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Original Paper

Digital Gaming to Improve Adherence Among Adolescents and Young Adults Living With HIV: Mixed-Methods Study to Test Feasibility and Acceptability

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Abstract

Background: An estimated 50% of adolescents and young adults (AYA) living with HIV are failing to adhere to prescribed antiretroviral treatment (ART). Digital games are effective in chronic disease management; however, research on gaming to improve ART adherence among AYA is limited.

Objective: We assessed the feasibility and acceptability of video gaming to improve AYA ART adherence.

Methods: Focus group discussions and surveys were administered to health care providers and AYA aged 13 to 24 years living with HIV at a pediatric HIV program in Washington, DC. During focus group discussions, AYA viewed demonstrations of 3 game prototypes linked to portable Wisepill medication dispensers. Content analysis strategies and thematic coding were used to identify adherence themes and gaming acceptance and feasibility. Likert scale and descriptive statistics were used to summarize response frequencies.

Results: Providers (n=10) identified common adherence barriers and strategies, including use of gaming analogies to improve AYA ART adherence. Providers supported exploration of digital gaming as an adherence intervention. In 6 focus group discussions, 12 AYA participants identified disclosure of HIV status and irregular daily schedules as major barriers to ART and use of alarms and pillboxes as reminders. Most AYA were very or somewhat likely to use the demonstrated game prototypes to help with ART adherence and desired challenging, individually tailored, user-friendly games with in-game incentives. Game prototypes were modified accordingly.

Conclusions: AYA and their providers supported the use of digital games for ART adherence support. Individualization and in-game incentives were preferable and informed the design of an interactive technology-based adherence intervention among AYA living with HIV.

Introduction

The goals of the US National HIV/AIDS Strategy include increased HIV testing, linkage to care, retention in care, and viral suppression for all persons living with HIV [1]. For an estimated 36,000 adolescents and young adults (AYA) aged 13 to 24 years living with HIV, these are particularly critical goals [2]. AYA accounted for 22% of all new HIV infections in 2015, and those AYA who were perinatally infected are aging into adulthood [3]. Furthermore, with treatment guidelines recommending early initiation of antiretroviral treatment (ART), AYA represent a significant population being prescribed daily ART medications [4]. Despite the high efficacy of new ART drugs and more available fixed-dose single tablet per day ART regimens, adherence to daily treatment remains suboptimal among AYA; less than half (47%) of youth aged 18 to 24 years living with HIV in 2016 were virologically suppressed [5].

As the chronic nature of HIV becomes apparent to youth, placing emphasis on adherence support is essential. As many as 50% of AYA or their caregivers report a failure to adhere to prescribed regimens [6-9], and a review of more than 50 studies on pediatric HIV infection confirmed that 42% to 80% of youth had suboptimal ART adherence [10]. AYA living with HIV are at particular risk of poor adherence due to specific challenges. They are experiencing a developmental period with increased peer pressure, risk-taking, and a desire to be similar to their HIV-negative peers [11]. Autonomy also differs between AYA and adults living with HIV, as younger persons must frequently rely on parents or caregivers for treatment [12,13]. Furthermore, AYA living with HIV may experience a higher frequency of cognitive deficits, depression, and substance abuse issues compared to general populations [14]. Therefore, the development of effective, youth-friendly interventions to improve adherence among AYA living with HIV is critical to improving adherence and treatment outcomes among this population.

Current approaches to ART adherence monitoring and support include text messaging, self-reporting, pill counts, pharmacy refill assessments, and electronic monitoring with devices such as Wisepill, a portable medication dispenser that emits a wireless signal when opened, used for monitoring real-time adherence [15-24]. While a few studies have provided evidence of the feasibility, acceptability, and performance of electronic monitoring of ART adherence, use of the Wisepill dispenser for real-time adherence monitoring is currently understudied; the dispenser appears to be a promising adherence strategy to explore. Digital game-based interventions also have the potential to be a promising approach to increasing treatment adherence among AYA. These approaches capitalize on the daily interests of AYA who are estimated to spend as many as 7 hours per day interacting with computers, cell phones, and video games [25,26].

Combining Wisepill technology and youths' interest in digital gaming, we aimed to develop an intervention to link on-time Wisepill openings to in-game incentives to increase ART adherence among AYA living with HIV. As part of our gaming design process, we sought to better identify factors associated with nonadherence and identify digital gaming preferences among AYA and their health care providers. The objectives of this analysis were to use a formative research approach to describe barriers and facilitators to ART adherence among AYA living with HIV, identify their preferred digital game characteristics, and assess the feasibility and acceptability of the proposed intervention.

Methods

Study Setting and Approach

The study was conducted by a multidisciplinary research team comprising epidemiologists, qualitative researchers, HIV clinicians, and game development experts in Washington, DC. All study materials were reviewed and approved by the George Washington University and Children's National Medical Center (CNMC) institutional review boards. Participants were recruited from CNMC Special Immunology Services (SIS), a clinic that provides care for HIV-exposed and infected infants, children, and adolescents in the DC metropolitan region. The SIS primarily serves perinatally and behaviorally infected patients from birth to 24 years old and provides a range of HIV specialty services including medical care, case management, subspecialty referrals, mental health services, and nutritional support. These services are provided by an experienced team of physicians, nurses, social workers, psychologists, and clinical and behavioral researchers.

The formative portion of this study included 3 phases: phase I, game prototype development and subsequent game revisions; phase II, a focus group discussion (FGD) with treatment providers of AYA; and phase III, a series of FGDs among AYA ages 13 to 24 years living with HIV. In phases II and III, each FGD was conducted by 2 moderators: (1) a clinician researcher to facilitate discussions regarding HIV knowledge and adherence and (2) the videogame developer to demonstrate the game prototypes and lead discussions on game design and development.

Phase I: Game Prototype Development and Revisions

Theoretical Framework

Previous games for behavior change have shown positive results by using the compelling nature of game play to make health education entertaining and shift attitudes and emotions about chronic illness and treatments [27,28]. In our gaming design, we sought to use Wisepill dispensers for real-time adherence measurement and as a mechanism to provide incentives (eg, power-ups) for game play through the granting of microtransaction points for on-time pill box openings. Guided by Bandura's social cognitive theory [29], a widely used framework that can be used to assess HIV adherence [30-32], we hypothesized that our intervention would positively influence self-efficacy, risk perceptions, knowledge of HIV treatment goals, and social support of study participants. Using this framework, iterations of game prototypes were developed by Media Rez including a project code-named Virus Fighter/Body Voyage, designed to teach players about the effects of HIV on the body and immune system, including important concepts such as poor adherence and medication resistance (Figure 1).

This prototype demonstrated through gaming how HIV would get stronger if the player did not use ART as a weapon against the virus while also reinforcing how HIV is weakened if the player used ART. A second game, Adherence Warrior, was also developed with no explicit intent to be educational that included features that HIV care providers could potentially use as teachable moments to help educate AYA about the importance of ART adherence (Figure 2).

Game Modifications

Participant feedback from both health care providers and AYA was analyzed and informed revisions made to the initial game prototypes. This feedback was used to determine the optimal set of game features for the game prototypes used in a subsequent pilot intervention. As a result of the AYA feedback specifically, production on the Virus Fighter/Body Voyage game was suspended. In order to create sufficient game content to engage a variety of participants, prototypes of 3 distinctly different Wisepill-connected games were developed based on FGDs and survey feedback regarding desired game features. Participants would be able to play any of the 3 games at their discretion: a modified version of Adherence Warrior, the Berry Game, and Cat O'Polt, a new game that was developed in order to provide a game that was of moderate difficulty, potentially interesting to AYA, and adventurous. The games and pillbox interactions were also designed to meet important privacy, motivation, and information goals (Table 1).

Adherence Warrior Game

Adherence Warrior (Figure 2) features heroes in a fantasy world protecting their home village from invading monsters. The player manages a group of 3 brave adventurers who use weapons and magic to stop the invading monsters. To attack the monsters, 3 or more tiles are required to be matched in a row. Tiles can be moved 3 times for each of the 3 characters, which allows 9 attempts to make a match before the monster's attack. Players can collect many new kinds of tiles resulting in new kinds of magic spells, skills, attacks, and healing. Players also need energy to progress in the game, and unlike in similar games, players cannot gain this energy by in-app purchases; they can earn it through adherence. Players can figure out unique vulnerabilities in different monsters and use the most effective tiles against those weaknesses.

Figure 1. Virus Fighter images include HIV-like monsters that would invade CD4 cells.

Figure 2. In the Adherence Warrior game, players act as heroes protecting their village from invading monsters. To attack the monsters, three or more tiles need to be matched in a row. Players need energy to progress in the game, and they can gain this energy by opening their pillbox on time.

Table 1. Features of final games.

Feature	Description	Function
Privacy	Making games about players fighting HIV conveys a risk of unintentionally revealing a patient's HIV status when they would prefer privacy. To prevent this risk, we changed plans for a Body Voyage game fighting viruses and made 3 games designed to protect patient privacy and minimize the risk that using the intervention would disclose their status.	Increases app engagement by meeting the privacy needs of adolescent and young adult HIV patients.
Motivation	By making a direct connection between daily adherence and the kind of daily, in-game power-ups that players usually have to pay for with microtransactions, we attempted to motivate patients to take their medication on time. Opportunities to earn greater in-game power and access increases motivation for both engagement with the games and adherence with antiretroviral treatment (ART).	Direct motivation to increase adherence.
Motivation	The game incentivizes cooperation by letting the player build up available healing tiles and defensive tiles by not using them on less-injured heroes but instead saving them up for bigger healing effects on heroes who are more injured. In this way, the game puts the player in a caregiver role.	Having player in caregiver role motivates patients in their current self-care role to adhere to their ART.
Information	The system knows when patients do not open their pillboxes on time and sends out a feedback reminder when this happens in the form of a text message (which does not disclose anything about HIV).	Providing this timely information about adherence affirms adherence behavior and serves as a cue to action in a way that does not breach privacy.

Although the game contains no explicit HIV education (to avoid violating patient privacy), it was designed to have teachable moments that HIV care providers could potentially use to explain complex concepts associated with treatment. Provider FGDs reported that one of the most difficult concepts to teach is the potential for viral resistance to ART, which is commonly taught by metaphor. By creating the vulnerability system in the game, the provider can emphasize this similarity with HIV resistance. This provides a conceptual approach to understand complex adherence concepts and behaviors. In this way, the game not only avoids breaching the privacy of AYA living with HIV but also avoids coming across as didactic. The game itself does not try to lecture the patient through onscreen text but provides experiences designed to be used as teachable moments by caregivers. Enabling educational opportunities and points of connection for providers and patients through the game could be more effective for behavior change than simply having the game display health messages that are often ignored.

Berry Match

The objective of the Berry Match (Figure 3) game is to match as many identical berries as possible.

If 3 or more berries are matched in a row, the berries will switch places and the 3 matching berries will disappear and new berries descend. Points are awarded for all berries "eaten." Some levels have limited amounts of moves to win while others can be beaten by reaching the target score. Special blocking and trapping tiles add to the challenge. When the player takes his or her medication on time, they receive in-game currency that can be spent on special power-ups to solve especially tricky levels of the game. In similar commercial games, players must purchase these power-ups with cash through in-app purchases; in our gaming design they can earn the in-game currency by opening their Wisepill boxes on time.

Cat O'Polt

The goal of Cat O'Polt (Figure 4) is to direct a cat as it travels through the city collecting as many coins as possible while simultaneously avoiding obstacles.

With the right timing, the cat can make huge jumps over obstacles and even vault over buildings. The objective is to achieve the highest score possible before losing game play lives. In our gaming design, players can gain new lives by opening their pillbox on time.

As the next phase of the study, the Wisepill dispenser was integrated within each game and was linked to in-game power-ups for daily Wisepill openings as an incentive to improve ART adherence.

Phase II: Focus Group Discussion With HIV Providers

A semistructured FGD using a single category design was conducted among the specialty HIV care provider team at CNMC SIS and was aimed at identifying key facilitators and barriers to ART adherence among AYA and eliciting feedback on the game prototype and use of the Wisepill dispenser. The semistructured format allowed FGD moderators to probe emergent topics and themes during the discussion. Prior to the FGD, providers were administered a brief survey to collect basic demographic and practice-related characteristics. Providers were not remunerated for their participation in the FGD.

Phase III: Focus Group Discussions With Adolescents and Young Adults

AYA ages 13 to 24 years living with HIV and disclosed as to their HIV status were recruited during routine clinic visits at CNMC SIS. A series of multiple-category FGDs were stratified by age (13 to 17 and 18 to 24 years) to account for developmental differences and potential variances in game characteristic preferences among participants. A total of 12 AYA participated in 6 FGDs; 3 FGDs among participants aged 13 to 17 years and 3 FGDs among participants aged 18 to 24 years. Participant feedback from the first FGD was analyzed, and revisions were made to the initial game prototypes. During the second stage of FGDs, participants from the initial FGDs as well as AYA who had not previously viewed the games were invited to participate.

Figure 3. In the Berry Match game, players try to match as many berries as possible. Points are awarded for all the berries eaten. Players receive in-game currency in the form of special power-ups by opening their pillbox on time.

Figure 4. In the Cat O'Polt game, players control a cat travelling through the city trying to collect coins while avoiding obstacles. The objective is to achieve the highest score possible before losing all of one's gameplay lives. The player gains new lives by opening their pillbox on time.

Participants had the flexibility to explore multiple games and provide unrestricted input regarding user interface performance, acceptability of the art and animation, and response to game play. Additional input was also provided regarding the feasibility and acceptability of the games with respect to their potential to improve ART adherence.

Before the start of each FGD, participants completed a survey that collected information on their demographics, ART regimens, and current video game use. A separate survey using Likert scale ratings was administered to participants after demonstration of the video game prototypes to quantify their impressions of the games and their potential to improve adherence. All AYA participants were remunerated with gift cards and transportation vouchers for their participation in each FGD.

Data Collection and Analysis

All FGDs were audio-recorded and professionally transcribed verbatim for data analysis. A systematic analysis guided by a constant comparative analytic framework was used to employ content analysis strategies through the use of thematic coding to determine major findings. Constant comparative frameworks objectively identify patterns in data and discover relations between ideas and concepts [33]. This framework supported the use of summative content analysis, which involves comparing the content of data to interpret the underlying context [34]. Content analysis was achieved through thematic coding, which links the common themes and ideas discussed among study participants [35]. Qualitative data analysis was organized using both NVivo version 9 (QSR International) and ATLAS.ti version 7 (Scientific Software Development GmbH) qualitative

data analysis software by 2 independent coders and included 2 cycles: (1) each interview transcript was objectively analyzed using the aforementioned analytic approach and (2) coding across FGDs was compared to produce overall themes that support the purpose of the study. Codes were reviewed, and intercoder agreement was achieved where there were discrepancies in the categorization of the codes. Descriptive statistics were used to summarize response frequencies from the surveys. Mann-Whitney U tests were used to compare median responses to survey questions across 2 AYA age groups (13 to 17 years and 18 to 24 years).

Results

Provider Focus Groups

Provider Demographics and Focus Group Themes

The HIV provider FGD (n=10) included physicians (n=2), case managers (n=3), research coordinators (n=3), a clinic nurse (n=1), and a psychologist (n=1). The majority (6/10, 60%) of providers had at least 5 years' experience prescribing ART and delivering treatment and adherence support services, conducting clinical research, and providing HIV counseling and testing to AYA. During the FGD, several recurrent themes emerged related to ART and the potential role of video games to improve adherence, including (1) patient understanding (or lack thereof) of the concept of adherence, (2) daily barriers to patient adherence, (3) facilitators and promotion strategies for ART adherence, (4) provider educational methods to educate and support HIV treatment, (5) perceptions of the role of video games in ART adherence support, and (6) desired characteristics of video games for the patients (Textbox 1).

Textbox 1. Summary themes identified from the HIV provider focus group discussions and representative quotes.

Patient understanding of adherence and resistance

- "The concept of resistance...I don't think people understand what it means to be resistant. We keep trying to explain [you know what] it means the drugs don't work anymore...people do not see the consequence..."

- "...it's associated with negativity as opposed to being something that's empowering that I can take control of my medicines, I can take control of my life, I can have control over..."

Barriers to adherence

- "A lot of the times the patient...may have, like, issues about disappointing the clinicians and the providers and so they'll be less forthcoming about their actual adherence, and then when you confront them about their viral load and why what they're saying isn't matching then they'll, you know, give the puppy dog eyes and kind of disclose that 'actually I haven't been taking my medicine.'"

- "They don't feel sick, they don't feel like they need to take medicines, it's very abstract in terms of me talking about 'this is your CD4 count, this is your viral load, you take your medicine so your viral load goes down and your CD4 comes up'...but they don't feel the importance of it..."

- "And I think that taking their meds a lot of what I hear is 'Oh when I take my meds that reminds me that I have HIV. If I am reminded about HIV I just don't want to deal with it.' And as they get older and older it becomes more of an issue and they don't see the consequences. They don't see anybody dying around them from HIV, they don't see the ramifications of it."

Facilitators and promotion strategies

- "Actually our kids who are very concrete thinkers tend to do really well that they just take the medicine; they don't think about all the ramifications of why I'm taking medicines and I'm going to have to do this for the rest of my life..."

- "I feel like those kids [who have been told their HIV-positive status sooner] do better than the ones who are 13 or 14 and it's been a secret hidden and then they're being told that [they have HIV]...Those are the ones that really seem to struggle [with medication adherence]."

- "...we do have a few kids though, very few, but we have a few kids where the opposite happens where they get old enough to take their own meds and they actually weren't taking them and they do better and they all of the sudden become undetectable. When it was the parents' responsibility it didn't happen."

Provider educational methods

- "So the way I've used it...gaming analogies, I've told 'you need the grenade, you need the pistol and you need the AK-47, you need all 3 to kill off the virus. You can't just do one or else it's not going to work it's going to get stronger...like you need all 3 you don't need just one, it's not going to work...'"

- "Red, green, and yellow light and it's in regards to the immune system...I will tell patients frequently you're now in the yellow zone that means that I'm seeing the decline in your immune system and I'm trying to urge you not to let it become red zoned. And then obviously there [are] some patients when I will say... we are in the red zone your immune system is weak and it's not recovering. The longer we see it in the red zone the harder it will be to recover the immune system.'"

- "Because I've actually tried the video game analogy many times in terms of 'you know those little power packs you have to get so that your energy level goes really high that's what you're trying to do with your medicines, get that power pack...'"

Initial perceptions of role of video games

- "Yes that incentive is there and yes that reminder is there but after a while it just becomes like 'oh this is nothing I don't really care, whatever.'"

- "I wonder, first of all I think about gender differences, I wonder if it's going to be girls versus boys. And I think boys might be more interested in doing it."

- "I don't know how that's going to help because I think some of our kids forget but I don't think a lot of them forget. I think the thing rings and they go, 'oh this thing's ringing,' and they continue with playing the video game...Maybe if the video game dispensed it..."

Desired characteristics of a video game

- "One thing that I think is really important is that the game not peg them as being HIV positive"

- "And it might send you a message saying you've been doing great...and the second reward is missing and this is what you could do if you want."

- "And also I just want to say, to me, like, with the teenager is a very change in milieu. So I think having the same system of awards is boring. So I think what needs to be in any game is you need to completely change the system once they get it."

Perception and Experience With Antiretroviral Treatment Adherence

Providers expressed difficulty conveying the importance of medication adherence and explaining the consequences of poor adherence (ie, resistance) to AYA. Providers emphasized that AYA usually do not want to disappoint providers and described AYA as having a desire not to "feel sick," and not wanting to be reminded of having the virus. Providers also identified increasing difficulty with adherence as the patients got older—in addition to the perception among AYA that they were invincible. Providers emphasized the majority of AYA in care did not

witness people dying from HIV and therefore did not perceive the long-term consequences of not taking the medications as a threat to their lives. Providers described characteristics of AYA living with HIV that made adherence challenging, including concrete thinking, being less organized, and lacking the maturity to control their own ART regimens. Providers also believed that learning one's HIV-positive status at a young age was associated with improved ART adherence. Providers also described their efforts to use age-appropriate, culturally relevant analogies to increase understanding of viral resistance and ART adherence among AYA in care.

Perspective on the Potential Role of Video Games

With regard to the feasibility and acceptability of using video games to improve adherence, many providers were initially skeptical about the ability of gaming to improve adherence. They suggested that once the novelty of the gaming wore off, adherence levels might decrease. Providers also expressed concern that gender differences could emerge with males potentially being more engaged in gaming compared to females. Despite providers' initial skepticism, after seeing and experiencing the game prototype, the majority of providers expressed optimism and provided specific feedback for improving game design. Overall, providers were supportive of exploring the proposed gaming intervention and recognized its potential positive role in improving adherence among AYA in care.

Focus Group Discussions With Adolescents and Young Adults

Demographics

A total of 31 AYA were recruited for the study; however, only 12 were able to attend and participate in the FGDs. Among the 12 AYA who participated in the 2 rounds of FGDs, 7 were aged 13 to 17 years old and 5 were aged 18 to 24 years old (Figure 5).

