which a set of preliminary codes was formed. We tested these codes on the first 20 responses and on the basis of these responses revised the codes. We then coded all of the responses, with new codes introduced when responses did not fit the original categories. Finally, we merged some codes upon noticing more general trends or that the codes did not include sufficient enough responses to be informative. After the initial coding, results were cross-checked by another author. This resulted in small refinements in a few category names and 19 detailed coding suggestions that were decided on via consensus among the authors. Altogether, we had 70 codes reflecting 1314 quotations (for a full list of codes, see Multimedia Appendix 2). We then categorized the codes into more general categories, resulting in 8 categories of behavior change types. Because each quote could be coded with multiple codes, they could belong to multiple categories. The quotes are presented in this study with slight corrections to style and grammar.

In the second phase, we identified game features from Pokémon GO. We wished to understand how game features relate to different types of behavior change, so we analyzed the links between game features and behavior change.

Our analysis was built upon game design elements found by Meschtscherjakov et al [34] when they "analyzed the Pokémon GO app by systematically evaluating each possibility to interact with the app." They focused on elements they deemed as persuading "players to be more physical [sic] active." They "do not claim that this list is comprehensive, since the different game design elements overlap each other, and Pokémon GO is constantly updated with new features." The elements identified by Meschtscherjakov et al [34] were as follows:

- Reaching a higher level
- Catching new Pokémon
- Evolving new Pokémon
- Visiting PokéStops
- Exploring PokéStops
- Hatching eggs
- Fighting in gyms
- Collaborative fighting
- Exploiting special events

Because we were interested in behavior changes besides physical activity, we tried to identify game features missing from the list. By analyzing the answers in our data, we found 4 additional features:

- Finding specific Pokémon: Not all Pokémon are the same, as some are rarer or more powerful than others. Players care about which Pokémon they find.
- Using items: Players use different items during gameplay that either make playing the game easier or enable new actions. Lures are one of the most important items that change the social dynamic of the game.
- Pokémon theme: Pokémon GO is Pokémon-themed, but that is not a necessary quality. It could also have some other theme, and players could react differently to it.
- Game location tied to physical location: Pokémon GO is a location-based pervasive game. There are other Pokémon games that are not tied to specific locations, and players interact differently with these games.

After we identified these game features, we compared them to the behavior change categories found in the previous phase. We considered there to be a link between a game feature and a behavior change if either of 2 conditions was met: (1) the link was explicitly mentioned in the data ("I walked around the block to hatch my eggs") or (2) the link was likely based on our knowledge of the game and the behavior described in the data ("I continued to play because I wanted to get a Pidgeot." Pidgeots are Pokémon evolved from Pidgeys, suggesting a link to the game feature evolving new Pokémon).

We identified the most central game features (those that clearly stood out above the others based on frequency) that drove players toward each specific behavior change by counting the coded links between game features and behavior change. The exact quantity of the central links varied between different categories of behavior change, ranging from 3 to 5. These included 2 game features that appeared important for all behavior change categories.

Results

Summary

Our results comprise responses from 262 Pokémon GO players. Table 1 summarizes the background information of the respondents. A total of 78.2% (205/262) of the reported incidents were positive and 21.8% (57/262) negative. The incidents reflect 8 types of behavior changes, which we present in the following subchapters with the related game features that drive such changes.

On a general level, there were 2 game features behind all behavior changes: game location tied to physical location and catching new Pokémon. Thus, these are the 2 most central features that supported the respondents' (intentional or unintentional) behavior changes. The reason why these 2 features are so influential regarding behavior changes is their strong connection to Pokémon GO's fundamental game mechanics (merging the game world with the physical world) and purpose (catching new Pokémon). The following quotes illustrate how these features drove behavior changes.