Figure 5. HIV-infected adolescent and young adult focus group participant recruitment. FGD: focus group discussion.
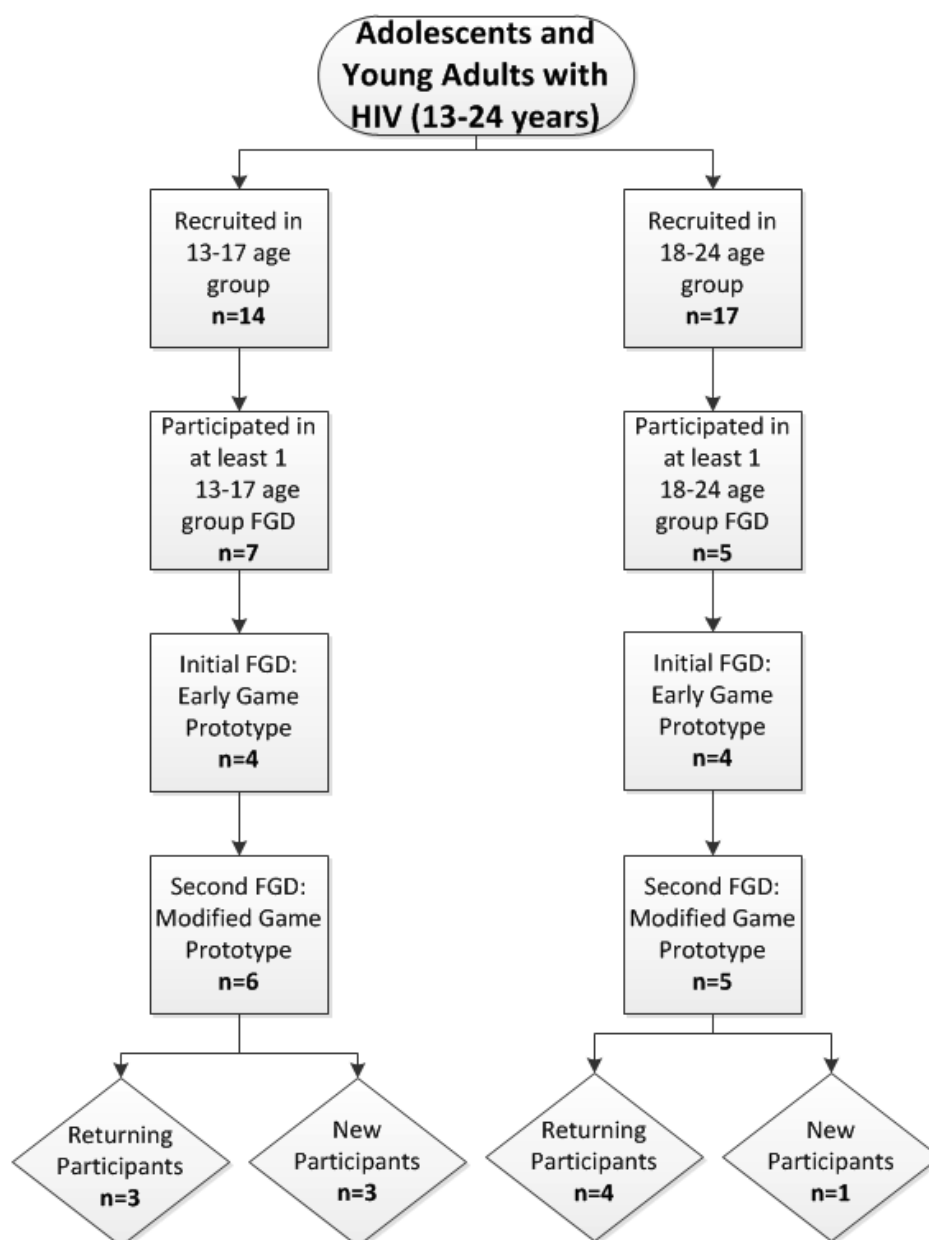
Table 2. Adolescent and young adult demographic, disclosure status, adherence, and access to video games characteristics (N=12).

Characteristic[a]	13-17 years (n=7)	18-24 years (n=5)	Total (N=12)
Age (years), mean (range)	14.7 (14-16)	19.2 (18-22)	16.6 (14-22)
Sex, n (%)			
Female	4 (57)	3 (60)	7 (52)
Male	3 (43)	2 (40)	5 (42)
Race/ethnicity, n (%)			
Non-Hispanic black	7 (100)	4 (80)	11 (92)
Other	0	1 (20)	1 (8)
State of residence, n (%)			
Maryland	6 (86)	2 (40)	8 (67)
District of Columbia	1 (14)	3 (60)	4 (33)
Education level, n (%)			
Grades 1-8	4 (57)	0	4 (33)
Grades 9-11	3 (43)	1 (40)	4 (33)
High school graduate/general equivalency diploma	0	4 (80)	4 (33)
Time since HIV disclosure prior to study enrollment, n (%)			
<6 months	2 (29)	0	2 (17)
6 months to 5 years	2 (29)	0	2 (17)
>5 years	3 (43)	5 (100)	8 (67)
Storage of HIV medications, n (%)			
In my bedroom	3 (43)	4 (80)	7 (58)
In the kitchen	4 (57)	1 (20)	5 (42)
Pills per day, mean (range)	4.3 (1-8)	2.2 (1-4)	3.4 (1-8)
Medication regimen, n (%)			
Once per day	4 (57)	5 (100)	9 (75)
Twice per day	2 (29)	0	2 (17)
≥3 times per day	1 (14)	0	1 (8)
Pillbox/dispenser use, n (%)			
In the past	1 (14)	1 (20)	2 (17)
Currently	4 (57)	3 (60)	7 (58)
Never	2 (29)	1 (20)	3 (25)
Adherence strategies[b], n (%)			
I do it myself	3 (43)	2 (40)	5 (42)
A relative helps me remember	5 (1)	2 (40)	7 (58)
I set an alarm	0	2 (40)	2 (17)
I receive a text reminder	0	1 (20)	1 (8)
7-day adherence, n (%)			
All the time (100%)	4 (57)	1 (20)	5 (42)
Most of the time (51-99%)	3 (43)	4 (80)	7 (58)
Half of the time to never (0-50%)	0	0	0
Video game device in household, n (%)	7 (100)	5 (100)	12 (100)
Gaming devices in household[b], n (%)			

Characteristic[a]	13-17 years (n=7)	18-24 years (n=5)	Total (N=12)
Wii	5 (71)	2 (40)	7 (58)
Xbox	4 (57)	2 (40)	6 (50)
Nintendo	0	3 (60)	3 (25)
Computer	2 (29)	2 (40)	4 (33)
Frequency of game play, n (%)			
Daily	0	1 (20)	1 (9)
Only on weekends	2 (29)	0	2 (18)
Anytime	2 (29)	4 (80)	6 (54)

[a]Totals may not sum to 100% due to missing data.

[b]Participants were allowed to check all that applied.

The mean age of participants was 16.6 years, 92% (11/12) were black, and 58% (7/12) were female (Table 2). All participants had been told about their HIV status, and many participants (8/12, 67%) had known for more than 5 years. All participants were prescribed ART, and 75% (9/12) were on a once-a-day ART regimen. Younger adolescents (ages 13 to 17 years) had a higher pill burden compared to older AYA (4.3 vs 2.2 mean number of pills, respectively). Seven participants (58%) were currently using some type of pillbox at the time of the FGDs.

Perspectives on Adherence

The following themes were identified during the AYA FGD: general HIV and ART knowledge, knowledge of viral resistance and ART adherence, barriers and facilitators to adherence, interest in and use of video games, and acceptability of video games for improving adherence (Textbox 2).

Knowledge of HIV, Adherence, and Barriers and Facilitators to Adherence

Participants in the younger FGD had a conceptual understanding of HIV, whereas older FGD participants demonstrated a deeper understanding of HIV and adherence concepts. Participants across both age groups expressed a similar understanding of viral resistance and adherence. When discussing barriers associated with adherence to ART, participants revealed a broad array of factors such as not wanting to be different from their peers, being afraid of inadvertently disclosing their status by taking the medications, having difficulties with the taste and size of medications, and facing time management challenges. Participants in all AYA FGDs shared personal motivating factors and facilitators associated with improving adherence.

Feasibility and Acceptability of Video Games for Adherence

All AYA participants had a video game device in their house with the most commonly reported gaming platforms being Wii (7/12, 58%) and Xbox (6/12, 50%). Additionally, 80% (4/5) of older AYA reported unrestricted access to video games compared to 29% (2/7) of younger AYA (Table 2). Prior to introducing the initial video game prototype, participants were asked to describe enjoyable aspects of video games and motivating factors for playing games. Participants generally expressed that they liked games that were engaging, had intense adventure, and posed a challenge. Discussion about the use and frequency of video game playing indicated that length of time spent on video game playing was dependent on the challenging nature of the game. Participants in the younger age group reported enjoying games as a leisure activity, while participants in the older age group were more interested in challenging games.

During the first round of FGDs, participants viewed demonstrations of the Wisepill ART dispensers, artwork and images for the prototype of Virus Fighter/Body Voyage (Figure 1), a game about the immune system, and an initial version of the Adherence Warrior (Figure 2) game. All FGD participants were comfortable with the Wisepill dispensers and believed that their medications would fit and that they would be able to carry the dispenser around without any issues. When introduced to the concept of linking the Wisepill to in-game incentives to improve medication adherence, AYA demonstrated acceptance of the concept. Younger participants thought the Wisepill would serve as an additional reminder to help them remember to take their medications, whereas the older participants focused more on the game content and emphasized a desire for the games to be engaging and interactive.

Textbox 2. Summary themes identified from the HIV-infected youth and young adult focus group discussions and representative quotes.

General HIV/antiretroviral treatmen knowledge

How antiretroviral therapy works and how it affects the body

- "I mean I heard it before, I forgot. We used to talk about it a lot but I wasn't listening 'cause I didn't understand. 'Cause I didn't want to take my medicine." [13 to 17 years]

- "My viral load goes down by taking the meds...taking the meds every day." [13 to 17 years]

- "I guess if you don't take it [ART] for a long period of time then the virus can start, like, making your body feel weird. If you don't start taking your medicine. You might, like, feel weaker, or...Medicines will stop being effective. 'Cause the virus will, I guess it'll get used to it. Or, something like that." [13 to 17 years]

Antiretroviral therapy and HIV knowledge

- "I just know that you get born with it or you get it through like sex and stuff. And it's like a disease that's in your immune system that takes over your immune system." [18 to 24 years]

- "You want the viral load to be really low because that's how much the virus is in your body, you want it to be low." [18 to 24 years]

- "They got some [pills] out here that's one a day, they got like, probably like 2 or 3 different kind that's one a day and then they got other kinds that's not one a day but for the people who take the ones that's not one a day it's probably because when they were younger, like if they had to live with it all their life like me then it messed up their medicine at first then now we can't take the one a day pill." [18 to 24 years]

Knowledge of adherence and resistance

Impact of not taking meds daily

- "It's like when you stop taking your medicine and it stops working or you want to take it and it doesn't work." [13 to 17 years]

- "It's when your medicine don't work, right, or don't want to...like help your body...I mean 'cause it doesn't work anymore." [13 to 17 years]

- "If you take it for a long time period that regardless. I don't know...medicines stop being effective..." [13 to 17 years]

- "Resistance is if I'm suppose[d] to take 4 pills a day, right, so I stop taking those 4 pills or something like that or maybe I might just take 3 of the 4 pills and that 1 pill or those 4 pills that I'm supposed to be taking that will eventually help me to, you know, like [new] medicine and stuff like that it's not going to work because I didn't take it and I was playing around with it." [18 to 24 years]

- "I think I heard it before but now I really remember what they were saying..." [18 to 24 years]

- "Yea, I've heard of resistance...resistance to medication...so like if you take it [medicine] and then if you don't take it for a long time and then take it again you could be resistant to it and then it won't work no more." [18 to 24 years]

Barriers/facilitators to adherence

Not wanting to be different, motivation from family, and forgetfulness

- "I always have been taking my medicine. But yes, I did have a time when I didn't [take my medicine]. Nobody else was taking medicine and I felt like I was the only one who was and I didn't want to be different and I didn't want to be the only one who was taking medicine and then questions of why I am taking it..." [13 to 17 years]

- "I felt I need to be around to see my brother graduate and I want to still be around to talk to people, motivation..." [13 to 17 years]

- "I can remember taking it in the morning but sometimes after school I forget because I'm doing like my homework and stuff." [13 to 17 years

Difficulty swallowing, reminders, and forgetfulness

- "It's, um, it was just hard taking it 'cause the pill was nasty or too big to swallow and the liquid was just disgusting..." [18 to 24 years]

- "I set 3 alarms every hour and I put those 3 alarms on repeat 3 times." [18 to 24 years]

- "When I turned 15 and 16 going to high school and all that then you start forgetting because it was like a whole bunch of stuff on my plate you know at the time." [18 to 24 years]

Interest and use of video games

Appeal of games

- "Just a good way to pass time. Especially if I'm not doing anything, like on Sundays. Just to get passed time I guess." [13 to 17 years]

- "I like a lot of adventure..." [13 to 17 years]

- "I play after homework...but in the summer, my mom doesn't care." [13 to 17 years]

- "Well it keeps my attention but I like a game that has an interesting story behind it or just keeps me involved 'cause I get a game quick." [18 to 24 years]

-

> "Well I play all types of games but one game my head was stuck on and that's because I can't beat it because it keeps changing is War Frame." [18 to 24 years]
>
> - "...the harder the challenge the better..." [18 to 24 years]
>
> **Acceptability of video games for adherence**
>
> Perceptions regarding the potential of games to assist with adherence
>
> - "Yeah...because I need something besides my alarm." [13 to 17 years]
>
> - "I think if you like playing video games you'd remember to take your medication." [13 to 17 years]
>
> - "I wish we could like have our own little profile." [13 to 17 years]
>
> Suggestions for improving the game prototype
>
> - "I don't know, it might work but for me there'd have to be a game where it's like, kind of like how XX said, like a puzzle or something like that or like a challenge game or whatever..." [18 to 24 years]
>
> - "Like I mean every person is different but for me it would be like a puzzle game. Like some of it makes you think and you have to like work for it at the end and then they'll be like a message or something." [18 to 24 years]
>
> - "I like the power-ups because you get it to do different like variety of stuff so you get to choose different stuff...if you have different stuff you can earn a higher score." [18 to 24 years]

In addition to the interactive FGDs, brief surveys using Likert scales were used to evaluate acceptability of the Wisepill and game prototypes among AYA (Table 3).

On a scale of 1 to 5, with 5 indicating strong agreement, most participants agreed the dispenser format was convenient (median 4.0) and linking it to the games would not be an issue (median 5.0). In assessing game design upon viewing the artwork for Virus Fighter, younger participants were less likely than older participants to like the idea of playing games about the immune system (median 4.0 vs 5.0, respectively; P=.01) and significantly more likely to agree that they preferred playing games about topics other than the immune system (median 4.0 vs 5.0, respectively; P=.01).

The feedback from the initial AYA FGDs led to suspension of production on the Virus Fighter/Body Voyage game, revisions of the Adherence Warrior game, and the development of a third game prototype, the Berry Game, both of which were shared with AYA during the second round of FGDs.

After playing the two intervention game prototypes, most participants were optimistic of the games' abilities to help them improve their adherence and provided suggested revisions that were incorporated by the researchers. Among the suggested changes were allowing for the customization of characters including both male and female avatars, adding music, having an in-game notification or reminder that encourages players to take their medication, and increasing the diversity of the games. Participants conveyed interest in games with a bonus stage and power-up capabilities that enabled additional features leading to more points. Participants also favored power-ups as a reward for ART adherence over gaining additional points, which emphasized their preference for playing games for the challenge rather than for winning.

AYA reported that they thought the games were interesting (median 5) and satisfying (median 5). Participants in the 18- to 24-year age group were more likely to report that the games were fun (median 5.0 vs 4.0, P=.03) and to prefer games about subjects other than the immune system (median 5.0 vs 4.0, P=.01) (Table 3). Using a separate Likert scale with a range of 1 to 4 with 4 indicating high likelihood, participants reported that they would play the games if they were available to them (median 4.0), they would use the games to help with taking their HIV medications (median 4.0), and they would be more likely to take their medication if they could get better power-ups in the games (median 4.0). Overall, preferred game characteristics, regardless of age group, included being (1) challenging enough to keep one's attention, (2) individually tailored based on interests, (3) competitive, (4) containing a virtual reward system to provide in-game incentives, and (5) easy to play.

Table 3. Acceptability of game prototype stratified by age group.

Game characteristics[a]	13-17 years (n=7), median response	18-24 years (n=5), median response	Total (N=12), median response
The game playing was very interesting[a]	5	5	5
The game playing was satisfying[a]	4	5	5
The game playing was fun[a]	4[c]	5[c]	5[c]
It was easy to learn how to play the game[a]	4	4	4
I liked the art and animation[a]	4	5	4
I liked the game environment[a]	3.5	4	4
I liked the game interface[a]	4	4	4
I like the 7-day organizer format of the pill dispenser[a]	4.5	5	5
The link to the pill dispenser was not a problem for me[a]	5	3	4
I like the idea of playing games about the immune system fighting off invaders[a]	4	5	5
I like the idea of playing games about subjects other than the immune system[a]	4	5	4
Games about the immune system make me more interested in the subject[a]	3.5	5	4
I would like to get a pop-up reminder to take my medications from the game on my phone[a]	4.5	4	4
I would play these games if I had them[b]	4	3	4
I would recommend the games to a friend[b]	3	3	3
I would be interested in playing these games in multiplayer mode with my friends[b]	3	2	2
I would use these games to help with taking my medications[b]	4	3.5	4
I would be more likely to take my medication if it would get me more points in the games[b]	3	3	3
I would be more likely to take my medications if it would get me better power-ups in the games[b]	4	4	4

[a]Responses provided on a scale of 1 to 5: *strongly agree* (5), *somewhat agree* (4), *neither agree nor disagree* (3), *disagree* (2), *strongly disagree* (1).

[b]Responses provided on a scale of 1 to 4: *very likely* (4), *somewhat likely* (3), *not very likely* (2), *don't know* (1).

[c]Significant differences between age groups using *t* tests ($P<.05$).

Discussion

Principal Findings

This study, which explored the potential for using gaming technology to support long-term treatment of HIV among AYA, demonstrated that it would be feasible and acceptable to use a digital gaming intervention linked to Wisepill dispensers to improve ART adherence. Qualitative data collected through FGDs elicited information from both HIV care providers and AYA participants. The FGDs with HIV care providers revealed concerns regarding the level of understanding of the importance of adherence and viral resistance as well as age-related challenges such as nondisclosure, treatment fatigue, and limited capacity to foresee long-term consequences of nonadherence among their AYA patients. The challenges to daily ART adherence were echoed by the AYA FGD participants as they identified common barriers to treatment adherence and strategies to improve adherence.

Despite the providers' concerns, participating AYA demonstrated an understanding of the concepts of resistance and adherence and acknowledged the multiple adherence barriers they face, which included changes in daily routines and fear and anxiety of disclosing their status to others, all of which are consistent with the existing literature [11,36,37]. Our discussions also indicated that AYA considered that having an understanding of the chronicity of HIV and the ability to set long-term goals were facilitators of adherence. These findings are not surprising considering the complex developmental periods of adolescence and young adulthood of altered levels of identification, self-regulation, and influence from peers [11]. As adolescents mature into young adults, strategies and messages to support adherence, self-management, and well-being should reflect shifts from concrete to abstract thinking and from an invulnerable to self-preserving mindset [12]. This is reinforced by our finding of AYA expressing willingness to try more creative approaches to facilitate better medication adherence, including playing video games.

The proposed approach of using Wisepill dispensers linked to games with microtransactions and power-ups was affirmed as acceptable by both HIV care providers and AYA living with HIV. Importantly, AYA participants in our study were receptive to the concept of using Wisepill dispensers for their adherence monitoring as the majority of them had some past experience with different types of pillbox or pill dispenser use. The feasibility and acceptability of using wireless electronic device monitors for adherence among HIV-infected persons has been demonstrated in other settings including in China and Uganda. In Uganda, adult HIV-infected patients described the Wisepill device easy to use and convenient, and it was found to be noninferior to the Medication Event Monitoring System pill bottle caps [15]. Further, among Chinese children aged 10 to 15 years, Wisepill dispensers were reported to be an acceptable and rigorous method of evaluating ART adherence and were found to be potentially useful for adherence support among adolescents living with HIV [38].

Our study was also informative in gathering key information from game users and providers about the role and the design of the game within the context of health promotion. All the AYA participants reported regular technology use and unfettered access to video games and provided overall positive feedback on the proposed game prototypes. Interestingly, among HIV care providers, initial discussions regarding the potential for gaming to improve adherence indicated some hesitation and skepticism, although some of them had described previously using gaming analogies to educate patients about HIV and adherence. Even though some providers used gaming analogies to explain the role of adherence in treatment, they were clear that the games should avoid defining the youth as being HIV-infected and should instead be positive and motivational. Similarly, the AYA participants were not particularly interested in an educational or HIV-themed game. This desire for noncontent-related games among providers and AYA in our study is in contrast to some other games developed for health-related purposes, which are both educational and disease-specific [39-41]. We believe that the desire to avoid the direct topic of HIV in gaming is closely linked to the sensitive nature of HIV disease and external and internal stigma experienced by people living with HIV. Therefore, our games were not specifically HIV-related nor did they include a community-gaming aspect to intentionally avoid inadvertent disclosure. In future iterations of the game, it may be possible to incorporate a community-gaming aspect in a confidential manner as well as potentially link the Wisepill device to existing popular games to address concerns about the durability and sustained use of a particular set of games.

Through our iterative study design, AYA provided important feedback and concrete suggestions to the game development process. They preferred games that were challenging, individually tailored, included a virtual reward system, and were easy to play. In other studies, video games that were developed using input from their target population have been proven effective in the chronic disease management of health conditions in AYA such as asthma, cancer, and diabetes [42]. In fact, a video gaming approach has recently been tested among AYA living with HIV that incorporates an adherence-based app inclusive of games [39]. The developers reported that AYA enjoy the interactive and customizable app elements and found this approach to be highly acceptable [39]. Further, studies among youth with chronic diseases have also found that game interventions result in improved self-management and decreased unanticipated medical visits [43]. Based on these studies and our data, we anticipate that our versions of the games will appeal to AYA living with HIV and will be effective in supporting medication adherence and improving HIV outcomes such as viral suppression.

Limitations

There are several limitations to our study worth noting. Despite high numbers of initial youth recruited, the number of youth participating in the FGDs was relatively small and participants were drawn from a convenience sample recruited from a single clinical center. Although common in qualitative research, the small sample size limits the generalizability of the study findings. Further, all participants identified as black or African American, reflecting the high burden of infection among these populations in the DC region as well as in the United States [28]. While this may limit generalizability of findings to AYA of other races or ethnicities, it should be noted that none of the video game prototypes were uniquely designed for black youth and were instead based on common video game prototypes used among diverse populations. Additionally, FGD moderators can affect the outcome of an FGD by intentionally or inadvertently inserting their personal biases into the participants' exchange of ideas. Since one of the moderators of our FGD was the developer of the video games being tested, the FGD participants could have been led into reaching certain assumptions and may have been somewhat influenced in their opinions. We attempted to reduce this potential bias by including a clinician-researcher as a moderator in each FGD to deter biased discussion and responses.

Conclusions

AYA living with HIV face multiple challenges with medication adherence and must develop effective strategies to help them remember to take their medications. Similarly, HIV care providers strive to support ART adherence and educate AYA about the long-term consequences of nonadherence. Given these challenges, the development of effective, youth-friendly interventions to improve adherence among AYA living with HIV is critical to achieving better health and outcomes of HIV disease. In the era of the widespread use and availability of technology including mobile phones and video games, the concept of using a technological approach to improve medication adherence is supported by both AYA and their HIV care providers. Inviting buy-in from youth to elicit their preferences as end-users of the game-based intervention and modifying the games accordingly to include non-HIV focused, interactive, adventurous, and challenging games is likely to result in stronger interest and engagement in the future intervention. The potential effectiveness of this approach will be tested in a future study among a cohort of 13- to 24-year-old HIV-infected AYA with suboptimal ART adherence at CNMC.

Acknowledgments

Conflicts of Interest

None declared.

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Abbreviations

ART: antiretroviral treatment
AYA: adolescent and young adult
CNMC: Children's National Medical Center
FGD: focus group discussion
SIS: Special Immunology Services

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Virtual Reality Clinical Research: Promises and Challenges

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Abstract

Background: Virtual reality (VR) therapy has been explored as a novel therapeutic approach for numerous health applications, in which three-dimensional virtual environments can be explored in real time. Studies have found positive outcomes for patients using VR for clinical conditions such as anxiety disorders, addictions, phobias, posttraumatic stress disorder, eating disorders, stroke rehabilitation, and for pain management.

Objective: This work aims to highlight key issues in the implementation of clinical research for VR technologies.

Methods: A discussion paper was developed from a narrative review of recent clinical research in the field, and the researchers' own experiences in conducting VR clinical research with chronic pain patients.

Results: Some of the key issues in implementing clinical VR research include theoretical immaturity, a lack of technical standards, the problems of separating effects of media versus medium, practical in vivo issues, and costs.

Conclusions: Over the last decade, some significant successes have been claimed for the use of VR. Nevertheless, the implementation of clinical VR research outside of the laboratory presents substantial clinical challenges. It is argued that careful attention to addressing these issues in research design and pilot studies are needed in order to make clinical VR research more rigorous and improve the clinical significance of findings.

Introduction

Contemporary research on computer-based virtual reality (VR) dates back to the early 1980s, although devices for presenting stereoscopic imagery (ie, using a slightly different image for each eye) such as the stereoscope started in the 1830s [1]. The exploration of VR use in clinical applications is accelerating rapidly with the advent of more powerful computer and graphics processors capable of rendering real-time three-dimensional

(3D) imagery, and the availability of relatively low-cost VR headsets such as the Oculus Rift or HTC Vive (see Figure 1).

As researchers with significant experience in researching VR for clinical applications, we have identified some major issues in the development of clinical VR research. Substantial challenges remain with theoretical ambiguity and immaturity, a lack of technical standards, problems of media versus medium, practical in vivo issues, and economic feasibility.

Background

There has been rapid growth in the reported use of VR in the treatment of a variety of clinical conditions, such as acute and chronic pain management [2-9], anxiety disorders [10-12], phobias [13-15], posttraumatic stress disorder (PTSD) [16-18], eating disorders [19], autism [20], and rehabilitation [21-26]. Additionally, its use in professional health care education has also been expanding rapidly [22,27-32].

One early clinical application of VR was for the treatment of acrophobia [33]. Graduated exposure to virtual environments with foot bridges, balconies, and a glass elevator were used with a railing placed around the user in the real world for them to hold on to. The intervention was reported as effective. Over the last 20 years, VR clinical applications have expanded to address other phobias and anxiety disorders. The most common approaches in this field have been to model virtual environments after existing exposure therapies using graduated exposure to a VR version of the object or situation that causes distress and use of VR cognitive behavioral therapies [34-37]. For PTSD, virtual environments have been used to simulate complex traumatic scenarios under control to treat war survivors [18,38]. Similarly, VR has been used in the treatment of body image and eating disorders [39-41]. These approaches leverage education, visual feedback, and simulations of critical situations to improve body self-perception.

These studies largely focus on health outcomes to determine the efficacy of VR treatments. While they reported positive clinical effects over a variety of VR experiences, they often pay limited attention to the nature of the hardware and software used. Furthermore, the VR therapies usually relied on custom virtual environments. However, the literature often lacks commentary on the design and development of them. Despite these limitations, VR-based treatments for treating fear-related and anxiety disorders appear to be the most established clinical applications of VR.

Another key area has been in the use of VR for pain management. The mechanism of VR pain control is primarily thought to be distractive, although the precise mode of action remains uncertain [6,42,43]. For example, VR has been used to manage acute pain during in-hospital treatments for burn patients [5,44-47]. Using VR for needle-stick pain has also been researched [6,48]. In the field of chronic pain, VR has also been applied [8,49-51]. Several researchers have explored VR use to treat phantom limb pain [52-55]. VR allows clinicians to present patients with a virtual representation of their missing limb. Through perception and motor training, patients experienced relief from phantom limb pain by seeing their virtual limb move in accordance to their voluntary motor signals.

Figure 1. VR clinical application papers published by year (PubMed).
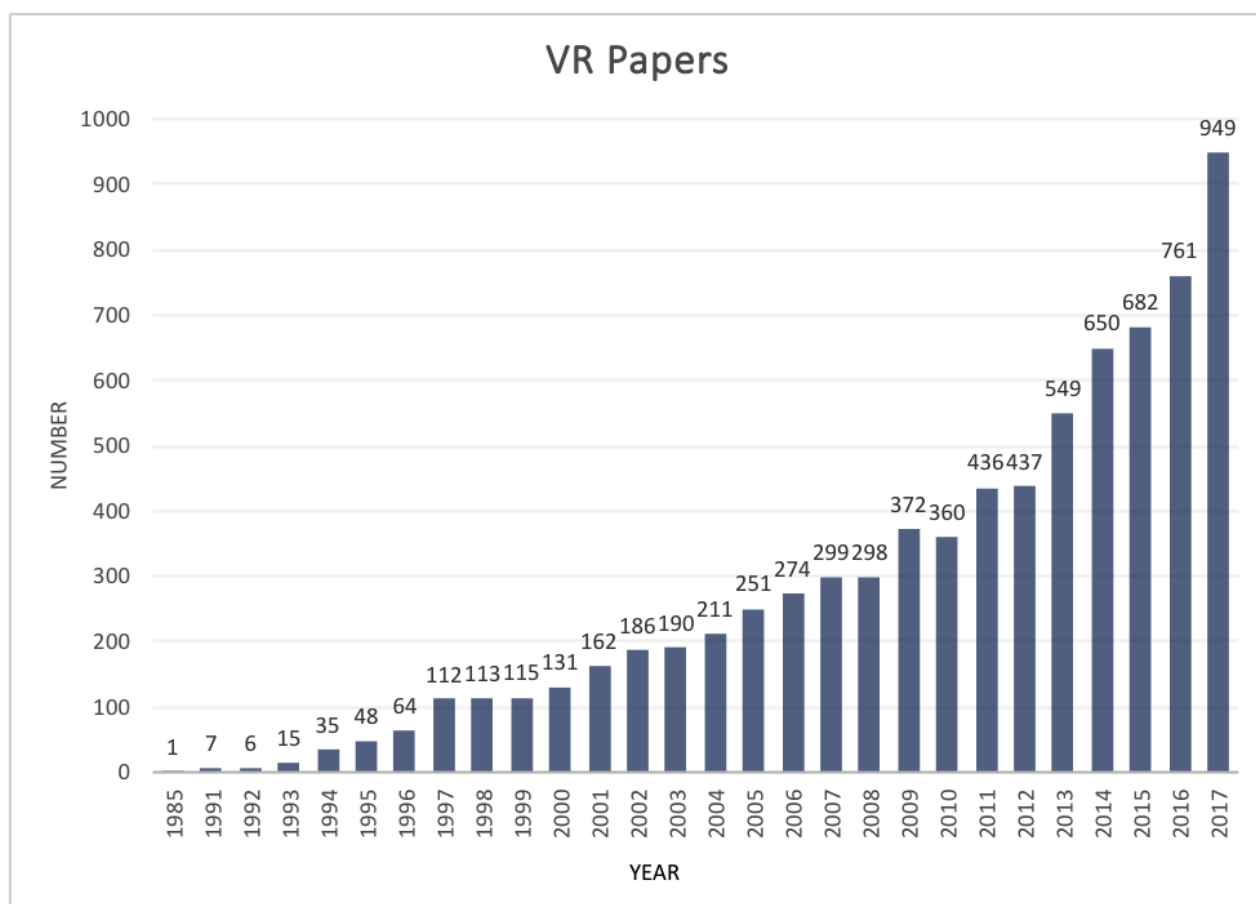
In the rehabilitation field, there has also been great interest in pairing assistive technologies (eg, robotics, treadmills, wheelchair on rollers, wearable sensors) and VR. The primary goals have been the development of tools that support patient motivation to engage with rehabilitation and to leverage the logistical advantages of digital technology, namely performance monitoring, telehealth, and patient self-management. Additionally, translating physiotherapy exercises and activity training into the VR space allows for much greater control over and variety of scenarios.

For example, robot-assisted upper limb therapy paired with VR visual feedback allows for graded exercises contextualized in a videogame environment [56-58]. In wheelchair simulators, VR enables users to practice wheelchair navigation skills in more dangerous situations such as traffic crossings and crowds without risk [59,60].

Clinical VR research to date has generally been positive, but overall research in this field is in the early stages and faces technical and theoretical hurdles. Most studies have used non-standardized techniques and tools in small-scale pilot studies. Over the last 4 years, the authors have conducted several clinical VR research projects [6,8,49] and found a number of challenges in the field that may limit the validity and generalizability of the work.

Challenges

Theoretical Ambiguity and Immaturity

As with the development of any new discipline, establishing a sound theoretical basis and standards is key to the growth of the field. However, there exists some theoretical ambiguity in the field due in part to its immaturity. Overall, VR may be considered as a growing field, defined by both its technology and its effects. The desired effect is to create an immersive experience, whereby the user is placed in a simulated environment that looks and feels as engaging as the real world. The person in this synthetic environment has a specific sense of self-location within it, can move to explore it, feels that the space surrounds them, and can interact with the objects within it. Overall, they feel a sense of presence in this environment, and their actions partially determine what happens within it [61,62].

Technically, the sense of immersion in a VR environment is largely achieved through visual and auditory stimuli that simulate 3D visual and auditory cues available in the real world. Haptic feedback can also contribute to this immersion. Visually, this is delivered to the user via a head-mounted display, which presents the computer-generated imagery (CGI) of the VR scene from the perspective of each of the user's eyes. The literature suggests that immersion is largely influenced by both visual and audio qualities, although a universally accepted definition is yet to emerge [63-67]. Immersion has been defined as the extent to which a user feels present in the CGI environment, rather than in their actual physical environment [68,69]. In computer science, immersion has more often been defined in terms of the technology and by the extent to which the computer is able to deliver an inclusive, extensive, surrounding, and vivid

illusion of reality to the senses of the participant [67]. Therefore, immersion is often referenced by technical considerations, such as field of view and positioning of the virtual body in the CGI. The inclusion of stereoptic imagery is widely thought to be the dominant factor that enhances the immersive experience. Other technical factors, such as greater display resolution or increased field of view are also significant [52,70].

Presence, on the other hand, refers to the sense of being within an environment that is generated through technological means [68,71]. It is viewed as the sense of actually being in a constructed world [68,69,71,72]. Two experiential and technology-dependent dimensions are considered to contribute to a sense of presence. The first dimension is vividness, or the production of a sensory-rich, mediated environment. The second is interactivity, defined as a user's ability to engage with the environment and modify its form or alter events through interaction with it. An analogy would be that you can become *immersed* through the text in a book, but feel a sense of *presence* in the story only when you feel you are actually there experiencing the events.

This differentiation of immersion from presence (which is seen as more of a subjective element) is fairly well established in computer science, but less so in clinical VR research, where the terms are often used interchangeably. For clinical use, a technical definition of immersion is limited, as it ignores the participant as a co-constructor of the experience. Therefore, concepts of presence and telepresence [68] are likely more useful to clinical applications. An immersive virtual environment can be considered to be a computer-generated environment that elicits the user's sense of presence or "being there." It can be seen as an environment that produces an esthetic perception connected to the ideal of total immersion in virtual space involving the willing suspension of disbelief [69,71,73]. In clinical contexts, this sense of presence is likely the key element of interest that differentiates the impact of VR from other distractive and cognitive approaches. Assessment tools that separate these aspects, such as the igroup Presence Questionnaire have been developed [74]. However, clinical VR literature rarely discusses these theoretical aspects nor provides robust theoretical explanations of how VR theory applies to the specific problem under investigation. As VR is essentially a technology-mediated phenomenon, this lack of theoretical distinction, between what actually constitutes a VR experience, at the least, makes meaningful comparisons between clinical studies complex.

Adding more complexity is the issue that the actual nature of the effect of VR on the clinical problem of interest is also often unknown. For example, VR environments are hypothesized to reduce pain by mediating cognitive attentional and distractive mechanisms. The use of VR might act directly and indirectly on pain perception in different ways by altering neurological signaling pathways involving attention, emotion, concentration, memory, touch, and the auditory and visual senses. However, there are competing theoretical explanations of pain and the exact mechanisms of how VR may attenuate it remain unclear [48,75-82]. It has been theorized that VR analgesia stems from the neurobiological interactions of areas of the brain that produce analgesic effect by regulating visual, auditory, and touch sensory experiences [80]. Hoffman et al state that VR works

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predominantly via distraction. Pain requires attentiveness, and humans have been found to have limited controlled attentional resources [83]. The level and impact of the distraction can depend on the level of the immersion—the more immersive the VR, the more effective in reducing pain [84]. Furthermore, using functional magnetic resonance imaging (fMRI) brain scanning, correlation in pain-related brain activity and subjective pain report was reported, thus, demonstrating the impact of VR on pain-related brain activity in all five regions of the brain [83].

VR has been shown to alter the sense of an individual's presence to that of being in a virtual world, therefore changing features of the individuals experience associated with sensory affective and cognitive processes.

The validity of clinical VR research also needs to be considered in the context of the theory development process. Overall, there are five major processes that occur in the development and establishment of a theory: (1) creating conceptual meaning, (2) structuring and generalizing the theory, (3) generating the theoretical relationships, (4) applying the theory, and then (5) theory validation by testing in different real-world applications [85]. At this stage of VR development for clinical use, the underpinning theory has yet to reach the higher levels of established validity.

Standardized Implementation

The type of VR technology implemented varies greatly between clinical studies. It is arguable that the current state of the art is very much technologically led rather than theoretically led, with each new iteration of clinical research using the latest VR applications and hardware with disparate approaches for a variety of clinical conditions. As the hardware and software continue to advance rapidly, studies even a year apart may be using completely different hardware or software and, in many cases, the technology is only vaguely defined [6,12,42].

Three-Dimensional Versus Two-Dimensional

Many clinical studies have used the term VR to describe significantly different multimedia technologies, including two-dimensional (2D) video screen presentations, 2D-rendered images presented on screens [86] and head-mounted displays [9,46,87], 360-degree 2D presentations on head-mounted displays [88], or computer-assisted virtual environment (CAVE) room-scale projection systems [89,90]. Others used 3D-rendered VR in motion-tracked stereoscopic head-mounted displays, with a wide field of view [8,9,91-93]. There are similar differences in audio use in these studies, with some using positional stereo sound (ie, location-specific sound that moves as the user moves their head) and others using non-spatial audio. Although health outcomes may be comparable, the nature and value of 3D versus 2D applications have not been widely explored in clinical applications.

Study Design

In addition to the theoretical issues, the nature of VR study design itself represents another significant hurdle. Systematic reviews/meta-analyses illustrate that many of these studies are statistically underpowered, although positive statistical results are frequently claimed [6,12,18,94-96]. To establish clinical efficacy of a therapy, large-scale quality randomized controlled trials are required. Comparative clinical studies also require a suitable control environment to contrast with the VR experience. Few studies make an adequate attempt to address this and frequently neglect to differentiate the effects of the media from the medium itself (both theoretically and in practice). For example, the medium of VR could be the use of VR technology and a head-mounted display to render a 360-degree stereoscopic and stereo audio environment with which a person can interact. The media may be a puzzle-solving interactive VR computer game, a VR rollercoaster ride, or a 3D-rendered high-definition video experience of a beach environment. Failing to explore if it is the VR experience itself or the medium used that is eliciting an effect is problematic. A good design will contrast a VR experience with a non-VR equivalent of the same experience, controlling for the effects of the medium compared to the media. These issues likely reflect some degree of confirmation bias among researchers, but this illustrates the need to implement larger-scale high-quality clinical VR studies.

Usability and Technical Proficiency

Another more practical challenge faced by clinical researchers is the usability of VR systems and the level of technical proficiency required to run them. Although current VR iterations are designed to be more user friendly, significant technical limitations remain. The use of head-mounted displays is problematic for some patients. They are cumbersome, particularly for patients with head or neck injuries, or for those who are particularly susceptible to eye strain. Additionally, VR applications are generally not usable by people with cognitive or significant visual deficiencies, as they are unable to access existing VR interfaces. Also, prolonged exposure to a screen a few centimeters from the eyes often leads to eye strain or headaches and represents an ongoing issue with VR systems [97,98]. Users with limited head or neck mobility often reported the systems were uncomfortable to use [8]. Furthermore, most advanced head-mounted displays have a cable tether that can be a distraction from the experience or a tripping hazard for older patients.

Cybersickness, as a side effect of VR, is also well documented and limits use by many patients, particularly those taking medications that can cause nausea [8,99-103]. Newer systems that operate at room-scale (ie, where the user can walk around in a pre-determined area) have addressed this to some extent, but many patients also have limited mobility and must use the system in a seated position. This gives rise to another problem: most VR applications are currently designed to be used as either room-scale or seated, with few working well in both configurations. The issue derives from the fact that room-scale VR navigation affords the user much greater range of motion to physically approach virtual items, while the seated position requires a set visual height, longer reaching movements, and controller-based navigation of the environment. The environment design and implementation requirements generally do not transfer well from seated to room-scale and vice versa. Many VR systems have implemented teleportation navigation systems to support moving through larger distances to overcome this issue, but again those designed for room scale use do not adjust well to use from a seated position.

The design and game paradigm of many VR experiences itself can also prove challenging for older patients. For users who have grown up with computer games, the nature of VR experiences is more readily understandable: traversing 3D-rendered worlds, using menus, navigating levels, storing and retrieving items, saving progress, solving game puzzles, and relating button-presses to abstract actions are all mechanics learned through experience. This alignment of VR with recreational gaming is exemplified by the marketing and delivery of HTC Vive and Oculus Rift VR applications through the Steam online gaming platform. Most clinical users are likely to be older adults, who have no such videogame literacy and often find learning these elements frustrating and distracting to their VR experience. Little work exists exploring the VR preferences of these users and the VR market is firmly dominated by the younger consumer.

Lab Versus In Vivo Practical Issues

Much of the existing VR research has taken place in lab or clinic settings. These environments can be optimized for VR systems. However, much remains to be known about the effects of regular and prolonged VR use for real-world and home applications, where they will be used for many chronic conditions. Certainly, there are common challenges for research requiring any kind of at-home technology implementation such as logistics, remote technical support, learning curve, and compliance. However, there are a few unique challenges to consider in the implementation of VR systems outside the lab.

Current VR systems require dedicated space and are susceptible to interference. Room-scale systems require a 5 ft^2 space, which may be intrusive to a patient's living space. Cables may pose tripping hazards. Infrared sensors, such as those used by systems such as the HTC Vive, may be interfered with by devices such as TV remotes, resulting in display cutting out, choppy visuals, and loss of tracking, thus disrupting the user's experience. Other environmental factors that disrupt infrared tracking, such as climate and reflection of light off windows or mirrors, can be easily mitigated in a lab setting but can be more difficult to cope with in a home. Furthermore, calibration for motion tracking of VR equipment is sensitive and thus movement of equipment must be minimized. Effective installation of VR equipment while still maintaining the usability of the home space is challenging and may be further complicated if there are pets or children in the home.

For clinical research, where a study may take weeks or months, these technological burdens are important to negotiate with participants in advance. Despite these challenges, our experience has shown that research participants are often enthusiastic and willing to accommodate the various needs of the equipment and research study. However, these attitudes may not necessarily carry over to commercial or non-research contexts.

Costs

Finally, the cost of VR still presents a challenge to implementing large-scale trials [11]. Although costs of head-mounted displays are dropping, quality VR environments still require high-end computer systems with advanced graphics processing to run them. VR applications are also expensive to develop. The current cost of a full system to run a quality VR clinical experience is around US $2,500 per unit plus maintenance costs, making clinical research with multiple users costly. As with any information technology, attrition of value is also rapid; newer technologies rapidly make older systems obsolete. A practical assumption of minimal resale value of a VR system after 3 years is not unreasonable.

Conclusions

Although clinical VR research looks promising, significant theoretical and practical challenges remain, such as theoretical ambiguity and immaturity, lack of technical standards, differentiating effects of media versus medium, value of 2D versus 3D applications, study design, usability, conducting in vivo research, and economic feasibility. Defining the impact of presence in clinical VR studies and differentiating the concept of presence from immersion (as they are often used synonymously) is a problem, and current research designs are often ill-equipped to differentiate the role of VR from confounding factors. More robust study designs contrasting VR experience with an equivalent non-VR control are required.