> *It [Pokémon GO] is an excellent motivator for my husband and I to exercise and walk at local parks. We bring our daughter and have loads of fun.* [Respondent 57; game location tied to physical location]
>
> *I walked around catching Pokémon and visiting PokéStops and walked like 10k in 2 days. I usually struggle to even leave the house.* [Respondent 22; catching new Pokémon]

Certain game features were not important for any type of behavior change. They were reaching a higher level, evolving new Pokémon, collaborative fighting, and exploiting special events [34]. This does not necessarily mean that these are not important features of the game, just that they were not associated with changes in the respondents' behavior.

Table 1. Sociodemographic characteristics of the sample (n=262).

Characteristics	Value, n (%)
Gender	
Male	82 (31.3)
Female	176 (67.2)
Other	4 (1.5)
Age in years	
<20	26 (9.9)
20-29	151 (57.7)
30-39	47 (17.9)
≥40	38 (14.5)
Employment status	
Student	105 (40.1)
Employee	120 (45.8)
Entrepreneur	10 (3.8)
Pensioner	10 (3.8)
Other	17 (6.5)
Highest education	
Comprehensive school/primary education	12 (4.6)
Vocational school (applied)	11 (4.2)
Upper secondary school/gymnasium	55 (21.0)
Tertiary education at university of applied science	36 (13.7)
Bachelor or master’s level at university	128 (48.9)
Licentiate or doctoral level	11 (4.2)
Other	9 (3.4)

Added Activity in Life

One way Pokémon GO affected the respondents’ routines was giving them more things to do. The respondents reported that while many of their existing activities were centered around their homes, Pokémon GO gave them a reason to leave their homes. Importantly, the respondents played the game for short bursts whenever it was convenient. They had no need to plan ahead how to incorporate Pokémon GO into their schedules and instead could play whenever a suitable opportunity presented itself.

The game features that drove respondents toward added activity in life were visiting PokéStops and Pokémon theme. Visiting PokéStops enabled added activity, since the PokéStops offered new potential locations for visitation. For instance, a cluster of PokéStops persuaded one player to walk around a waterfront during sunrise instead of going home after a night shift. Familiarity with the Pokémon theme was another trigger for respondents to deviate from their previous activities:

> *Pokémon was a big part of my childhood and the familiar characters that I loved as a kid helped me to motivate myself enough to go out and move around.* [Respondent 239]

Enhancing Routines

Several respondents reported how Pokémon GO became part of their usual routines. They continued going through their daily routines (eg, walking the dog, going to work, buying groceries), but these routines were enhanced by the addition of activities related to Pokémon GO. The routines themselves did not change, but they became more enjoyable. Being able to play Pokémon GO in short sessions while doing something else was key to this type of game engagement.

The game features that drove the respondents toward enhancing their routines included hatching eggs and finding specific Pokémon. The respondents expressed that they easily complemented their walking routines with the goal of hatching eggs. For example, one of the respondents stated, “I love walking if I have a goal, I cannot stand walking without a goal.” Similarly, the respondents complemented activities such as walking home from work by looking for new or otherwise meaningful Pokémon. They described how finding such Pokémon brought an additional layer of enjoyment to otherwise boring routines.

Exploration

Pokémon GO encouraged the respondents to explore their surroundings. For instance, the respondents reported that they intentionally set out to find specific PokéStops. Some even reported that they chose to use new paths to familiar places because of the game, making them more aware of their usual surroundings. In addition, a few respondents described how the game led them to explore their surroundings unintentionally while looking for a Pokémon.

Exploration was linked with the game feature exploring PokéStops. The respondents expressed that going around different PokéStops was a good way to find new and interesting places both in their hometown and when traveling. As PokéStops are typically located at landmarks, the respondents became curious to see landmarks in the physical world. Thus, because PokéStops are located at these particular spots, they provided value besides just collecting items.

> *Seeing completely new things in my surroundings, all because of the game had PokéStops singling them out.* [Respondent 76]

> *We were on holiday, visiting another city, and walked around seeing places and playing.* [Respondent 206]

Increased Physical Activity

One of the central changes in behavior reported was an increase in physical activity. Most respondents played Pokémon GO for both fun and as a form of exercise. While some claimed that the game was a good motivator to exercise more, others said the increase in physical activity was an unintentional but welcome side effect of playing Pokémon GO.

Two game features that drove the respondents toward increased physical activity were hatching eggs and Pokémon theme. The walking distance required to hatch an egg led the respondents to walk or run more (eg, "I'm walking 5k a day at least, [for] them eggs"). The game's theme (ie, being about Pokémon) also increased physical activity: the respondents reported feelings of interest, fandom belonging, and nostalgia toward Pokémon as a trigger to be physically active or make exercising more fun with the game.

> *Being a huge fan of Nintendo and Pokémon [...] I was extremely excited to try it out considering how it might get me more motivated to exercise and have fun at the same time!* [Respondent 27]

> *I love that I finally get to go on adventures outside, get some fresh air and exercise, AND play a game from a series I'm fond of (and have grown up with my entire life).* [Respondent 63]

Strengthening Social Bonds

One-third of the respondents played Pokémon GO alone, meaning that most played it with others: friends, children, parents, or significant others. Based on the responses, Pokémon GO made it easy for the respondents to spend quality time with people important to them. The respondents even described how playing the game was made more meaningful when the experience was shared with others. However, the highly social nature of playing Pokémon GO made a few respondents potentially risk becoming outsiders, as they reported playing only because it was expected of them.

The game features behind strengthening social bonds included finding specific Pokémon, Pokémon theme, and using items. The moment of capturing a rare Pokémon not only delighted the respondents but made some of them happy for each other (eg, "Catching rare [Pokémon] and being happy for friend too"). Many of the respondents described their shared interest in the Pokémon theme, which increased their feelings of affinity. Last, some of the respondents perceived using items (eg, lures) as social favors and acts of goodwill, thus forming positive impressions of other players. However, using items also triggered negative feelings about free-riders (people not contributing to but taking advantage of others' lures).

Lowering Social Barriers

The respondents reported that Pokémon GO made socializing with strangers possible, giving the players something they could share with people they did not know. This extended to people who were often in close physical proximity, like neighbors. Another thing the respondents remarked on was that Pokémon GO erased or lowered social barriers between people of different ages: the respondents themselves ranged from students to pensioners, and they described how the game made them socialize with players of all ages. Pokémon GO supports this by dividing players into teams, focusing play around specific locations, and having items that also help other players. A small minority of respondents encountered problems with the lowered social barriers, however, reporting how strangers made them feel uncomfortable.

Two game features that lowered social barriers were fighting in gyms and using items. The items that appeared to all players (eg, lures) brought respondents together momentarily and offered an easy way for them to interact with other players. Similarly, the respondents reported that they teamed up with other players in gyms, making them natural spots for starting a conversation with unknown players. For instance, one player described, "I am forty, so I was quite happy to meet a coplayer even ol[der] than I am. We met at a gym."

Increased Positive Emotional Expression

Pokémon GO play often had positive emotional connotations for the respondents. They reported how they expressed positive emotions, like happiness or positivity, while playing. They also described activities that have a positive emotional valence, like laughing, smiling, and being silly. These emotions were not reserved to interactions between close friends, and the respondents described how happiness or joy spread among strangers playing together as well. Sometimes this was associated with people teaching each other how to play the game and discussing how different features of the game work.

More specifically, positive emotional expression linked to the game feature finding specific Pokémon. According to the data, encountering a favorite, rare, or otherwise meaningful Pokémon triggered emotional reactions of excitement. In many cases, this was because the appearance of a specific Pokémon was a surprise that the respondents could not foresee.

> *The excitement, the reaction of my friends getting excited, and high fiving [sic] when we caught a great Pokémon :).* [Respondent 103]

Self-Treatment

Some of the respondents also wrote of intentionally using Pokémon GO to treat some aspect of their health, ranging from weight loss and improving fitness or mood to finding ways to use the game for help with anxiety or depression. Not all of the respondents were equally serious about this use of Pokémon GO for self-treatment, but at least for some respondents it was a part of their overall health management.