Practical challenges also remain, as existing high-end VR systems remain cumbersome and require technical proficiency to use. VR systems are not always user-friendly for patients. Moreover, issues of eye and neck strain and cybersickness remain as practical barriers to wider use. For those undertaking clinical VR research, it is important to keep these issues in mind during efforts to improve the evidence base for these technologies as health interventions.

Conflicts of Interest

None declared.

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Abbreviations

2D: two-dimensional
3D: three-dimensional
CGI: computer-generated imagery
PTSD: posttraumatic stress disorder
VR: virtual reality

Review

Implementations of Virtual Reality for Anxiety-Related Disorders: Systematic Review

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Abstract

Background: Although traditional forms of therapy for anxiety-related disorders (eg, cognitive behavioral therapy, CBT) have been effective, there have been long-standing issues with these therapies that largely center around the costs and risks associated with the components comprising the therapeutic process. To treat certain types of specific phobias, sessions may need to be held in public, therefore risking patient confidentiality and the occurrence of uncontrollable circumstances (eg, weather and bystander behavior) or additional expenses such as travel to reach a destination. To address these issues, past studies have implemented virtual reality (VR) technologies for virtual reality exposure therapy (VRET) to provide an immersive, interactive experience that can be conducted privately and inexpensively. The versatility of VR allows various environments and scenarios to be generated while giving therapists control over variables that would otherwise be impossible in a natural setting. Although the outcomes from these studies have been generally positive despite the limitations of legacy VR systems, it is necessary to review these studies to identify how modern VR systems can and should improve to treat disorders in which anxiety is a key symptom, including specific phobias, posttraumatic stress disorder and acute stress disorder, generalized anxiety disorder, and paranoid ideations.

Objective: The aim of this review was to establish the efficacy of VR-based treatment for anxiety-related disorders as well as to outline how modern VR systems need to address the shortcomings of legacy VR systems.

Methods: A systematic search was conducted for any VR-related, peer-reviewed articles focused on the treatment or assessment of anxiety-based disorders published before August 31, 2017, within the ProQuest Central, PsycINFO, and PsycARTICLES databases. References from these articles were also evaluated.

Results: A total of 49 studies met the inclusion criteria from an initial pool of 2419 studies. These studies were a mix of case studies focused solely on VRET, experimental studies comparing the efficacy of VRET with various forms of CBT (eg, in vivo exposure, imaginal exposure, and exposure group therapy), and studies evaluating the usefulness of VR technology as a diagnostic tool for paranoid ideations. The majority of studies reported positive findings in favor of VRET despite the VR technology's limitations.

Conclusions: Although past studies have demonstrated promising and emerging efficacy for the use of VR as a treatment and diagnostic tool for anxiety-related disorders, it is clear that VR technology as a whole needs to improve to provide a completely immersive and interactive experience that is capable of blurring the lines between the real and virtual world.

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Introduction

Background

Anxiety-related disorders such as specific phobias, posttraumatic stress disorder (PTSD), and general or specific anxiety (eg, public speaking or social anxiety) disorders stand as 1 of the most common, growing mental health disorders worldwide [1]. In 2014, 19.5% of individuals above the age of 16 years had shown signs of anxiety or depression, with the United Kingdom alone experiencing a 1.5% increase from 2013 [1]. To combat the symptoms of anxiety-related disorders, 1 of the most effective treatment methods has been exposure therapy, which stems from the broader practice of cognitive behavioral therapy (CBT) [2]. In exposure therapy, patients undergo a process of systematic desensitization, where a series of systematic steps are employed to gradually expose the patient to an anxiety- or fear-inducing stimulus, with the ultimate goal of minimizing the patient's intense and adverse behavior toward the stimulus. Furthermore, the therapists may employ methods to change the patient's cognitions about the stimulus, such as through psychoeducation, to reinforce treatment gains from systematic desensitization [3].

Traditionally, stimuli in exposure therapy are presented through in vivo exposure (IVE) or imaginal exposure (IE), each of which carries its own set of advantages and disadvantages. IVE involves live exposure to the stimuli, often being utilized to treat specific phobias or anxieties such as arachnophobia (fear of spiders) [4], acrophobia (fear of heights) [5], and social anxiety [6]. Although IVE is considered to be the most effective method for helping the patient overcome their anxiety or fear, disorders such as aviophobia (fear of flying) and social anxiety may require sessions to be conducted in public, therefore posing a risk of breaking patient confidentiality; become too expensive to perform single or repeated exposure sessions; and introduce uncontrollable variables that may hinder the overall treatment (eg, behavior of living organisms and weather conditions) [7-9]. Even if these issues can be addressed, some individuals may feel that confronting an anxiety- or fear-inducing stimulus may be too aversive, which may lead to participants dropping out of treatment or not seeking treatment at all [5]. IE can address many of the limitations of IVE, as patients are tasked with generating the stimulus in his or her imagination rather than confronting a live version of the stimulus; however, the patient may be potentially unable or unwilling to generate a vivid imaginal representation of the stimulus [10].

Since the early to mid-1990s, therapists have attempted to seek an alternative to IVE and IE through the use of virtual reality (VR) technologies through a process known as virtual reality exposure therapy (VRET). VR technology includes a wide range of configurations, including head-mounted displays (HMDs), external projection setups such as the CAVE Automatic Virtual Environment [11], and simulators [12], all of which vary in terms of technical specifications (eg, display resolution, tracking accuracy, and field of view). Regardless of the form of VR, VRET generally follows the same treatment protocols as traditional exposure therapy but renders the anxiety or fear-inducing stimulus within a virtual environment that immerses the user with sensory stimuli. These stimuli are often limited to the user's visual and auditory senses but may sometimes incorporate tactile stimuli through an apparatus (eg, force feedback gloves, toy spiders) to allow VR users to feel objects with their hands. By utilizing a customizable virtual environment, VRET offers an unparalleled level of control for the therapist to manipulate factors that could not be controlled in a standard IVE session and tailor the sessions based on the patient's needs—all in the confines of the therapist's office [9,13].

Despite a major interest in VR during its inception, VR was often expensive, uncomfortable, and required special training to operate. The computers used to run VR were barely able to do so, leading to low-quality VR experiences (eg, jagged graphics and inconsistent and low frame rates) that could lead to simulator sickness, characterized by symptoms of nausea, headaches, and dizziness [6]. In addition to simulator sickness, early HMDs were also heavy, resulting in users experiencing neck pain after prolonged use. Furthermore, without adequate software distribution systems to sell or share VR programs, special training would often be required to create VR programs to suit the research or therapists' needs. These limitations ultimately restricted the use and research of VR-based psychotherapy to well-funded or specialized institutions [14].

Although early VR technologies have been largely inaccessible to a mass audience, recent developments in VR technologies have addressed many of the issues that plagued legacy units. Both the HTC Vive and Oculus Rift, which released in 2016, were lighter and powerful enough to render high-quality visual and auditory stimuli. Both HMDs were also integrated with major digital distribution services such as Steam, which has attracted both small, independent developers and large, professional developers alike to create high-quality VR programs. Renewed interest in VR also led to a push for mobile VR, a less powerful yet inexpensive version of computer-based VR that could run on modern mobile phones (e.g. iPhone, Google Pixel, etc.).

Objective

The aim of this systematic review was to explore previously established VR studies within psychotherapy to inform future VR research. Although modern VR HMDs are still relatively new, evaluating how past studies have utilized the VR technologies of their era can serve as a comprehensive guide as to how VR-based psychotherapy programs can improve in the future as well as whether the limitations observed in past studies are still relevant with the current iteration of VR systems. Topics covered in this review will mainly cover the efficacy of VRET treatment, its uses as a diagnostic or assessment tool, and innovations in the pursuit of greater VR experiences in relation to psychological disorders in which anxiety is a key symptom, including specific phobias, PTSD and acute stress disorder (ASD), specific and general anxiety disorder, and paranoid ideations.

Methods

Databases Searched

ProQuest Central, PsycINFO, and PsycARTICLES were the databases used to conduct a comprehensive search of the past literature. Studies must have been published before August 31, 2017, peer-reviewed, published in a scholarly journal, written in English, and have full-text availability.

Search Terms

The command line used for the search was as follows: "virtual reality" AND (phobia OR anxiety) AND (treatment OR therapy). Although VR is a common referential acronym for virtual reality, the full term was exclusively used during the search to streamline the search process and avoid any other terms that may use the VR acronym (eg, variable reward and voice recognition). An initial 2419 studies were collected from the 3 databases used to conduct this search.

Figure 1. Systematic Review Search Prisma. HMD: head-mounted display; VR: virtual reality.
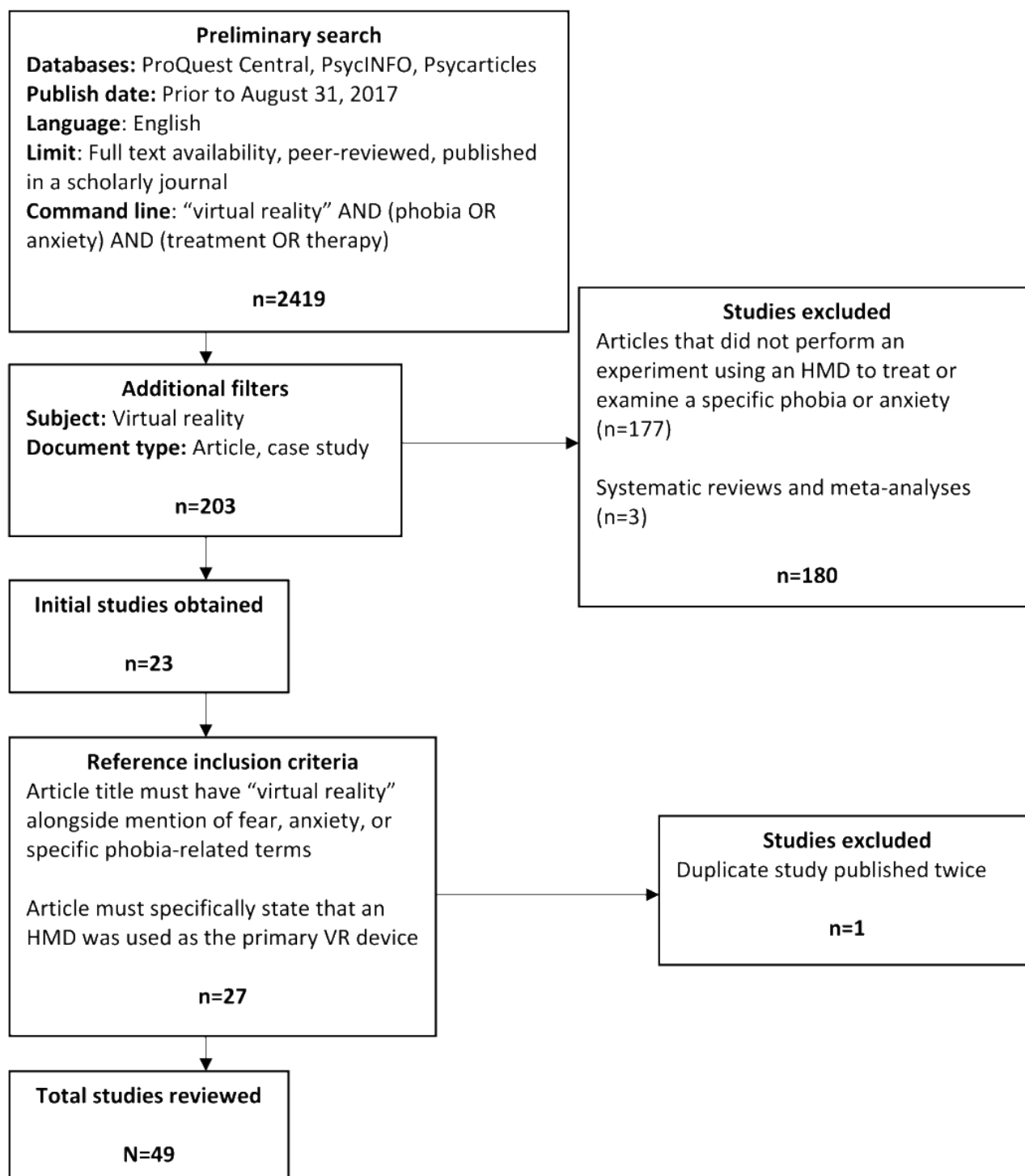
Table 1. Specific phobia treatments.

Author	Phobia type	Methodology	Sessions, n	Session length	Follow-up	Intervention (patients, n)
Botella et al [17]	Claustrophobia	Case	8	35-45 min	1 month	VRET[a] (n=1)
Botella et al [18]	Agoraphobia	Controlled	9	1 hour	12 months	VRET (n=12); IVE[b] (n=12); WL[c] (n=13)
Carlin et al [9]	Arachnophobia	Case	12	50 min	None	VRET (n=1)
Emmelkamp et al [19]	Acrophobia	Controlled	3	1 hour	6 months	VRET (n=17); IVE (n=16)
Garcia-Palacios et al [7]	Arachnophobia	Controlled	3-10 (4)[d]	1 hour	None	VRET (n=12); WL (n=11)
Maltby et al [13]	Aviophobia	Controlled	5	50 min	6 months	VRET (n=20); EGT[e] (n=23)
Moldovan and David [20]	Multiple	Controlled	1	60 min	None	VRET (n=16); WL (n=16)
Muhlberger et al [8]	Aviophobia	Controlled	1	180 min	None	VRET (n=15); RT[f] (n=13)
Rothbaum et al [21]	Acrophobia	Controlled	7	35-45 min	None	VRET (n=12); WL (n=8)
Rothbaum et al [22]	Acrophobia	Case	5	35-45 min	None	VRET (n=1)
Rothbaum et al [23]	Aviophobia	Case	6	35-45 min	1 month	VRET (n=1)
Rothbaum et al [24]	Aviophobia	Controlled	8	1 hour	6 months	VRET (n=15); IVE (n=15); WL (n=15)
Rothbaum et al [25]	Aviophobia	Controlled	8	1 hour	12 months	VRET (n=13); IVE (n=11)
Rothbaum et al [26]	Aviophobia	Controlled	8	N/A[g]	6 and 12 months	VRET (n=25); IVE (n=25); WL (n=25)
Shiban et al [27]	Arachnophobia	Controlled	2	N/A	None	MCE[h] VRET (n=15); SCE[i] VRET (n=15)
Whitney et al [28]	Acrophobia	Case	8	N/A	None	VRET+VPT[j] (n=1)

[a]VRET: virtual reality exposure therapy.

[b]IVE: in vivo exposure.

[c]WL: waiting list.

[d]Mean value.

[e]EGT: exposure group therapy.

[f]RT: relaxation therapy.

[g]N/A: not applicable.

[h]MCE: multiple context exposure.

[i]SCE: single context exposure.

[j]VPT: vestibular physical therapy.

Inclusion and Exclusion Criteria

For the initial 2419 studies collected, the following inclusion and exclusion criteria were implemented. Parameters were set to limit the studies only to those whose subject was on VR (n=217) and whose document type was either an article or a case study (n=203). Studies that did not perform an experiment using an HMD for treating or examining a specific phobia or anxiety were excluded (n=177) as were other systematic reviews or meta-analyses (n=3). HMDs were chosen as the VR system of choice for this review as the systems were the most accessible compared with CAVE and simulator-type systems, alongside the notion that the most prominent modern VR systems are HMDs. In total, 23 eligible studies met the inclusion criteria.

Another search was conducted based on the references detailed in each of the initial 23 eligible studies. Inclusion criteria for this search were that the reference title must have mentioned "virtual reality" alongside terms related to fear, anxiety, or a specific phobia, as well as having explicitly used an HMD within the study itself. A total of 27 additional studies were collected through these criteria, although 1 study appeared to have been published twice in 2 years with some minor differences; therefore, the most recent version of that study was kept [15], whereas the older version was excluded [16], resulting in only 26 additional studies. In total, 49 studies were examined for this review.

Information found in Figure 1 exhibits the process in which the studies in this review were obtained based on the inclusion criteria as well as the number of studies excluded based on the initial exclusion criteria.

Studies were also placed into 1 of the 5 categories for the purposes of this review: phobia treatments (see Table 1), PTSD treatments (see Table 2), anxiety treatments (see Table 3), paranoia evaluation (see Table 4), and innovations and evaluation (see Table 5).

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Quality Assessment

Quality assessment of the collected studies was examined by both authors using the inclusion and exclusion criteria. The quality of each of the 49 studies was also appraised through the mixed methods appraisal tool (2011), which was designed to assess the methodological quality of quantitative (randomized, nonrandomized, and descriptive), qualitative, and mixed-methods studies used within systematic reviews [60].

Table 2. Posttraumatic stress disorder and acute stress disorder treatments.

Author	Study type	Trauma type	Follow-up	Interventions and patients, n
Gerardi et al [29]	Case	War	None	VRET[a] (n=1)
Cardenas-Lopez et al [30]	Uncontrolled	Assault	None	VRET (n=6)
McLay et al [31]	Controlled	War	None	VRET (n=10); TAU[b] (n=10)
Reger et al [32]	Uncontrolled	War	None	VRET (n=24)
Reger et al [33]	Controlled	War	3 and 6 months	VRET (n=54); IE[c] (n=54) ; MA[d] (n=54)
Cardenas Lopez and de la Rosa-Gomez [34]	Case	Assault	None	VRET (n=1)
Rothbaum et al [35]	Case	War	3 and 6 months	VRET (n=1)
Rothbaum et al [36]	Controlled	War	3, 6, and 12 months	VRET with D-cycloserine (n=53); VRET with alprazolam (n=50); VRET with placebo (n=53)

[a]VRET: virtual reality exposure therapy.

[b]TAU: treatment as usual.

[c]IE: imaginal exposure.

[d]MA: minimal attention.

Table 3. Anxiety treatments.

Author	Anxiety type	Study type	Sessions, n	Session length	Follow-up	Comparisons and patients, n
Alsina-Jurnet et al [37]	Performance	Uncontrolled	1	90 min	None	High test anxiety (n=11); Low test anxiety (n=10)
Anderson et al [38]	Social	Case study	6 to 10	Unknown	Unknown	VRET[a] (n=2)
Anderson et al [6]	Social	Controlled	8	Unknown	3 and 12 Months	VRET (n=25); EGT[b] (n=25); WL[c] (n=25)
Harris et al [39]	Social	Controlled	4	12-15 min/exposure	None	VRET (n=8); WL (n=6)
Padrino-Barrios et al [40]	Dental	Controlled	1	Unknown	Unknown	VR[d] exposure first half (n=15); VR exposure second half (n=15)
Repetto et al [41]	General	Controlled	8	Unknown	Unknown	VRET with biofeedback (n=9); VRET without biofeedback (n=8); WL (n=8)
Tanja-Dijkstra et al [42]	Dental	Controlled	1	Unknown	1 week	Active VR (n=22); Passive VR (n=23); No VR (n=24)
Wallach et al [43]	Social	Controlled	12	1 hour	None	VRET (n=28); CBT[e] (n=30); WL (n=30)

[a]VRET: virtual reality exposure therapy.

[b]EGT: exposure group therapy.

[c]WL: waiting list.

[d]VR: virtual reality.

[e]CBT: cognitive behavioral therapy.

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Table 4. Paranoia or paranoid ideations evaluation.

Author and population	Pateints, n	Age in years, mean (SD)	Analysis
Fornells-Ambrojo et al [44]			Qualitative
Early psychosis (clinical)	10	24.2 (2.3)	
Healthy (Nonclinical)	10	23.8 (2.3)	
Freeman et al [45]: Assaulted 1 month before	106	34.4 (11.6)	Quantitative
Freeman et al [46]: Local adult	200	37.5 (13.3)	Quantitative
Freeman et al [47]			Quantitative
Low nonclinical paranoia	30	44.2 (11.2)	
High nonclinical paranoia	30	36.0 (11.7)	
Persecutory delusions	30	44.2 (11.7)	

Table 5. Virtual reality evaluations and innovations.

Author	Disorder	Aim
Cornwell et al [48]	Social anxiety	Evaluating the relationship between trait social anxiety and startle reactivity
Geuss et al [49]	Acrophobia	Assessing perceptual estimates and actions of gaps within VR[a]
Hartanto et al [50]	Social anxiety	Evaluating the efficacy of various social stressors within VR
Orman [51]	Performance anxiety	Assessing effects of VR exposure on performing musicians
Owens and Beidel [52]	Social anxiety	Evaluating the efficacy of VR stimuli for social anxiety VRET[b]
Park et al [53]	Social anxiety	Assess the virtual interactions of patients with schizophrenia with digital avatars
Pertaub et al [15]	Public speaking anxiety	Evaluate participant responses toward positive, negative, and static virtual audiences
Powers et al [54]	Social anxiety	Evaluate a VR-based interactive dialogue system to elicit the same level of fear from an in vivo conversation
Price et al [55]	Social phobia	Evaluate the importance of presence within VR as a predictor of treatment response for social anxiety VRET
Qu et al [56]	Social phobia	Evaluate the influence of virtual bystanders on the participant's self-efficacy, anxiety, social evaluation, vicarious experience, and cognitive consistency
Regenbrecht et al [57]	Acrophobia	Assessing the relationship between presence and fear of heights within VR
Slater et al [58]	Social anxiety	Assessing the efficacy of low-fidelity VR on social anxiety VRET
Veling et al [59]	Social anxiety	Evaluate the effects of childhood trauma on social stress reactivity and psychopathology within VR

[a]VR: virtual reality.

[b]VRET: virtual reality exposure theory.

Results

Quality Assessment Outcomes

The 49 studies received an average rating of 86.73% and a modal rating of 100% (n=30). A total of 10 studies were classified as qualitative, 21 studies as quantitative randomized, 15 studies as quantitative nonrandomized, and 3 studies as quantitative descriptive based on the parameters set by the mixed methods appraisal tool [60].