In addition to game location tied to physical location and catching new Pokémon, which were found to be behind all behavior changes, a game feature that aided self-treatment was hatching eggs. It was connected to reaching goals related to physical activity.

> *I combine it with my FitBit in order to maintain mobility (I have 2 types of rheumatism and fibromyalgia). I get my steps on the FitBit by hunting Pokémon.* [Respondent 64]

The specific game features that drove the identified behavior changes are summarized in Table 2. Many of the specific features are linked with several different types of behavior change.

Table 2. Features of Pokémon GO and their related behavior change types.

Feature	Behavior change type							
	Added activity in life	Enhancing routines	Exploration	Increased physical activity	Strengthening social bonds	Lowering social barriers	Increased positive emotional expression	Self-treatment
Catching new Pokémon	✓	✓	✓	✓	✓	✓	✓	✓
Visiting Pokéstops	✓							
Exploring Pokéstops			✓					
Hatching eggs		✓		✓				✓
Fighting in gyms						✓		
Finding specific Pokémon		✓			✓		✓	
Using items					✓	✓		
Pokémon theme	✓			✓	✓			
Game location tied to physical location	✓	✓	✓	✓	✓	✓	✓	✓

Discussion

Principal Findings

To extend previous studies that have presented initial insights about games and behavior change [9,10], this study set to explore the various types of behavior changes and the game features that drive these changes. We found 13 game features that drove behavior change in 8 different categories, demonstrating that pervasive games can lead to various types of behavior changes. In line with BCSS literature [47,69], the behavior changes that arise from pervasive games can be either intentional or unintentional. Further, a pervasive game such as Pokémon GO can influence behavioral outcomes in all 3 ways: formation, alteration, and reinforcement of behaviors. Our findings are in line with previous findings on the physical [30-35], psychological [32], and social aspects [38] of Pokémon GO. However, while these previous studies proposed potential behavior changes that Pokémon GO could induce, our study provides empirical evidence that demonstrates how the game has enabled players to change their behavior in various ways. Moreover, our study identified which game features drive these changes.

Our 8 categories of behavior change can be abstracted further: they relate to either social behavior, people's routines, or their drive for self-improvement (see Table 3).

Table 3. Behavior change categories.

Pokémon GO behavior changes	Behavior change category	Game features
Strengthening social bonds, lowering social barriers, increased positive emotional expression	Social	Catching new Pokémon, fighting in gyms, finding specific Pokémon, using items, Pokémon theme, game location tied to physical location
Added activity in life, enhancing routines, exploration	Routines	Catching new Pokémon, visiting Pokéstops, exploring Pokéstops, hatching eggs, finding specific Pokémon, Pokémon theme, game location tied to physical location
Increased physical activity, self-treatment	Self-improvement	Catching new Pokémon, hatching eggs, Pokémon theme, game location tied to physical location

Most of the game features in Pokémon GO that linked to behavior change are related to the game being about Pokémon. This could be interpreted as the game designers' success in designing the game so its central activities are well integrated in its theme. This is also apparent in our questionnaire data, with many respondents discussing things related to Pokémon being a wide-ranging transmedia franchise. The respondents grew up watching Pokémon being caught, hatching, and fighting against each other, so they expect these activities from a game about Pokémon. One lesson from our research is that pervasive games' themes should be reflected in their mechanics, which seems to be a new finding in BCSS research. Indeed, a recent review identified 93 behavior change techniques, but none were related to theme [70].