Summary of Papers

Specific Phobias

The implementation of VRET for the treatment of specific phobias typically mirrors traditional phobia treatment protocols; treatment rationale was explained upon or before the patient's arrival, information-gathering procedures were used to assess the patient's phobic level, and a stimulus hierarchy would be established based on the information gathered. Levels of the stimulus hierarchy would vary based on the phobia being treated but generally would incorporate a new level or factors as the patient progresses. For example, acrophobia patients undergoing VRET would often progress through greater heights [19,21,22], whereas aviophobia patients would experience the next stage of a flight (eg, stationary and take-off) [8,23,24,26]. In short, regardless of the research methodology used or the specific phobia examined, treatment procedures were consistent across the 16 specific phobia studies.

A few studies compared the efficacy of VRET with that of a pre-established treatment including standard IVE [18,19,24], relaxation therapy [8], or exposure group therapy [13]. In 1

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study comparing treatment outcomes of VRET, IVE, and a waiting list condition for participants with agoraphobia, no significant differences were observed at the posttreatment and 12-month follow-up assessments between those that underwent VRET or IVE, but both groups did demonstrate significant improvements over those in the waiting list condition [18]. The comparison for VRET and relaxation therapy yielded similar results; however, it was found that although VRET was more effective in reducing flying avoidance in participants, it was only marginally better at reducing the participants' fear of flying ratings compared with relaxation therapy [8]. Finally, in a comparison of VRET and exposure group therapy, more VRET participants experienced clinically significant change compared with exposure group therapy participants based on posttreatment assessments, but the significant difference disappeared between the 2 groups during the 6-month follow-up [13].

Posttraumatic Stress Disorder and Acute Stress Disorder

Studies investigating the efficacy of VRET on PTSD and ASD typically focused on patients who developed the disorder due to wartime combat or physical assault. Initial sessions followed the same format and components as the ones used for specific phobias, but VRET sessions were more personalized for each patient. For example, veterans were given a virtual environment that matched the war environment that they had participated in, which included a jungle for the Vietnam War [35] and a desert city for Middle Eastern wars [29,31-33,36]; victims of physical abuse unrelated to war were placed in an urban environment [30,34].

A comparison of VRET, IE, and waiting list conditions found that, although VRET and IE both led to significant improvements in PTSD symptoms compared with the waiting list, IE was superior based on the Clinician-Administered PTSD Scale (CAPS), a structured interview performed by the clinician to gauge the severity of PTSD-related symptoms [61]. Follow-up assessments conducted at 3 and 6 months also indicated that those who underwent IE experienced continual improvement, whereas those who underwent VRET did not [33].

Another study sought to compare VRET with a treatment-as-usual condition, which consisted of patients performing their pre-established treatments, which included or was a combination of prolonged exposure, eye movement desensitization and reprocessing, and group therapy. A posttreatment assessment using CAPS indicated that 70% (7/10) of patients that underwent VRET showed at least a 30% improvement, whereas only 11% (1/9) of treatment-as-usual patients showed the same level of improvement. Although this difference was deemed as significant, the authors noted that a small sample size and wide variability in the treatment-as-usual condition limited the interpretations of the study's outcomes [31].

Finally, 1 study investigated whether augmenting VRET with D-cycloserine, a glutamate receptor that had been demonstrated to improve the efficacy of exposure therapy for severe anxiety disorders, would also benefit VRET. All participants in the study underwent VRET but were given D-cycloserine, alprazolam (used primarily as a pharmacological treatment for anxiety), or a placebo pill. The study reported no significant differences in treatment outcomes for any of the groups based on CAPS scores; however, participants who were dosed with D-cycloserine experienced significant extinction learning that was not observed in the alprazolam and placebo groups, suggesting that the use of D-cycloserine helped to enhance learning effects during VRET [36].

Anxiety

Studies that focused on general or specific (social, public speaking, dental, or test) anxiety utilized VR as a method to deliver VRET or VR distraction interventions. Although VRET for general and specific anxiety largely mirrored the same procedural format as the VRET done for specific phobias, PTSD, and ASD, VR distraction was used to comfort patients during a dental procedure. Although VRET aims to address problematic behaviors and cognitions by exposing patients to a virtual simulation, VR distraction serves to give patients a more positive experience during an otherwise anxiety-inducing situation [40].

A comparison was conducted for the efficacy of VRET to CBT and waiting list conditions for the treatment of public speaking anxiety, and findings were largely concurrent with the specific phobia studies; both treatment groups experienced significant improvements over the waiting list, but did not significantly differ with each other based on posttreatment assessments [43]. A similar finding was reported when VRET was compared with EGT as an intervention for public-speaking anxiety across posttreatment, 3-month, and 12-month follow-up assessments; however, the study had a small sample size that limited the findings [6].

A study that evaluated VRET for the treatment of general anxiety disorder incorporated biofeedback and a mobile, rather than a computer-based, VR system. The virtual environments for the biofeedback group, which depicted various scenes associated with relaxation, could change based on the patient's heart rate and physiological activation; a reduction in either results in a reduced intensity for certain stimuli within the virtual environment. Virtual environments for the VRET without biofeedback and waiting list groups experienced the same scenes but without the additional biofeedback features. Those who were in the biofeedback group were reported to have a significant decrease in behavioral avoidance and state anxiety, whereas the VR without biofeedback group only experienced a significant decrease in behavioral avoidance, and the waiting list group experienced no significant changes [41].

VR distraction was utilized for both dental anxiety studies in this review, which were conducted during either a simulated [40] or live [42] procedure. The stimulated dental procedure study compared active VR, passive VR, and no VR; those in the active VR condition could freely navigate around the virtual environment, whereas those in the passive VR condition could not. Those with higher levels of dental anxiety in both the active and passive VR conditions were reported to have less vivid memories of the procedure compared with those that completed the procedure without VR [40]. Similar findings were reported for the live procedure study in which an oral prophylaxis (teeth cleaning) was performed. Participants were randomly assigned to 1 group that received VR distraction during the first half of the procedure and another group that received the VR distraction

during the second half. Participants in both groups experienced significantly greater calmness during the portion of the procedure when they received VR distraction compared with the portion when they did not [42].

Paranoia or Paranoid Ideations

The process of diagnosing paranoia has been difficult to do in real settings, as therapists must be able to discern whether an individual's claims are legitimate or based on true paranoid beliefs. Through the use of VR, the diagnostic process for paranoia can be more reliable as the therapist has more control over the virtual stimuli, environment, and situational factors; avatars in the virtual environment cannot physically harm nor be harmed by the patient, and paranoid beliefs that surface during VR exposure can be verified [47]. As there were not a lot of studies dedicated to this topic, each study employed the same task within the same virtual environment: participants rode a London Underground train for a few minutes surrounded by avatars with neutral expressions and mannerisms.

In 1 study, individuals were found to be twice as likely to experience some form of persecutory thoughts during VR exposure if they reported paranoid ideations in day-to-day life [46]. This finding provided support toward the notion that neutral avatars were capable of eliciting paranoid thoughts, which was further confirmed in another study that compared the reactions of individuals belonging to clinical paranoia, high nonclinical paranoia, and low nonclinical paranoia groups [47].

Innovations and Evaluations

Although previous sections covered how VR has been used to treat or study certain anxiety-based disorders, it is worth noting the studies that have sought to either study VR-specific features or create innovative programs to enhance VR-based treatment. For example, an interactive dialogue system for a study on social anxiety was developed to elicit fear responses during VR exposure to match the fear response levels observed in in vivo conversations. Although the study reported that participants believed in vivo conversations were more realistic than the ones held in VR, fear ratings were found to be significantly higher for VR conversations than for in vivo ones. Although realism is an important factor, the authors considered that fear was a more important factor in the context of treating symptoms of social anxiety [54].

Another study sought to use dynamic social dialogue systems to manipulate the participant's feelings of anxiety in real time and effectively demonstrated that different ratios of positive and negative responses could serve as effective anxiety stressors to manipulate the participant's anxiety level in any direction (low to high) at any time [50]. Other studies aimed to evaluate changes in audience behaviors and other social stressors (eg, number of avatars present and ethnic diversity) and demonstrated similar levels of efficacy in manipulating the patient's anxiety levels [52,59].

Several studies were also conducted to evaluate whether VR stimuli were capable of eliciting real emotions, a crucial factor for the treatment and assessment of specific phobias and other anxiety disorders. There are some mixed findings; although a study on acrophobia found evidence that participants experienced real fear when exposed to a virtual cliff [57], a study on woodwind performance anxiety found inconsistencies in subjective anxiety ratings during a performance in a virtual concert hall [51]. For the latter, the authors speculated that an increase in heart rate during VR exposure may have been due to the nature of performing on a wind instrument rather than due to the VR exposure, and the inconsistent subjective anxiety ratings could have been due to performers finding the act of performing to be psychologically calming rather than anxiety-inducing.

Discussion

Principal Findings

In relation to VRET, there appears to be an overwhelming amount of positive evidence that the VR-based treatment has an equal or greater efficacy toward the treatment of specific phobias and anxiety, but not as much for PTSD and ASD. This evidence comes from a mix of experimental designs, including case studies, controlled randomized trials, and within-group designs, with some studies also offering follow-up results as evidence of VRET's effects beyond posttreatment. Although the use of VRET for PTSD and ASD was effective, it appeared that some patients seemed to gain continual improvement when treated with another treatment option such as IE [33]. Regardless, those who underwent VRET consistently showed significant improvement over those in the waiting list groups in the specific phobia, specific anxiety, and PTSD and ASD studies that compared the 2 together.

The use of VR to aid in the diagnosis of paranoia was also largely shown to be effective and was further reinforced due to every study related to the topic in this review using the same procedures and virtual environment to study or differentiate between individuals with varying levels of paranoia. Although VR was not used as a treatment tool for paranoia, it does provide a safe environment for the patient while simultaneously giving therapists and researchers a way to accurately identify any paranoid ideations that may arise due to VR exposure.

Finally, there have been many innovations to bolster the user's sense of immersion, or the feeling of being present, within an environment afforded by VR technology, at least for programs focused on treating social anxiety disorders. These innovations were largely focused on making VR avatars more realistic and sociable, ranging from increasing the realism of a person-to-avatar conversation to the manipulative behaviors of multiple avatars that comprise a virtual audience. In general, these innovations achieved their purpose by eliciting a greater amount of fear within the participant [54] or providing a dynamic manipulation of participant anxiety levels [50,52,59]. As for the evaluation of VR elements, simply recreating an object that the participant fears, such as a virtual cliff for those with acrophobia [57], is enough to generate real fear, although testing VR's efficacy on some tasks, such as performing on a woodwind instrument [51], may prove to be difficult due to the nature of the task itself and how it may conflict with common psychological or biometric measures.

Limitations

Although a large number of studies were included in this review, some topics appeared to be more researched than others, thus providing varying levels of quality and quantity. In particular, there were a small number of studies dedicated to paranoia, and although every study included in this review related to paranoia utilized the same virtual environments and procedures, the results may have been strengthened with more variety in the types of virtual environments used beyond the London Underground.

This issue also persists for the specific anxiety and PTSD and ASD studies in this review, where there was 1 clear subject that dominated, whereas there were only a few studies that ventured beyond what was commonly researched. For specific anxiety, there were more studies focused on social or public speaking anxiety, with only a couple of studies focused on dental anxiety, and the PTSD and ASD studies largely focused on war-induced trauma rather than physical assault–induced trauma.

Future Research

The landscape of modern VR has changed drastically compared with the VR systems used in most of the studies included in this review. Although legacy VR systems were expensive, required users to receive special training to operate or create VR programs, and were limited to facilities that could invest in the technology, modern VR has provided cheaper entry points, a vast library accessible through popular digital storefronts such as Steam or Google Play and Apple App Store, and user-friendly experiences. Although the most powerful VR systems available today are mostly geared toward gaming, the same systems can provide some use toward the study, diagnosis, or treatment of various anxiety-based disorders.

One area of research that would be worth pursuing is a self-directed rendition of VRET that can be done within a patient's home with little to no therapist interaction. As there is an overwhelming amount of positive evidence toward the efficacy of VRET, at least in relation to specific phobias and anxieties, the next step toward evolving VRET may be to evaluate whether those with mild to moderate anxiety-based systems may benefit from merely exposing themselves to anxiety-inducing stimuli within a virtual environment. Self-directed interventions provide patients with care in areas with limited to no access to therapists as well as to those who may be reluctant to see a therapist [62]. By utilizing a self-directed approach to VRET, it may be possible to allow individuals with low anxiety severity to treat themselves at their own pace, within their own home, and without the need for a therapist.

Conclusions

This review evaluated a variety of topics related to the use of VR for anxiety-based disorders, including VRET for specific phobias, specific anxieties, PTSD and ASD, and paranoia, while also outlining various innovations and evaluations conducted by studies to either improve the experiences afforded by VR or investigate the various factors that contribute to its efficacy toward anxiety-based treatments. These studies provided generally positive evidence toward the diagnostic and treatment capabilities of VR for anxiety-based disorders; however, research into VR has generally been limited to institutions that had the resources to invest in it. With the advent of more affordable, user-friendly, and supported commercial VR systems, more VR research can finally be done by building on the foundation laid out by the early studies to both replicate past findings and establish new uses for VR within psychotherapy.

Conflicts of Interest

None declared.

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Abbreviations

ASD: acute stress disorder
CBT: cognitive behavioral therapy
CAPS: Clinician-Administered PTSD Scale
EGT: exposure group therapy
HMD: head-mounted display
IE: imaginal exposure
IVE: in vivo exposure
MA: minimal attention
MCE: multiple context exposure
PTSD: posttraumatic stress disorder
RT: relaxation therapy
SCE: single context exposure
TAU: treatment as usual
VPT: vestibular physical therapy
VR: virtual reality
VRET: virtual reality exposure therapy
WL: waiting list

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<u>Original Paper</u>

Developing Digital Games to Address Airway Clearance Therapy in Children With Cystic Fibrosis: Participatory Design Process

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Abstract

Background: Children affected with cystic fibrosis do respiratory exercises to release the mucus stuck in their lungs.

Objective: The objective of our study was to develop prototypes of digital games that use breath pressure to make this daily physiotherapy more fun.

Methods: We used a participatory design approach and organized short events to invite contributors from different disciplines to develop game prototypes. From the 6 prototypes, 3 were tested by 10 children during a prestudy. The source code of the games, of which 2 continue to be developed, has been released on the internet under fair use licenses.

Results: We discuss 7 themes of importance in designing games for health, combining our experience with a review a posteriori of literature.

Conclusions: This study provides examples of games and their pitfalls as well as recommendations to create games for health in a participatory approach that enables everyone to improve and adapt the work done.

Introduction

Burden and Treatment of Cystic Fibrosis

Cystic fibrosis (CF) is a chronic disease estimated to affect 70,000-100,000 people worldwide [1]. Although advances in therapeutic care may now provide a life expectancy of >40 years [2], respiratory diseases still represent the main cause of morbidity and mortality [3]. The expectoration of airways' surface bacteria is normally assured by a layer of slippery mucus produced by the lungs' epithelial cells. Because the mucus is thick and viscous in patients with CF, mucus and bacteria accumulate, which results in the obstruction, infection, and inflammation of the airways. Therefore, reducing the progression of respiratory diseases is of the utmost importance to prevent early death in patients with CF [4].

Airway clearance techniques, such as positive expiratory pressure (PEP) physiotherapy, have been highlighted as effective means to diminish an airway's obstruction, infection, inflammation [5], and subsequently reduce pulmonary exacerbation [6]. By expiring through a tube that limits the flow of air, the device forces to make longer expirations, which help in keeping the airways open and removing the mucus stuck in the airways [7]. However, the burden of the treatment regimen with regard to CF has been highlighted numerous times [8], especially for children [9]. PEP physiotherapy presents the most time-consuming activity in the treatment, and poor adherence to this therapy is reported in almost half of the children affected with CF [10,11].

The Use of Digital Games to Increase the Treatment Adherence

Transforming the respiratory therapy into a digital game has shown promising results in increasing adherence [12,13]. Digital games are artificial systems in which players interact, which comprise conflict, rules, and quantifiable outcomes [14]. Games for health is an emerging field of "serious gaming," that is, playing with a purpose beyond entertainment [15]. Games for health have shown promising results in increasing knowledge, delivering persuasive messages, modifying behaviors, and improving health outcomes [16,17]. Advantages of such games over other therapeutic methods appear in our practice, including the following: making respiratory therapy fun through storytelling and interaction; altering time perception through immersive experience; making the long-term impact of daily therapy visible; developing and validating knowledge through learning sequences and game levels; fostering a constructive mindset through meaningful quests and collaborative gameplay; and collecting data on a regular basis about the effectiveness of the therapy.

However, Baranowski et al [16] emphasized that games for health should be much more engaging than the ones currently available to be truly effective. They recommend involving multidisciplinary stakeholders in all development phases to ensure the usability, desirability, and feasibility of games. Involving children affected could help them take ownership of their care by designing levels and gameplays to make their treatment fun.

This paper presents an overview of the participatory design process [18] used in the development of 6 games aimed at increasing the adherence to PEP therapy. The games were based on the traditional PEP therapy technique, in which an electronic pressure sensor was added to the PEP mouthpiece, transforming breath to a digital signal used to control the game character. In addition, this study will briefly describe each game that was developed and present the pilot evaluation we used. Because the development process of games for health and discussion of failures in their design are rarely documented [19], we will conclude by summarizing the challenges we faced and by stating what we learned, so that it might help researchers and practitioners avoid the same pitfalls.

Methods

Participatory Design Process

The project started in January 2014 between 2 game design students and the CF pediatric team at Sainte-Justine Hospital (Montreal, Canada). The clinicians were looking for a novel way to make respiratory therapy more engaging for their young patients. An initial environment scan and literature review targeting CF games showed us only a few games (*AstroPEP*, *CFpal*, *Creep Frounter*, *Flower for all*, *KIbreath*, *LudiCross*, and *MyCarnival* [12,20]), which were all very basic games and were not available to the public. Discussions enabled the students to understand the PEP exercise to build the game (Figure 1). Furthermore, an electronic pressure sensor that was developed previously was used so that breath could act as an input for the game (Figure 2) [21]. The project was then named "Breathing Games" [22].

Initial Developments

It took up about 800 hours to develop the 3 initial prototypes—*Globule*, *Ange-Gardien*, and *PEP Hero*. The key elements of the games were defined (Figure 3), including goals, gameplay, levels, obstacles, mechanics, game flow, visual universe, story, and character. The aim was to experiment with different game mechanics to test with children. *Globule* was designed as a simple puzzle, which could easily include a level editor so that children could create their own levels. *Ange-Gardien* was conceived as a tower defense, where children could manage different resources with an increasing level of difficulty. *Celebrations* was designed as a contemplative game, which inspired from open worlds, where children could explore different spaces without a defined goal. In *Globule*, the breath exercise served to collect elements that could be used in the game; in *Ange-Gardien*, breath activated towers that would kill enemies; in *Celebrations*, it gave energy to the character so that it may move. *Globule* and *Ange-Gardien* were developed part time between January and April 2014 by 2 game design and 2 sound design students. *Celebrations* was abandoned because of the resources required to develop a multiplayer game.

In February 2014, the team took part in a 3-day cocreation event (hackathon) organized at Sainte-Justine. The team presented the project, and 5 young professionals with skills in visual arts, user experience, electronics, and communications joined. The team then created *PEP Hero*, a side-scrolling game. One participant worked on the user interface, another on the visuals, 3 on the design and coding, 2 on communications, and one on the electronics.

Our approach to developing the games was pragmatic; we designed the games and the CF team was available for advice. We developed the prototypes in cycles according to the value created for the end user (agile method, Figure 4). All contributions were made without funding. We used the broadly used game engine Unity 3D, which, unfortunately, is not free (libre) and open source.

Figure 1. A graph of positive expiratory pressure exercise, own representation. Red lines, inspirations; green lines, holding; blue lines, expirations. Credit: breathinggames.net.
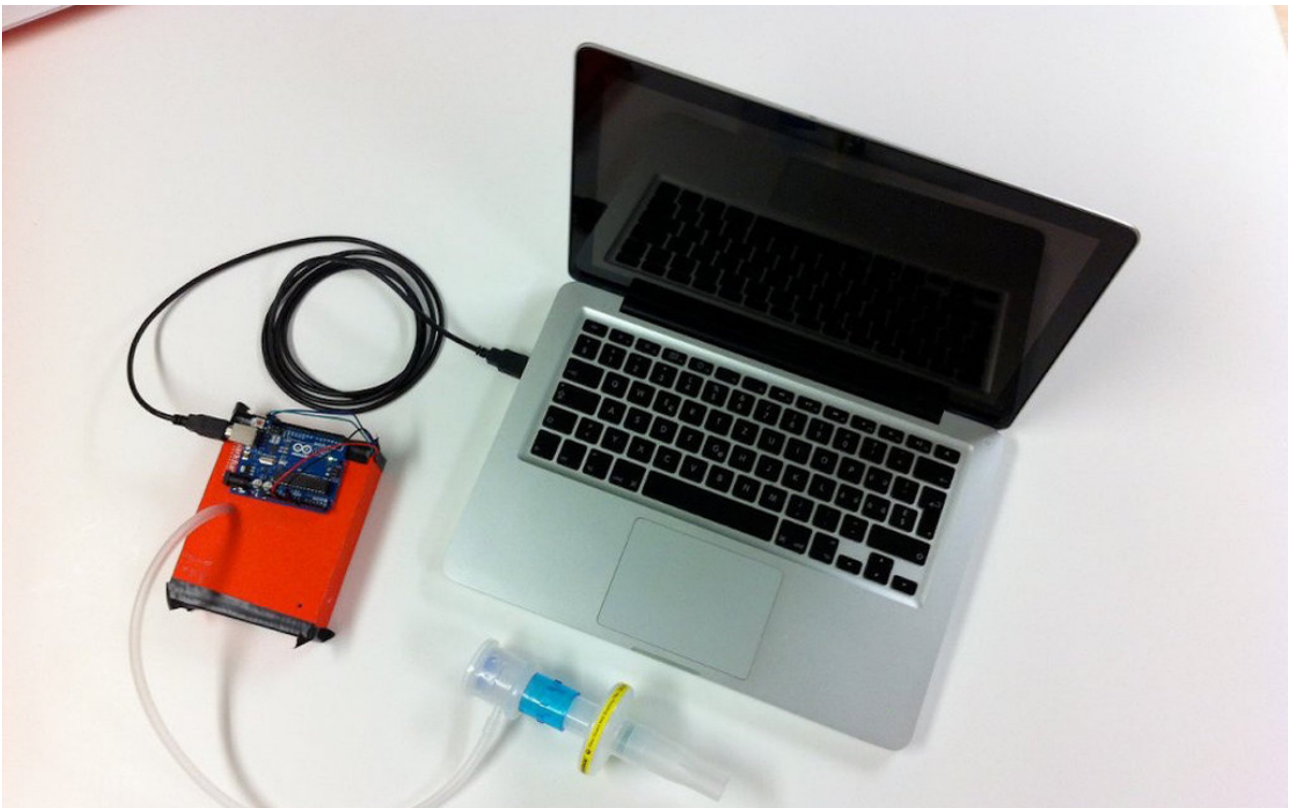
Figure 2. A device transforming expiratory breath into digital data through a pressure sensor. Credit: breathinggames.net.
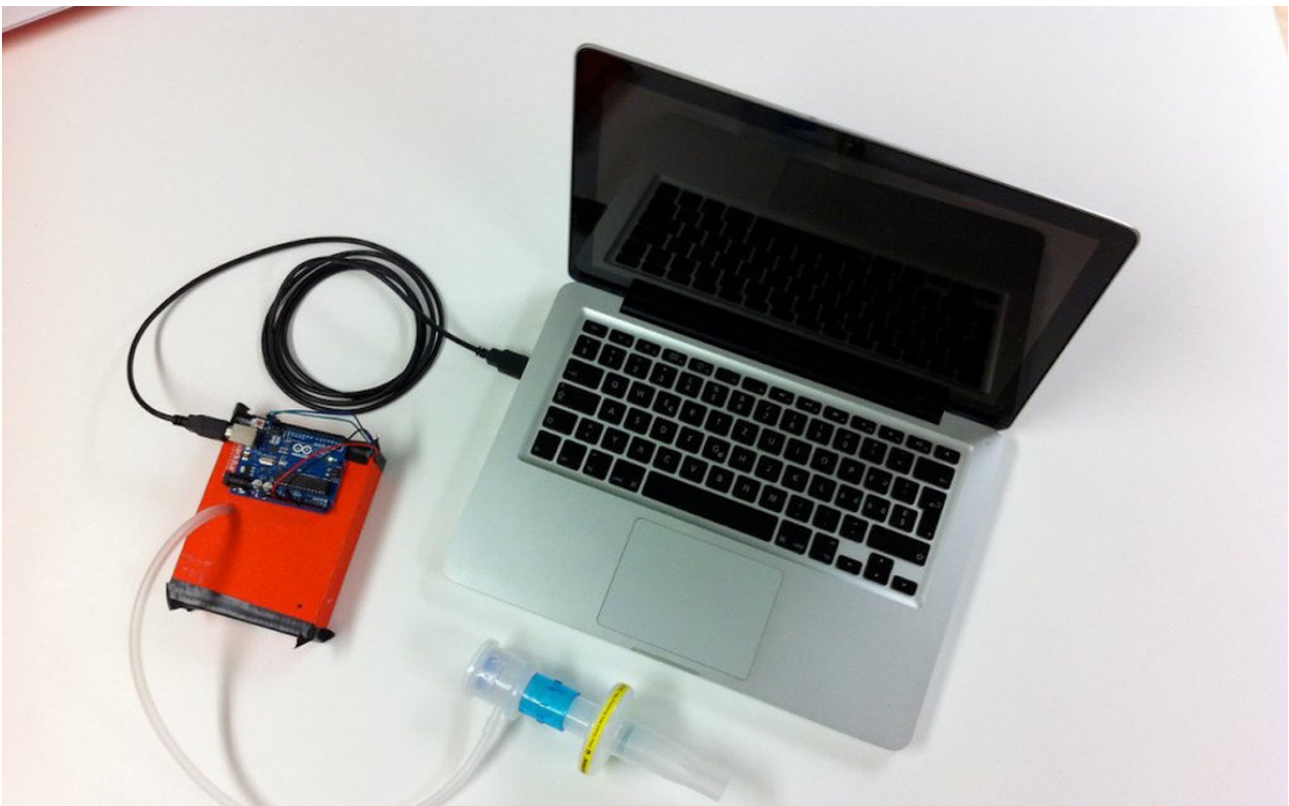
Figure 3. The document describing the key elements of the game Globule. Credit: breathinggames.net.

Figure 4. Agile participatory development of games. Credit: breathinggames.net.
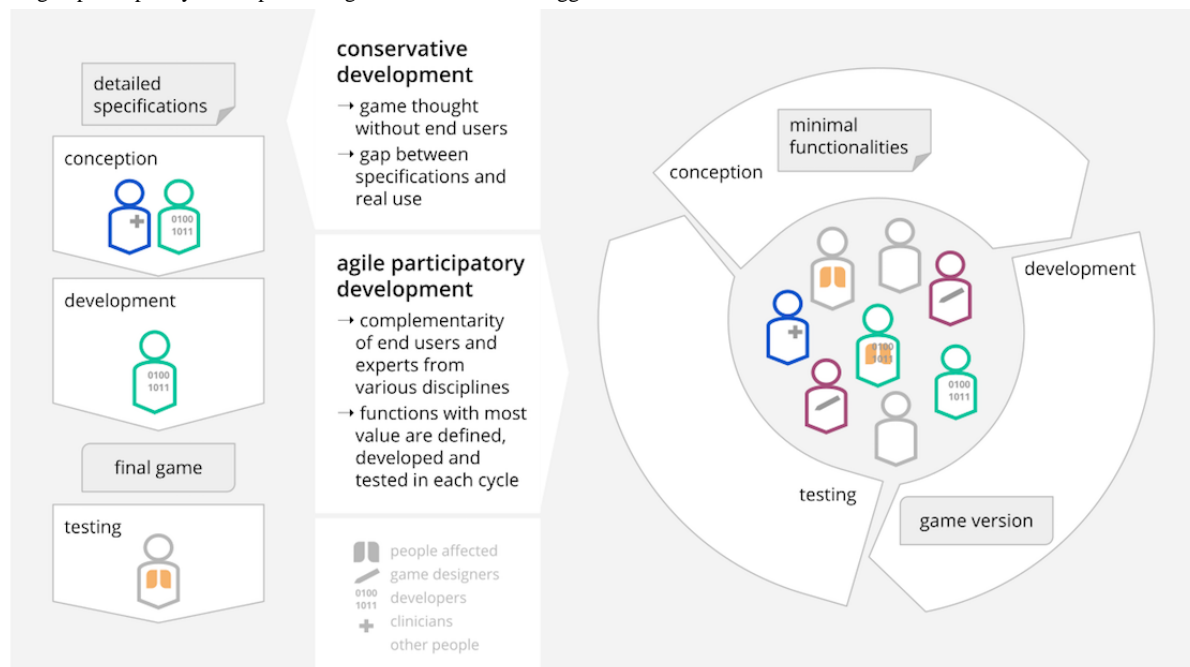
Beyond the iterative process, people from different disciplines, including game designers, software developers, visual artists, sound composers, electronics engineers, physiotherapists, and pulmonologists, were involved. Children affected were involved in testing, but we were not able to mobilize patients with CF and family community during the cocreation process. We hypothesize that this is because of the burden already related to CF care. Involving end users is however important to develop more effective games [17]. A critical reflection on the role of serious games was also done during this period [23].

Initial Tests

To test the prototypes, parents of children who had to come to the CF clinic for a visit were contacted by phone; those interested were invited to meet the game designers during their visit. Written consent was obtained from the 10 participants. Children aged 7-11 years answered a preliminary questionnaire, which focused on their play preferences (eg, favorite game, time spent playing daily) and design preferences (eg, favorite music to relax to, favorite designs for a spaceship). Children were then invited to play 2 or 3 games, each game having 1 or 2 levels. Each game was presented before they played. Children then answered the second questionnaire to evaluate each game (eg, difficulty of the game, integration of physiotherapy, what should be improved, favorite and worst moment in the game). The whole process required about 30 minutes with about 5 minutes of play. The prestudy was approved by the Sainte-Justine ethics panel (#3918).

In the first questionnaire, children answered questions on their access to various technologies—internet, laptop, computer, tablet, smartphone, and the Microsoft Kinect (often used in active video games on CF). They had started their treatment between ages 7 and 9 years and underwent it alone, accompanied, or both. When they did not want to do the treatment, they answered that it was because they had no time, they did not think about it, or because it was boring; 2 children said that they always did their therapy. They wanted to do the treatment for their health and their parents. In addition, children reported they played games for 5-60 minutes per day. Questions about preferences—favorite game, movie, book, hero, color, animal, relaxing music, the game they play the most, and the activity they like—resulted in very different answers. We had planned that such questions would help us customize the games. However, the children needed sample answers, and their proposals were often too diverse to inform us.

New Developments

It took over 1000 hours to develop 3 further prototype games: *Heritage*, *Bloïd*, and *Les aventures du Briand*. Building on the previous learning, we conceptualized *Heritage* in November 2014. The game was developed during 5 cocreation events by >20 contributors. In addition, 3 students in software development worked respectively on the breath input [24], the game design [25], and the creation of a game core [26]. *Heritage* included a settings panel so that the exercise could be adapted to practices of different countries. *Bloïd* and *Les aventures du Briand* were conceived during a game jam in March 2016 and continued at another game jam in February 2017 (Figure 5). These 3-day cocreation events were called jams to appear less technical and involved 15 contributors and collaborations with the University Hospital of Canton Vaud (CHUV), the Genevan Federation against CF (FGLM), and Lift Conference. In addition, a participatory design process similar to the one adopted for the prototypes was used. In these 3 games, the breathing exercise is fully integrated to the gameplay, and the breathing cycle is not represented as a chart.

New Tests

Heritage and *Bloïd* were tested informally during the game jams by a few children and adults, who gave a positive feedback. A mixed-methods study is being prepared to test these games. *Les aventures du Briand* requires further development before it can be tested.

Figure 5. Timeline of the game development. Credit: breathinggames.net.
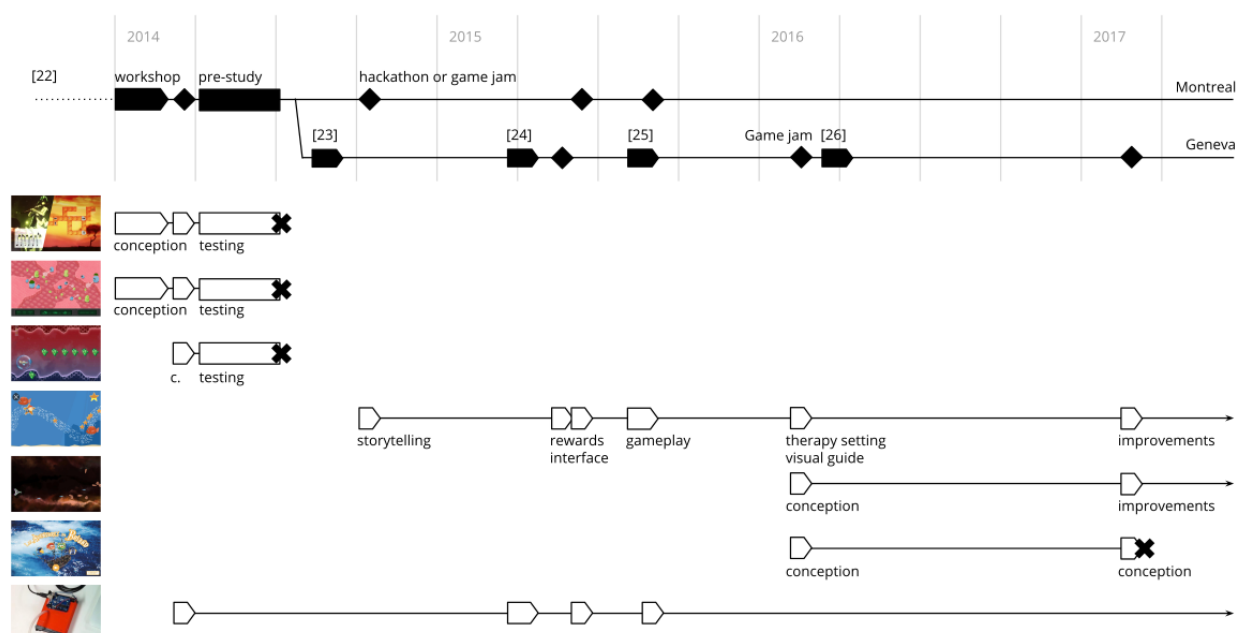
Results

Games Developed

Globule

Gameplay

Globule (Figures 6 and 7) is a puzzle game that uses an expiratory pressure device. The breathing exercise and the gameplay are separated to potentially add the breathing component to existing games. Each game level is composed of the following 3 phases: 1) children do their breathing exercise based on the therapeutic pattern; for each breath done with the right duration and pressure, children receive an arrow pointing north, south, east, or west; 2) children have a break to expectorate mucus; and 3) they play the puzzle by placing the arrows to direct the character toward a goal. Children are also able to select among 3 environments: the desert, the jungle, a futuristic universe.

Tests

Overall, 8 children tested the prototype [27]. After playing, most children found that the game was very fun, how to play was easy to remember, doing the therapy while playing was easy, and that the game was adapted to the treatment. All children liked to play with the arrows, path, and the level that was more difficult. One child did not understand the purpose of the game.

Regarding improvements, children proposed to add characters, have more time to set the arrows, add guitar music, correct the mistakes, correct the exhalation time, and connect it to the hardware (we had a problem with the pressure sensor in that individual test). In addition, children suggested we add levels, music, and more variety to make the game interesting over many weeks. Children mostly rated the game high; the first child testing the game gave a negative evaluation because the pace of the exercise was too fast, which was corrected.

Strengths

Based on our observations, children were able to perform the expiratory time and constant pressure required for the therapy, and get rewarded for their performance. The puzzles are easy to customize and construct (visuals for the squares, protagonist, and background), which could enable children to create and share their own maps. The minimalist story (collecting arrows to reach a goal) seemed to positively impact children.

Limits

The puzzle in itself has no connection to breathing. Parents mentioned that separating the breathing exercise and the game requires more time than the therapy alone, which they see as inadequate, given the time already required daily.

Status

The development of the game was discontinued due to the aforementioned limits.

Figure 6. The sketch of the game Globule. Credit: breathinggames.net.
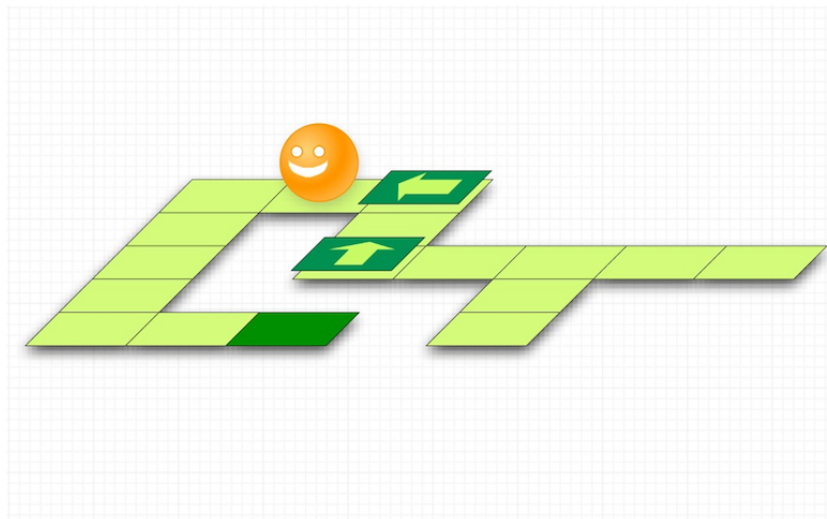
Figure 7. The visual of the game Globule: breathing exercise to collect arrows (left), and puzzle (right). Credit: breathinggames.net / F Moncomble.

Ange-Gardien

Gameplay

Ange-Gardien (Figures 8 and 9) is a strategy tower defense game that uses an expiratory pressure device. Here, the breathing exercise and the game are combined. Children defend the little guardian angel that fell from his shoulder after being kicked by the devil on the other shoulder. The devil wants to capture the angel before the child saves it. When the game starts, the child sees a map with different paths and places to build towers. The child receives a certain number of points to build different kinds of towers, representing wind, fire, and water. Then, enemies arrive on different paths. The child clicks the tower to activate, and breathes out to make that tower shoot at the enemies around. Each devil destroyed gives points. Each demon reaching the other side of the map reduces the number of lives of the angel. After 5 seconds, the towers deactivate, prompting the child to inspire. When the breathing cycle is done, no more enemies appear because children must do their expectorations. On the next level, towers can be built or upgraded using points. The game was developed and tested on the basis of geometric shapes; visuals were prepared but not integrated into the game.

Tests

Only 2 children tested the game because of delays in the development. After playing, children found that the game was very fun, remembering how to play was easy, doing the therapy while playing was easy, and that the game was adapted to the treatment.

Children liked to set the towers and the evolution of the scene. Regarding improvements, a child proposed to correct a bug in the gameplay. In addition, children suggested adding levels, colors and other visuals, towers, enemies to make the game interesting over many weeks. Children rated the game high on a scale from 10 (best) to 1 (worst).

Figure 8. A sketch of the game Ange-Gardien. Credit: breathinggames.net.

Figure 9. Visuals for the game Ange-Gardien. Credit: breathinggames.net / J Danger.

Strengths

The mechanics can evolve from very simple to complex strategic gameplay and breathing cycles can easily be related to different parts of the gameplay. The game can be adapted to multiple players and can also include input from the children's relatives.

Limits

Although this was not brought up by the testers, the angel devil may not be well perceived depending on religious beliefs. In one design, the enemies are represented as mucus; this created a discussion whether integrating elements of the disease in the game would support or discourage the children in their efforts.

Status

The development was discontinued because of major changes in the game engine. The gameplay should however be reused.

PEP Hero

Gameplay

PEP Hero (Figures 10 and 11) is a side-scrolling space shooter that uses an expiratory pressure device. The game simply adds a visual universe on the top of the therapeutic exercise. The child is the captain of a spaceship that goes up when breathing out and down when breathing in. By directing the vessel, the child is able to collect items. Afterwards, the child has a break to expectorate and can then start a new cycle. The game included various vessels and items to collect, but their selection was not functional during the tests.

In the first individual test, the green items were spread over the screen; this did not fit with the exercise because the child did not know when to breathe. The items were then aligned, which helped the child to have a continuing exhalation but did not show them when to breathe in. Thus, additional items were added for the inspiration phase, that helped the child adopt a regular breathing pace.

Figure 10. A visual of the game PEP Hero. Credit: breathinggames.net / K Berthiaume.
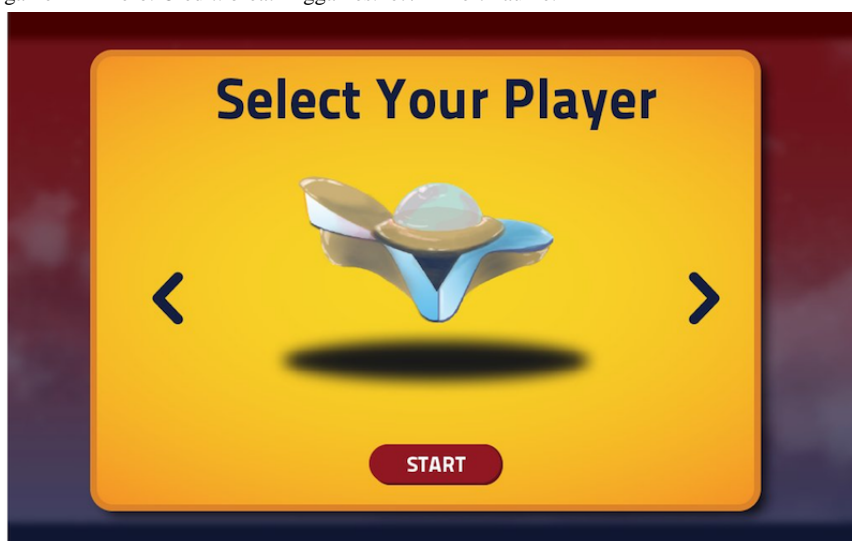
Figure 11. A visual universe of the game PEP Hero. Credit: breathinggames.net / K Berthiaume.
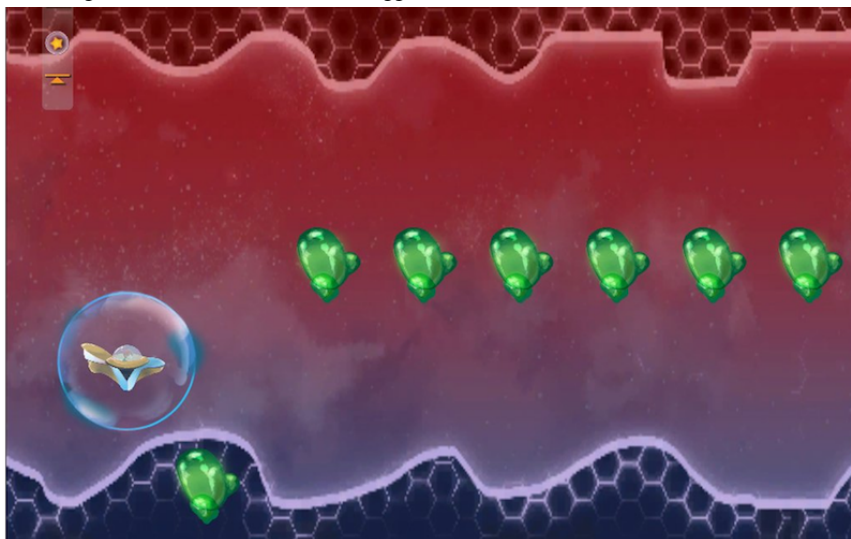
Tests

Overall, 8 children tested the game. After playing, most children found that the game was very fun, remembering how to play was easy, doing the therapy while playing was easy, and that the game was very adapted to the treatment.