In our study, in addition to game location tied to physical location, the two game features not specifically related to Pokémon (using items and collaborative fighting) both relate to collaboration. It is possible that Pokémon GO's theme drew in players more interested in collaboration than competition or that once players started playing, their behavior was affected. Our respondents noted how the game created possibilities for positive social encounters. In media discourse, digital games are often considered conducive to antisocial behavior [71]. In contrast, Pokémon GO strongly encourages social interaction. Another study noted that 70% of their respondents never played alone, which is in line with our findings [43]. Even when playing does not require social interaction, it can act as a social catalyst [72]. Our findings demonstrate this happens by strengthening bonds between family and friends and by creating social encounters that facilitate community-building between strangers.

One reason why playing Pokémon GO is such a social experience is because the game encourages players to openly express enthusiasm and positive emotions, which spread to other players. The respondents reported greater positive expressions when people gathered at shared locations to engage in positive activities. Previous research has also noted Pokémon GO's positive effect on psychological well-being [32]. In our questionnaire answers, laughter and smiles were shared due to the game's ability to support friendly collaboration (eg, sharing a lure) without the need for rivalry. This indicates that game developers can benefit from designing activities that can be shared between players without making them challenge each other.

One way that Pokémon GO encouraged social interaction was perhaps not intended by the designers, however. When the game was first released, the servers would randomly disconnect, and the game would crash or hang. There were also few tutorials for the game. Many details of its working were not obvious to new players, and the only source of information was other players: some of our respondents even mentioned asking for advice and being taught how to play by other players. These encounters did not happen with all players but considering how rare it is for strangers to teach each other new skills, this is perhaps not surprising. According to Edwards et al [70], 75% of smartphone apps for health promotion use some form of social support, but teaching other players does not seem to be a common technique.

Pokémon GO changed respondents' daily routines by altering where they went. The game made respondents visit new places and select new routes, increasing their encounters with new surroundings and sites. The respondents valued the discovery of new and interesting places. Therefore, the developers of pervasive games could benefit from design decisions that lead players to visit interesting places. This can also have secondary benefits to education and tourism. The focus on physical locations has a drawback, however: some Pokémon GO players complained that it was impossible for them to play because they lived outside large urban centers. This confirms a previous finding that Pokémon GO can reinforce existing geographic advantages and disadvantages [43].

Our study further supported that Pokémon GO requires a low amount of effort to play. For example, the respondents played while doing other things, such as going to work or walking the dog. This made an otherwise routine experience more enjoyable. Based on our data, this was tied to the notion of Pokémon GO being easy to play while doing something else. By implication, for this to be possible, the game should be easy to start and stop and not require a lot of focus from the player, who might be holding onto a leash or groceries while playing. This is also important because playing Pokémon GO while moving from one place to another can be distracting and thus dangerous [32,43].

One central type of behavior change in this study relates to increased physical activity. With our data, conclusions on how long-lasting this behavior change was cannot be made, but it is obvious that at least in the short term, the game increased the physical activity of many respondents. This indicates that pervasive games can be used to promote physical activity. Further, individuals who do not see exercise as enjoyable can use these games to become more active and make physical activities more fun. The game features that motivate players to move are related to two additional aspects: first, Pokémon GO sets concrete goals for players by showing how many Pokémon they need to find and by letting them hatch eggs by walking a specified distance, and second, the game ties the players' motivation to something they already care about: Pokémon. The other game features may be less important than the connection to a cultural phenomenon that the players already know and love. Previous research has identified goal setting as an important motivator, but the effects of theming have not been explored [8,70].

Finally, we want to highlight the game feature that was strongly tied to all forms of behavior change: game location tied to physical location. Pokémon GO had such a big impact on respondents' behavior because it is a pervasive game.

Limitations

Our chosen method for data collection—an online survey—has some general limitations. Sometimes participants respond to open-ended questions in the briefest time possible to minimize what they perceive to be burdensome. To mitigate this, the respondents were asked to recall their incidents and describe them with as much detail as possible before responding. Additionally, following CIT procedures, inquiring about the experience was divided into multiple questions. As such, most of our respondents did give rather detailed responses. However, using an online survey did not allow us to ask follow-up questions regarding, for example, more precise details of the experience such as with whom the respondents played the game. Thus, future research may consider using qualitative interviews.

Another limitation is that the survey was distributed through discussion forums and social media channels; thus, we were likely to reach only players who follow those channels. To mitigate this limitation, we aimed to distribute the survey widely, and it became apparent that the invitation was spread to other channels by the respondents themselves. While our sample was reasonably large for this kind of study, participation biases cannot fully be known due to a lack of knowledge about the population solicited.

What we do know is that the respondents did not represent a global sample, and it is likely that the data is skewed geographically, which might have affected the types of experiences detailed in the answers. Unfortunately, the collected data does not enable a detailed examination of the respondents' countries. Further, our sample was female dominant (176/262, 67.2%), which is close to the 63% reported by Sonders [73], but other market research indicated a more male dominant gender distribution of Pokémon GO players [74]. Thus, it is likely that women are overrepresented in our sample.

One final limitation of CIT is that it relies on self-reporting; thus, our findings are based on the respondents' subjective perceptions. The respondents also reported more positive than negative incidents. This is supported by the claim that CIT captures respondents' outstandingly positive and negative experiences without paying attention to ordinary experiences [60]. This can be due to various reasons, such as individuals' positive general attitudes toward games, their possible tendency to report positively about games, or the hype and entertainment purpose of Pokémon GO. While we believe that our discovered behavior change types reflect various Pokémon Go experiences, these detailed findings may not be fully applicable in ordinary experiences for this reason.

Conclusions

The purpose of this study was to examine types of behavior changes pervasive games can induce in their players and kinds of game features that drive different behavior change types. We analyzed the types of behavior changes players of Pokémon GO experienced and which game features are behind the identified behavior changes. The research data was collected from players of the game using CIT [59]. Following a qualitative approach, we analyzed the data by coding and categorizing it.

We contribute to extant knowledge by examining a variety of different behavior change types in one study, while prior studies have focused on a limited set of behavior change types (eg, increased physical activity). Thus, we offer a more comprehensive categorization by identifying different behavior change types enabled by the game and its features. Our second contribution is connecting the behavior changes to game features. We identified 13 game features in Pokémon GO, extending the features found by Meschtscherjakov et al [34] by 4: finding specific Pokémon, using items, Pokémon theme, and game location tied to physical location. Notably, when analyzing the relation between game features and behavior change, we noticed that two features were common to all behavior changes: catching new Pokémon and game location tied to physical location.

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Conflicts of Interest

None declared.

Multimedia Appendix 1
Checklist for Reporting Results of Internet E-Surveys (CHERRIES).
[PDF File (Adobe PDF File), 73 KB - games_v8i2e15967_app1.pdf]

Multimedia Appendix 2
Frequency of codes related to behavior change.
[PDF File (Adobe PDF File), 30 KB - games_v8i2e15967_app2.pdf]

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Abbreviations

BCSS: behavior change support system
CHERRIES: Checklist for Reporting Results of Internet E-Surveys
CIT: critical incident technique
IT: information technology

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Corrigenda and Addenda

Correction: Developing Theory-Driven, Evidence-Based Serious Games for Health: Framework Based on Research Community Insights

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In “Developing Theory-Driven, Evidence-Based Serious Games for Health: Framework Based on Research Community Insights” (JMIR Serious Games 2019;7(2):e11565), an error was found in Reference 2 of the reference list. Arnab S was listed as the author, but should have been listed as the lead editor, instead. The correct author of the book is Kato PM, instead of Arnab S. The correct reference is:

> *Kato PM. The role of the researcher in making serious games for health. In: Arnab S, Debattista K, Dunwell I, editors. Serious Games for Healthcare: Applications and Implications. Hershey, Pennsylvania: IGI Global; 2013:213-231.*

This correction will appear in the online version of the paper on the JMIR website on April 28, together with the publication of this correction notice. Because this was made after submission to PubMed, PubMed Central, and other full-text repositories, the corrected article has also been resubmitted to those repositories.

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