Children liked everything, including the ending, the visuals, and the first level. Regarding improvements, children proposed to increase the duration of inhalations (corrected after the individual test) to make the first expected breathing visible and solve a bug. Children suggested to add other elements such as levels and colors to make the game interesting over many weeks. Children rated the game high on a scale from 10 (best) to 1 (worst).

Strengths

The strength of the study was that simple mechanics mimicked the breathing exercise with the advantage of giving direct feedback about the correct pressure and duration of breathing. Visuals can be easily adapted.

Limits

A long-term interest could be hard to ensure because the mechanics are very simple.

Status

The development was discontinued, as *Heritage* was created, developing further similar mechanics.

Heritage

Gameplay

Heritage (Figures 12 and 13) is a side-scrolling game using an expiratory pressure device, in which a child defends the cultures of different countries. For Greece, for example, the character has to catch a thief who has seized Poseidon's trident-fork. If he recovers it, the character must then find who stole Aphrodite's potion, Zeus' lightning, Gaia's seed bag, Hermes' shoes, and Athena's rouet to collect more points. In the end, the God of the Seas will then prepare the meal for the party with his trident-fork; Aphrodite will take care of the atmosphere; etc. During the journey, a child learns facts and figures about different countries.

Figure 12. A visual universe of the game Heritage: the setting of the exercise. Credit: breathinggames.net / N Wenk.

Figure 13. A visual universe of the game Heritage: breathing exercise. Credit: breathinggames.net / C Skrapits / N Wenk / J Danger.
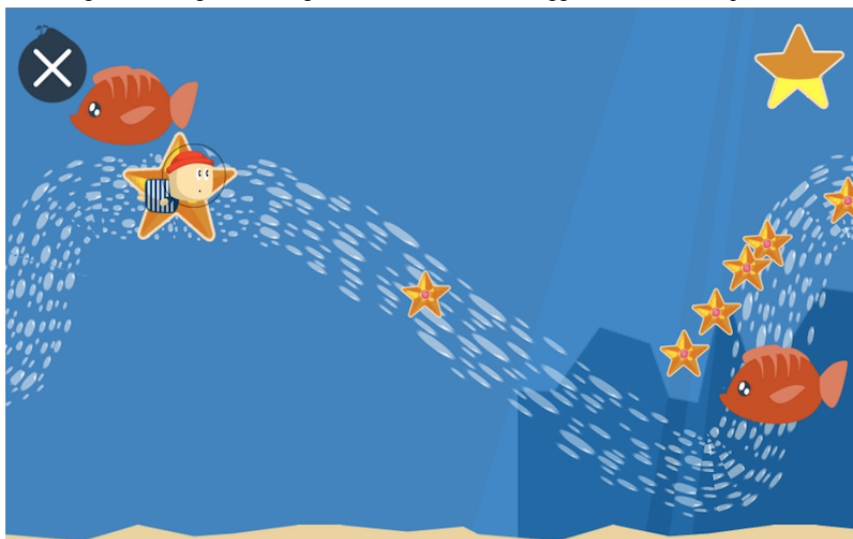
A table was created during a cocreation event to imagine different stages (daily exercise) with each stage having 6 levels (breathing cycles). For each level, cultural elements were defined. Peru, for example, was proposed by a participant who knew the country. For Peru, the background elements would be the sky, nonplayer supporting character would be the goddess *Pachamama*, the stolen object would be the earth, the transport means would be a condor, obstacles would be clouds, the asset would be an *unku* (piece of cloth). Graphic elements were created by different artists, who, while keeping the same line, always changed parts of already existing elements.

Bloïd

Gameplay

Bloïd (Figures 14 and 15) is a side-scrolling space shooter that uses an expiratory pressure device. In this game, a spaceship has to thwart the traps of an intergalactic journey to reach a mysterious planet mentioned in a prophecy. When the child breathes in, meteorites appear in front of the spaceship; when the child breathes out, projectiles are launched to destroy the meteorites. The keyboard is used to direct the ship. Over time, the number of meteorites that appear at each inspiration grows to encourage players to extend their expiration, slow down their pace, and develop their lung capacity; this enables them to gain a better score. The visuals were created to be realistic and favor immersive play.

Initially, the goal was to create a game similar to the previous ones based on the traditional CF exercise. The team of designers, developers, musicians, and patients found however that the proposed pattern was too limiting to create compelling gameplay that would really increase adhesion. Hence, they decided to create a more flexible exercise, in which breathing would be less constrained. *A posteriori*, the gameplay relates more to a heart rate variability exercise (cardiac coherence) that can help cope with stress.

Les Aventures du Briand

Gameplay

Les aventures du Briand (Figures 16 and 17) is an adventure game that uses an expiratory pressure device. In this game, a player is the captain of a ship, who has to breathe to solve challenges faced by the crew. The game is composed of different mini-challenges related to breathing exercises. Similar to *Bloïd*, the team that conceived the game wanted to break free from a strict breathing exercise and instead, opt for a more flexible pattern. The outcomes of the game need to be further researched on.

Figure 14. A visual of the game Bloïd: introductory explanations. Credit: breathinggames.net / A D-Pierson / K Piccand.

Figure 15. A visual of the game Bloïd: breathing exercise. Credit: breathinggames.net / A D-Pierson / K Piccand.
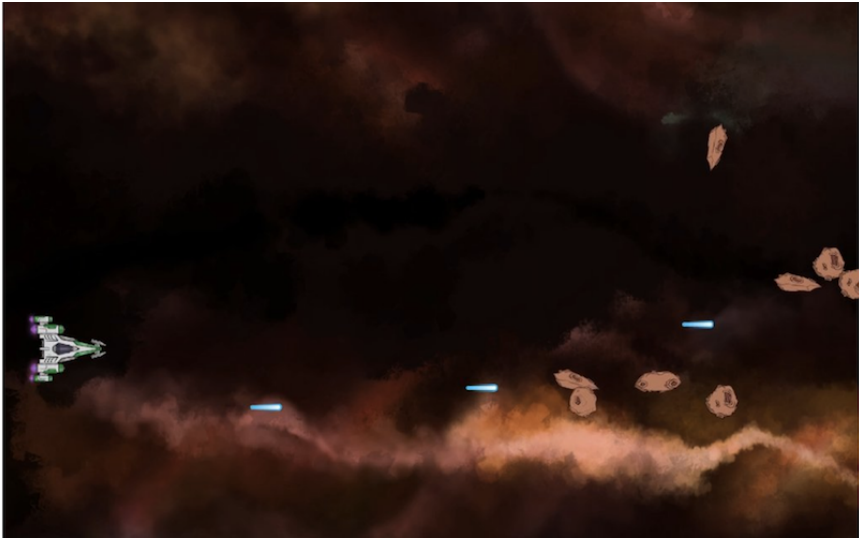
Figure 16. A visual of the game Les aventures du Briand: start screen. Credit: breathinggames.net / J Danger.

Figure 17. A visual of the game Bloïd: breathing challenge. Credit: breathinggames.net / J Danger / C Koker.
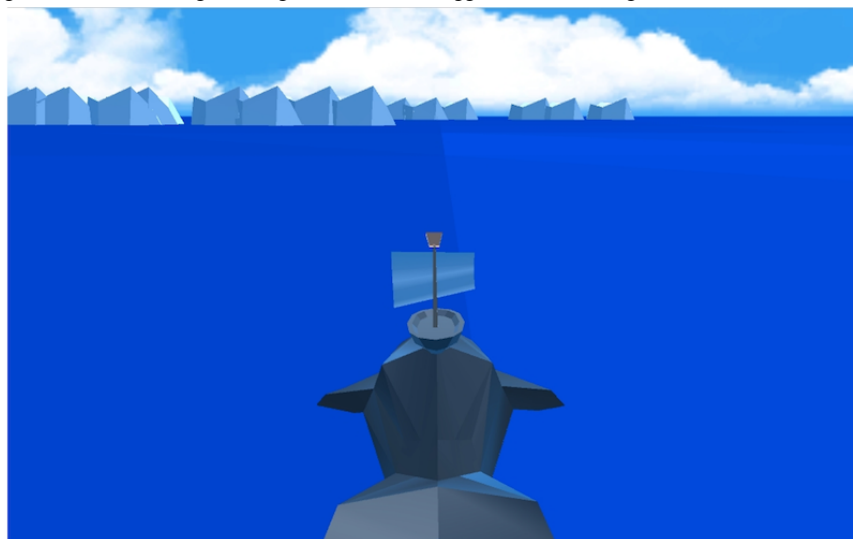
Discussion

Principal Findings

Our approach to developing these games was pragmatic; we applied our understanding of game design to achieve a goal defined in collaboration with clinicians. Although we collectively discussed and documented key elements of different games, we did not follow any specific methodology but built on our experience and intuition. In this section, we synthesize findings from publications collected around digital games conception. Building on this new body of knowledge, we highlight key elements and learnings in the field that we had realized beforehand. The 7 themes presented are based on recurring elements mentioned in the publications selected.

People Involved in the Creation

Literature Findings

Games for health are highly influenced by the team conceiving them—the diversity of backgrounds, their perspective of health (from the reductionist biomedical management of a disease to a holistic promotion of well-being), and the level of participation in decision making.

End users should be actively involved in the creation process—their input about their pleasure of playing, interests, ways of learning, and beliefs can help make the games more relevant [28]. Multidisciplinary teams can help them translate their ideas into design elements [29]. Experts, on the other hand, can help integrate health knowledge and broaden the narrative [30]. Medical care professionals can ease the interactions with the patients while keeping ethics in mind [31] but will often not be able to evaluate the game or its safety [32].

DeSmet et al [17] shared a participatory approach that seems more adapted to create narratives, characters, and other game elements than to develop gameplay.

Learning Outcomes From the Field

The involvement of young professionals in game design, software development, visual arts, and project management was essential to realize the prototypes. In addition, electronics engineers, communications specialists, and people in the free software community contributed to building the breathing sensor, increase our Web-based outreach, and sketch the sociolegal framework, respectively.

Despite collaborations with patient associations, we were able to mobilize only one CF family through all of our events. To address this gap, patients with CF have been recruited by our partner hospital for an upcoming event in France. The contribution of medical care professionals was particularly useful in setting the goals, mechanics, and content for the games, and to answer questions during the events. Owing to their status, they may, however, overshadow the experience and needs of patients and push the focus on managing the disease versus the promotion of health and well-being of a person overall in the long term. Bringing too much medical content may reduce the fun and impact of a game.

Cocreation Process

Literature Findings

When creating a game for health, designers can either copy a successful example of gameplay, integrating the medical content into the story, or conceive a game that embeds medical information into the gameplay. The first can help in memorizing information, whereas the second allows for targeting more complex learning needs [15].

Working in short cycles gives the ability to attain better results, value rapid learning, and fine-tune the existing work in a short period. Dow et al [33] stated that contributors working in cycles on a new task are as efficient as contributors working sequentially on a task they master.

Learning Outcomes From the Field

Given that the work evolved through events, the games were developed using an agile methodology: prototypes were designed and a minimal viable product was developed and further improved by prioritizing the functions to be added. Because the aim was to make a well-defined physiotherapeutic exercise more attractive, the team worked on how to create gameplay around it. In a less binding context, creating a story

and gameplays where health-related content can be easily embedded appears more appealing.

The immediate documentation of the work, including uploading the source code of the game, and of editable visual and sound elements is essential. The tools and the fair use licenses used are described in another paper [18].

One key learning outcome after hosting many health game jams is that such events are well adapted to raise awareness, foster collaboration, recruit long-term contributors, and create a multitude of prototypes to test different ideas. Because they are ephemeral, these events, however, do not allow the creation of high-quality games. Prototypes realized during game jams can, however, be redeveloped by a multidisciplinary team of professionals and tested during dedicated cocreation events.

Gameplay

Literature Findings

Sciart described gameplay as "a ludic experience regulated by game rules, mediated by game mechanics, and oriented to the satisfactory achievement of goals predetermined by the game and agreed upon by players." page 103 [34]. Gameplay can be separated into the rules of the game world (mechanics), a player's interaction with these rules (dynamics), and the emotional experience that emerges (affects) [15].

Orji et al [35] propose to either create a variety of gameplay ("competition and comparison, cooperation, customization, personalization, praise, self-monitoring and suggestion, simulation, and reward," page 473) that can mobilize different kinds of players ("achiever, conqueror, daredevil, mastermind, seeker, socializer, and survivor," page 473) or adopt the gameplay that better answers all players, possibly through comparison or self-monitoring. Indeed, gameplay can fill different kinds of needs—one player will like to explore, the other to compete, the third to socialize; one will like fast actions, another to solve problems, and a third one to build strategies. To help design the player experience, the following 6 elements can be checked: voluntary participation; a commitment toward a goal; a physical involvement; the creation of meaning; the perception of feelings; and the creation of social relations [36].

Learning Outcomes From the Field

The types of games (quiz, adventure, shooter, tower defense, etc) were considered for the prototypes rather than categories of players or experiences. Given the time required for the therapy, the games that separated the respiratory exercise from the gameplay were abandoned. Even basic gameplay and simple stories were positively perceived by children. For each game project, the teams focused on developing one level of the game with a polished visual, sometimes sounds and music, and an end screen. This, however, does not allow us to test the evolution of the gameplay and challenges throughout the games.

For future events, it appears more adequate to conceive many levels with placeholders (eg, colored shapes instead of designed elements) and to develop in parallel a database of visual and sound elements that can be used in the different levels or games.

Storytelling

Literature Findings

In games for health, narratives can help players develop skills, experiment with new situations and behaviors, and change their beliefs in regard to health. For children, fantasy and nonsensical elements can increase their involvement and fun and encourage them to develop their creativity [37]. Death and other sensitive subjects can be included when learning is provided [38]. Addressing situations that affect players and creating meaningful decisions allow them to reflect on their ideals and values and possibly learn about societal issues [38]. In addition, the game creators have to decide the extent to which the story can differ from the mainstream knowledge about health.

Sciart [34] recommends that the game evolves according to the not-too-obvious decisions players have to make, and that players should not be able to replay and change these decisions. Khaled et al [39], however, states that players often expect to replay to improve their experience. The number of choices should increase during the game as players strengthen their skills, and this also increases the game effectiveness [17].

Learning Outcomes From the Field

Although a story, and sometimes a sketchboard, was written for different games, it was only appearing through the visuals and not in the initial gameplay. While this can easily be added afterwards, for example, by cropping existing characters and creating a dialogue between them, it did not allow us to really test and improve the storytelling. For *Heritage*, the story was built for different levels, each building on a different culture. For other games, the story generally gave some context and the quest. A reflection on what meaningful decisions players can take would certainly improve the quality of these narratives. Furthermore, games could include time references (day or night, seasons, etc) to diversify the experience. An unsolved question is the impact of including elements related to CF (lung, mucus, etc) in the game.

Character and Customization

Literature Findings

For Khaled et al [39], developing the relation between players and their character impacts the immersion and appropriation of knowledge beyond the game. Being able to customize the character can help, even if it does not add much to the gameplay. The interaction sought by the designer should define a player's perspective; should they have a global vision of the world, should they be embodied, or both? Using nonhuman androgynous characters or fully customizable characters can help avoid stereotypes often seen in mainstream games. Guidelines to avoid marginalization, for example, providing an option to zoom, are available [40].

Learning Outcomes From the Field

The characters developed were nonstereotyped and included animals, aliens, angels, a starship, and some people. For *Heritage*, one idea was that players could collect and wear clothes from different cultures. No customization was implemented because of a lack of resources. Inviting visual

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artists to create a database of elements to customize the characters could be valuable.

Feedback and Rewards

Literature Findings

Players need not focus on how to play but to immerse themselves in the experience. Learning how to play should be easy and should not require a tutorial or explanation. Sufficient feedback should be provided but not so much that the players get distracted [40]. Health information should be of real use for patients, and additional information should be available on demand. Visual representations and colors should be valued [41]. Rewarding players with points, material, and other awards is useful as long as it creates meaning for players. Intrinsic motivation should be sought and encourage the feelings of autonomy, competence, and belonging. Feedback may be adapted to the social context of players too [42]. For Flanagan and Nissenbaum [43], the reward system explicitly highlights the values behind the game; it can value creativity, competition, exploration, social interactions, etc. For them, players should choose whether they want to compete.

Learning Outcomes From the Field

The visual representation of the breathing exercise was central in different games. Players received items when doing the exercise correctly, and a gauge showing the on-time breath was also visible in some games. Although the representation helps players know what is expected, it also limits the interest in the long term. *Bloïd* hid the exercise behind its gameplay—the breath in brought meteorites, breathing out allowed the player to shoot at them, and the number of meteorites grew over time to encourage a slow breath; this allowed us to create more immersion and shift the focus away from the medical element. *Les aventures du Briand* intended to have many mini-games whose results would impact the global quest.

For all games, the rewards were closely linked to the breathing exercise and were only positive: the team did not want to penalize a wrong exercise but encourage a good one. There was a discussion about creating 2 separate reward systems, one for the health-related part and another for the quest; however, this was not implemented. Better integrating these questions while defining the story and gameplay could help ensure more variety and meaning in the rewards.

Evaluation and Diffusion

Literature Findings

Games for health should be validated with research and also be easily accessible and foster reliable information, technical efficiency, data privacy, and ease of use. The regulation regarding medical devices is changing. The French Health Authority published best practices covering these issues [44] and the Food and Drug Administration is reviewing its process [45]. Health Canada recommends checking if regulation exists, especially when the software influences decisions on health [46]. Beyond best practices, a "Mobile Application Rating Scale" was developed by the Queensland University [47]. Graafland et al [48] created a specific tool to assess the didactic and interactive experience of games for health.

Learning Outcomes From the Field

Access to health innovation is essential. From the beginning of the initiative, the source code of the games was released online under a license that enables every interested person to use, reproduce, and improve them. In addition, efforts were made to document the cocreation process. As mentioned earlier, the games presented were not tested extensively, but a study is planned to evaluate *Heritage*, *Bloïd*, as well as other games to be developed around CF.

Conclusions

The participatory design of games for health is an excellent tool to bring together people and introduce them to multidisciplinary work. Recurring short events around the same topic enable participants to prototype and test a large variety of gameplay modes, get acquainted with and raise awareness on health issues, and find contributors ready to engage in the long term. Such events are, however, not adapted to build high-quality games.

From the 6 games prototyped, 3 were abandoned because of unsatisfactory choices in their design (separation between the breathing exercise and the game in *Globule*), technical issues (major changes in the game engine for *Ange-Gardien*), and a scope that was too ambitious (the team working on *Les aventures du Briand* spread before a functional version of the game with mini-games was ready). *PEP Hero* was rewritten as *Heritage* to allow the customization of the breathing exercises. *Bloïd* was improved with additional visuals. Both *Heritage* and *Bloïd* are going to be tested and further developed.

To create further games for health, the key learning outcomes (Figure 18) from the 7 themes addressed are to develop prototypes that show the gameplay for different game levels and to separately create a database of visual and sound assets that can be used throughout the game (customizable characters, universe, rewards, etc). Moreover, the story should encourage meaningful decision making, embed health information while not building the game around it, and foster autonomy and inclusion. As briefly mentioned, special attention should also be given to the evaluation and accessibility of the game, its source code, and its cocreation process so that a maximum number of persons can use and modify it.

Figure 18. Recommendations to design games for health. Credit: breathinggames.net.

Acknowledgments

Conflicts of Interest

The author cofounded and leads Breathing Games.

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Abbreviations

CF: cystic fibrosis
PEP: positive expiratory pressure

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Original Paper

Emotion-in-Motion, a Novel Approach for the Modification of Attentional Bias: An Experimental Proof-of-Concept Study

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Abstract

Background: Individuals with heightened anxiety vulnerability tend to preferentially attend to emotionally negative information, with evidence suggesting that this attentional bias makes a causal contribution to anxiety vulnerability. Recent years have seen an increase in the use of attentional bias modification (ABM) procedures to modify patterns of attentional bias; however, often this change in bias is not successfully achieved.

Objective: This study presents a novel ABM procedure, Emotion-in-Motion, requiring individuals to engage in patterns of attentional scanning and tracking within a gamified, complex, and dynamic environment. We aimed to examine the capacity of this novel procedure, as compared with the traditional probe-based ABM procedure, to produce a change in attentional bias and result in a change in anxiety vulnerability.

Methods: We administered either an attend-positive or attend-negative version of our novel ABM task or the conventional probe-based ABM task to undergraduate students (N=110). Subsequently, participants underwent an anagram stressor task, with state anxiety assessed before and following this stressor.

Results: Although the conventional ABM task failed to induce differential patterns of attentional bias or affect anxiety vulnerability, the Emotion-in-Motion training did induce a greater attentional bias to negative faces in the attend-negative training condition than in the attend-positive training condition (*P*=.003, Cohen *d*=0.87) and led to a greater increase in stressor-induced state anxiety faces in the attend-negative training condition than in the attend-positive training condition (*P*=.03, Cohen *d*=0.60).

Conclusions: Our novel, gamified Emotion-in-Motion ABM task appears more effective in modifying patterns of attentional bias and anxiety vulnerability. Candidate mechanisms contributing to these findings are discussed, including the increased stimulus complexity, dynamic nature of the stimulus presentation, and enriched performance feedback.

KEYWORDS

Introduction

Attentional Bias Modification in Anxiety

We operate in a complex and dynamic world in which we are continuously confronted with an ever-changing stream of perceptual information. The limited capacity of our cognitive system means we can only attend to certain information, while other information is filtered out. Such filtering does not operate in the same manner across all individuals; however, it has become clear that there is a relationship between such attentional selectivity and individual differences in emotional vulnerability [1]. Specifically, research has shown that elevated anxiety vulnerability, whether indicated by elevated levels of trait anxiety or the presence of anxiety pathology, is associated with an attentional bias that favors the processing of negative information [2]. Moreover, studies that have manipulated patterns of attentional bias (using attentional bias modification [ABM] procedures) have shown that attentional bias causally contributes to anxiety vulnerability, as a change in attentional bias produces a consequent change in anxiety vulnerability [3,4-6].

The observation that ABM tasks delivered in the laboratory can exert a beneficial impact on anxiety responses to stressor has led a number of researchers to investigate whether extended exposure to such ABM training can reduce anxiety dysfunction in real-world settings. The most frequently used ABM procedure is based on the dot-probe task [7]. In this task, participants are briefly exposed to stimulus pairs, comprising 1 negative and 1 non-negative stimulus, before a small visual probe is presented, which participants are required to identify. A contingency between the position of the probes and the position of the negative stimuli is introduced, whereby probes are either always presented in the location where the non-negative stimulus was just displayed (encouraging the adoption of an attentional bias away from negative information) or else probes are always presented in the location where the negative stimulus was just displayed (encouraging the adoption of an attentional bias toward negative information). There is now a substantial body of evidence showing that such ABM tasks, configured to reduce attentional bias to negative information, can attenuate the symptoms of social anxiety disorder [8,9], generalized anxiety disorder [10,11], and subclinical obsessive-compulsive symptoms [12].

Although such encouraging findings highlight the potential clinical benefits of ABM procedures, it is important to recognize that in a number of ABM studies, the intended attentional training procedure has failed to affect emotional vulnerability [13-16]. Overall, meta-analyses show that the clinical effectiveness of the implementation of ABM procedures is small but nonetheless significant [17-21]. However, careful consideration of this literature suggests a clear pattern. In the studies where the intended ABM procedure successfully changed attentional bias, this produced a medium-sized and significant effect on emotional vulnerability. In contrast, in studies where the intended ABM procedure did not change attentional bias, no significant impact on emotional vulnerability was observed [22-26]. These results indicate that future research efforts should

focus on developing more effective procedures than the dot-probe task to modify attentional bias [27-29]. Moreover, researchers have raised concerns about the suitability of the conventional probe-based training task for use with clinical cohorts because of its monotonous nature and low face validity [27].

Gamification of Attentional Bias Modification Paradigms

In recent years, some investigators sought to adapt existing ABM procedures to make them more engaging by gamifying them. Gamification refers to the use of game design elements in nongame contexts [30]. Several levels can be discerned in the gamification of ABM tasks, from simply adding game elements to existing training tasks, to adding extrinsic rewards, adding intrinsic motivators, adding a game shell, to using an existing off-the-shelf game [31]. It is thought that maintaining a close connection with validated ABM tasks and adding intrinsic motivation and a game shell may be optimal for ABM gamification [31].

Existing gamified training protocols have been variants of the original probe approach; however, all these protocols share in common the limitation that they seek to train attentional selectivity using very simple static displays that typically present only 1 or 2 stationary emotional stimuli [28,32-36]. This contrasts markedly with real-world settings, which generally require individuals to engage in patterns of attentional scanning and tracking within a complex and dynamic environment [37]. In addition, these studies have been hampered by design limitations. In some cases, these studies have lacked a control condition [33,34]. Moreover, most of these novel procedures have been delivered in studies that afford no opportunity to compare their efficacy with that of the conventional probe-based ABM approach. Without such a comparison, it remains unknown whether a novel ABM task can achieve attentional bias change under conditions where the conventional probe-based ABM task fails to do so or whether a novel task can produce change in anxiety vulnerability when such change is not elicited by a conventional probe-based ABM approach.

These studies did, however, incorporate different gamification and other (nongame) elements to enhance engagement with the tasks to improve their effectiveness in modifying attentional bias [36,38]. Some studies have included *motivating feedback* or *goal metrics*, in the form of real-time visual performance feedback or points [32,35] or block-by-block feedback on performance [28]. Others have implemented more *elaborate displays* or a *game-shell* to increase intrinsic motivation [33,35,39-43]. Another element thought to increase intrinsic motivation is *goals-directed learning*, which directs players to particular goals to increase targeted skills (eg, through instructing participants to attend to positive information) [44]. However, despite inclusion of these gamification elements, the majority of these studies continue to rely on either relatively sparse or mostly static stimulus displays.

This Study

The objective of this study was to develop and evaluate a novel candidate ABM procedure designed to modify attentional

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selectivity within a task setting that, like most real-world contexts, requires participants to selectively distribute attention while processing a complex and dynamic emotional environment. The task required participants to search for and track 1 particular target stimulus presented on screen among multiple moving distractors, based on its emotional valence. This screen display thus realizes the *elaborate display* gamification element, as it presents a large number of stimuli that dynamically move across the whole screen. The task also incorporated the gamification elements of motivating feedback through a game-by-game high score that participants were encouraged to try to beat as well as the element of goals-directed learning, as participants were explicitly instructed to track 1 particular emotional expression. The task was built upon the same principles as the original probe-based ABM task, in which the training condition was designed to increase attentional bias toward positive information, and the task performance would be improved to the extent that participants adopted a more positive attentional bias [6]. Similarly, in the corresponding training condition of the gamified task, performance will improve to the extent participants allocate attention to positive stimuli.

Our primary aim was to evaluate the capacity of this new candidate ABM procedure, which we have labeled the Emotion-in-Motion task, to induce a group difference in selective attentional responding to negatively and positively valenced information and to causally impact anxiety vulnerability, as evidenced by the strength of state anxiety responses to a controlled laboratory stressor. We also delivered the conventional probe-based ABM procedure to a separate cohort of similar participants under equivalent laboratory conditions. This conventional probe-based ABM task does not include any of the gamification elements introduced in the Emotion-in-Motion task. Specifically, there is no elaborate display (only 2 static images are presented), no motivating feedback after each block (only trial-by-trial feedback), and no goals-directed learning (participants are simply instructed to discriminate the identity of a probe). We chose to compare our novel Emotion-in-Motion task with the probe-based ABM task, as this is the procedure most commonly used in studies aiming to modify patterns of attentional bias [17,18,21].

This study design will enable us to determine (1) whether both the conventional probe-based ABM task and this new, complex, dynamic Emotion-in-Motion ABM task produce a group difference in attentional bias in line with the allocated attentional

training condition, (2) if both tasks prove capable of so modifying attentional bias, whether the Emotion-in-Motion ABM task impacts attentional bias to an equal or greater degree than does the conventional probe-based ABM task, (3) whether both the conventional probe-based ABM task and this new, complex, dynamic Emotion-in-Motion ABM task serve to induce a group difference in anxiety vulnerability as a function of allocated training condition, and (4) if both tasks prove capable of so influencing anxiety vulnerability, whether the Emotion-in-Motion ABM task impacts anxiety vulnerability to an equal or greater degree than does the conventional probe-based ABM task.

Methods

Participants

A total of 129 undergraduate students at the University of Western Australia completed the study. In line with previous research, participants who did not show an elevation in state anxiety in response to the intended stressor were excluded before analyses [28]. This led to the exclusion of 19 participants, with 110 participants remaining. Participant characteristics are shown in Table 1.

Conventional Probe-Based Attentional Tasks

Overall, 55 participants completed the conventional probe-based bias training and assessment tasks. These participants were randomly assigned to either an attend-positive or attend-negative training condition. Participants assigned to these 2 conditions of the probe-based tasks did not differ significantly in age, trait anxiety scores, or gender (all $P>.05$).

Emotion-in-Motion Attentional Tasks

Overall, 55 participants completed our novel Emotion-in-Motion bias training and assessment tasks. Participants were randomly assigned to either an attend-positive or attend-negative training condition. Participants in these 2 conditions of the Emotion-in-Motion tasks did not differ significantly in age or trait anxiety scores (both $P>.05$). These 2 groups did differ significantly in gender ratio, $P=.03$, with a higher proportion of males in the attend-negative condition than in the attend-positive condition. Consequently, we considered gender ratio as a covariate in our analyses of the data, which provided reassurance that observed effects of this experimental manipulation remained evident when this group difference in gender ratio was accounted for.

Table 1. Age, gender, and trait anxiety scores (using the Spielberger Trait Anxiety Inventory) for participants completing the conventional probe-based and the Emotion-in-Motion attentional tasks in each of the 2 training conditions.

Condition	Age, mean (SD)	Gender, female/male	Trait anxiety, mean (SD)
Conventional probe tasks			
Attend-negative condition (N=27)	19.33 (2.86)	14/13	38.44 (8.14)
Attend-positive condition (N=28)	19.50 (2.60)	19/9	41.18 (11.08)
Emotion-in-Motion tasks			
Attend-negative condition (N=28)	19.78 (3.62)	17/10	47.18 (8.18)
Attend-positive condition (N=27)	18.50 (0.95)	23/3	43.22 (9.24)

Materials

Attentional Tasks Stimuli

The face stimuli for the attentional tasks were selected from the Karolinska Directed Emotional Faces stimulus set [45]. These images were cropped to show only the face and the neck. The face stimuli for the training tasks were photos of 32 individuals, half of them were female and half were male. For the assessment tasks, photos of 8 different individuals were selected, half of them were male and half were female. There were 2 photographs of each individual, 1 in which they depicted a happy expression and 1 in which they depicted an angry expression. Each photograph was 258 pixels (width) by 323 pixels (height). The stimuli were the same size in the Emotion-in-Motion and probe-based tasks. For the Emotion-in-Motion training task, the 32 identities were grouped into 8 stimulus subsets, each containing the photos of 8 identities, 4 female and 4 male. Each stimulus subset was used in 1 of the 8 blocks delivered in this Emotion-in-Motion task.

Emotion-in-Motion Attentional Bias Modification Task

The aim of this task was to induce, in a complex and dynamic task environment, selective attending to angry or happy faces, depending on the assigned training condition. To provide readers with a first-hand impression of this Emotion-in-Motion task, the task can be viewed on the Web [46].

The Emotion-in-Motion ABM task consisted of 8 3.5 min blocks or *games*. During each block, 8 placeholder rectangles moved dynamically around the screen over a black background. Each rectangle contained an image of a face, each with a different identity. At all times, the target rectangle displayed a face with an emotional expression that differed from the emotional expressions displayed by the faces in all 7 other rectangles on screen, and participants were required to attend to and track this rectangle. In the *attend-negative* condition, the target rectangle displayed a face with an angry expression, whereas the other rectangles displayed faces with happy expressions. In the *attend-positive* condition, the target rectangle displayed a face with a happy expression, whereas the other 7 rectangles displayed faces with angry expressions. Participants were instructed to find the target rectangle and track it using the mouse cursor. All the rectangles, including the target, constantly switched faces. Participants were instructed to keep tracking the target rectangle (ie, depicting the single face with the expression differing from that of the other 7 faces) even when the face presented within changed, as long as the emotional expression of the face presented remained the same (ie, when the face in the target rectangle switched to a different identity, participants were required to keep tracking the rectangle as long as the emotional expression of the new face was the same as the emotional expression of the previous face). At random intervals, the emotional expression of a target face would change in addition to its identity, at which point this ceased to be the target rectangle. At that same moment, 1 of the other rectangles would assume a face depicting this emotion, and thus identifying it as the (new) target rectangle. At these points, participants had to quickly find the new target rectangle and start tracking it.

At the start of a block, each face remained constant for the first 2000 milliseconds. Thereafter, individual faces within a rectangle switched to a different identity (but same expression) randomly at any point between 1 and 2000 milliseconds throughout the block. Within each block, the target rectangle switched (thus, an expression switch occurred) 60 times, at random intervals of 5 to 10 seconds. All 8 rectangles moved with different randomly determined trajectories, at a randomly determined speed of between 30 and 50 pixels per 100 milliseconds. Thus, although the rectangles moved at different speeds, each rectangle's speed was constant within a game. The rectangles bounced off the screen edges and other stimuli they contacted at an angle of reflection that matched their angle of incidence. The target rectangle was never indicated; however, when the mouse cursor was correctly located in the position of the current target rectangle, this cursor disappeared *behind* the rectangle (to not obscure the face presented within) and remained hidden as long as the participant kept it on target.

The onset of each block was preceded by a 3-second countdown presented in the center of the screen. At the end of each block, participants were presented with a tracking score (ie, the percentage of time during that game they were tracking the target rectangle), a switching score (ie, the average speed with which the participant was able to shift their cursor to the next target rectangle), and a total score for that block (generated by combining the tracking score and the switching score). The screen also displayed the participant's highest prior (total) score. Participants were instructed that they would play several games of this task and were encouraged to beat their current high score in each successive game.

Emotion-in-Motion Attentional Bias Assessment Task

The training contingency was removed from the Emotion-in-Motion training task to create the assessment task used to reveal the impact of this training on attentional selectivity. Thus, participants were required to track a rectangle displaying a face with a happy expression (among 7 rectangles displaying faces with angry expressions) on half of the blocks and to track a rectangle displaying a face with an angry expression (among 7 rectangles displaying faces with happy expressions) on the other half of the blocks. This assessment task delivered 12 short blocks, each of which contained 5 target switches, resulting in a total of 60 target switches across the assessment task. In 6 of these blocks, the target rectangle displayed a face with an angry emotional expression, and in 6 blocks, the target rectangle displayed a face with a happy emotional expression. The order of these block conditions was randomly determined, with the constraint that a maximum of 2 consecutive blocks could have a target with the same valence. Each block started with a 5-second countdown.

To obtain a measure of attentional bias to negative information, an attentional bias index (ABI) was computed by subtracting the average tracking score a participant obtained in blocks where targets were happy faces from the average tracking score the participant obtained in blocks where targets were angry faces. Therefore, a higher positive score on this index reflects greater attention to negative information, as it represents more successful tracking of angry than of happy faces.

Other Experimental Tasks

The Trait Anxiety Assessment, conventional probe-based ABM, and assessment tasks as well as the anxiety reactivity assessment task are described in Multimedia Appendix 1.

Procedure

Participants were tested individually in a sound-attenuated room. Once informed consent from participants had been obtained, participants were instructed to sit at a comfortable viewing distance from the computer screen (approximately 60 cm), were given instructions, and completed the first assessment task. After completion of the training task, they completed the original assessment task again. Next, participants completed the anxiety reactivity assessment task containing an anagram stressor task preceded and followed by a measure of state anxiety. At the end of the session, participants were debriefed about the purpose of the study. The entire experimental session lasted about 1 hour. This study was approved by the University of Western Australia's Human Research Ethics Committee, protocol RA415243.

Results

Impact of Attentional Training Procedure on Attentional Bias

The criteria to identify outliers are described in Multimedia Appendix 1. The ABI scores obtained before and after the training task are shown in Table 2.

Attentional Impact of Conventional Probe-Based Training

Application of the outlier criteria led to the exclusion of 4 participants (2 in the attend-positive training condition). To examine whether the conventional probe-based training task was capable of modifying attentional bias, a mixed-methods analysis of variance (ANOVA) was performed with the within-subjects factor attentional assessment point (pretraining assessment, posttraining assessment) and the between-subjects factor training condition (attend-positive training, attend-negative training). The ABI scores obtained by participants who completed this conventional probe-based training task served as the dependent variable.

Results showed neither a significant main effect of attentional assessment point, $F_{1,48}<1$, nor of training condition, $F_{1,48}=2.246$, $P=.14$. Most importantly, the critical interaction between attentional assessment point and training condition fell short of significance, $F_{1,48}=3.018$, $P=.09$, $\eta^2_p=.059$.

Attentional Impact of Emotion-in-Motion Training

Application of the outlier criteria led to the exclusion of 3 participants (1 in the attend-positive training condition). To determine whether our novel Emotion-in-Motion attentional training procedure was effective in modifying attentional responding to negative information, the ABI scores obtained by participants who completed this task were subjected to a mixed-design 2x2 ANOVA that again considered the within-group factor attentional assessment point (pretraining assessment vs posttraining assessment) and the between-group factor training condition (attend-positive training vs attend-negative training). This analysis revealed a significant main effect of training condition, $F_{1,50}=4.602$, $P=.04$, $\eta^2_p=.084$, subsumed within a higher-order interaction of attentional assessment point x training condition, $F_{1,50}=5.629$, $P=.02$, $\eta^2_p=.101$. At pretraining, there was no significant difference between the ABI scores obtained by participants in the attend-positive training condition and participants in the attend-negative training condition, $F_{1,50}<1$. In contrast, at posttraining, participants in the attend-negative training condition showed significantly higher ABI scores as compared with participants in the attend-positive condition, $F_{1,50}=9.903$, $P=.003$, Cohen $d=0.87$. Although the change in attentional bias from pre- to posttraining fell short of significant for participants in the attend-negative training condition, $t_{25}=-1.162$, $P=.26$, Cohen $d=0.229$, there was a significant change from pre- to posttraining for participants in the attend-positive training condition, $t_{25}=2.114$, $P=.045$, Cohen $d=0.415$. Overall, this pattern of results confirms that the 2 training conditions exerted a differential impact on attentional bias to negative information, and the direction of the observed attentional training effects was as expected. When controlling for the gender, by adding this as a covariate, this interaction between attentional assessment point and training condition remained significant, $F_{1,43}=4.393$, $P=.04$, $\eta^2_p=.087$.

Table 2. Attentional bias index scores pre- and posttraining for participants who completed the conventional probe-based attentional bias training and assessment tasks or the Emotion-in-Motion attentional bias training and assessment tasks in either the attend-positive training condition or the attend-negative training condition.

Assessment point	Attend-positive condition, mean (SD)	Attend-negative condition, mean (SD)
Conventional probe training		
ABI[a] pretraining	−5.669 (50.752)	−3.116 (29.591)
ABI posttraining	−15.101 (45.33)	11.002 (36.9)
Emotion-in-Motion training		
ABI pretraining	0.449 (6.041)	1.011 (5.968)
ABI posttraining	−2.739 (6.545)	2.445 (5.261)

[a]ABI: attentional bias index.

Table 3. State anxiety scores pre- and postanagram stressor for participants who previously completed the conventional probe-based attentional bias training task or the Emotion-in-Motion attentional bias training task in either the attend-positive training condition or the attend-negative training condition.

Assessment point	Attend-positive condition, mean (SD)	Attend-negative condition, mean (SD)
Conventional probe training		
State anxiety pretraining	30.680 (10.858)	26.200 (12.176)
State anxiety posttraining	43.600 (9.734)	40.440 (11.623)
Emotion-in-Motion training		
State anxiety pretraining	31.292 (10.149)	29.541 (11.699)
State anxiety posttraining	39.458 (11.026)	41.458 (10.879)

Impact of Attentional Training Procedure on Anxiety Vulnerability

The state anxiety scores obtained using the analog mood scale given before and after the final anagram stressor are shown in Table 3.

Emotional Impact of Conventional Probe-Based Training

Application of the outlier criteria on participants included in the attentional bias assessment analyses led to the additional exclusion of 1 participant (in the attend-positive condition). To examine whether the 2 training conditions had a differential impact on anxiety reactivity, state anxiety scores were subjected to a mixed-methods ANOVA with the within-subjects factor state anxiety assessment point (prestressor assessment vs poststressor assessment) and the between-subjects factor training condition (attend-positive training vs attend-negative training). Results showed a significant main effect of state anxiety assessment point, $F_{1,48}=159.991$, $P<.001$, indicating that state anxiety increased from before the anagram stressor (mean 28.440, SD 11.639) to after the anagram stressor (mean 42.020, SD 10.729). However, neither the main effect of training condition, $F_{1,48}=1.664$, $P=.20$, nor the critical interaction between state anxiety assessment point and training condition, $F_{1,48}=.378$, $P=.54$, $\eta^2_p=.008$, were significant.

Emotional Impact of Emotion-in-Motion Training

Application of the outlier criteria on participants included in the attentional bias assessment analyses led to the additional exclusion of 4 participants (2 in the attend-positive training condition). The same 2x2 ANOVA as reported above was conducted on state anxiety scores to examine whether in participants who completed the Emotion-in-Motion training procedure, the 2 training conditions had a differential impact on anxiety reactivity. This analysis revealed a significant main effect of state anxiety assessment point, $F_{1,46}=125.99$, $P<.001$, $\eta^2_p=.73$, again reflecting the fact that state anxiety increased from before the stressor (mean 30.58, SD 10.87) to after the stressor (mean 40.54, SD 10.88). This main effect was now subsumed within a significant two-way interaction of state anxiety assessment point and training condition, $F_{1,46}=4.39$, $P=.04$, $\eta^2_p=.09$. When controlling gender, by adding gender as a covariate, this interaction between state anxiety assessment

point and training condition remained significant, $F_{1,43}=4.638$, $P=.04$, $\eta^2_p=.097$.

Follow-up t tests revealed that immediately following the attentional training procedure but before the anagram stressor experience, participants who had received the 2 training conditions did not differ in their levels of state anxiety, $F_{1,46}=.31$, $P=.58$, $\eta^2_p=.01$. Participants in each Emotion-in-Motion attentional training condition responded to this stress manipulation by displaying an elevation in anxious mood state (attend-positive training: $F_{1,23}=55.84$, $P<.001$, $\eta^2_p=.71$ vs attend-negative training: $F_{1,23}=70.56$, $P<.001$, $\eta^2_p=.76$). However, the magnitude of the elevation in state anxiety evoked by this stressor was significantly attenuated in those participants who had received the Emotion-in-Motion attend-positive attentional training compared with those participants who had received the Emotion-in Motion attend-negative attentional training condition (mean 8.17, SD 5.35 vs mean 11.92, SD 6.94; Cohen $d=0.60$). Thus, those participants who had been exposed to the Emotion-in-Motion task training contingency designed to reduce attentional bias to negative information subsequently came to display relatively attenuated elevations of anxious mood state in response to the anagram stressor experience compared with participants who had been exposed to the training condition designed to increase attentional bias to negative information. In addition, the elevation in anxiety in the positive training condition of the Emotion-in-Motion task (mean 8.17, SD 5.35) was significantly smaller than the elevation in state anxiety in the positive training condition of the conventional probe-based training task (mean 12.92, SD 8.83), $t_{47}=2.35$, $P=.02$, Cohen $d=0.67$.

Discussion

Principal Findings

The objective of this study was to develop and evaluate a novel ABM procedure intended to systematically alter selective attentional responding to emotional information in a complex and dynamic task environment. Our results showed that our novel Emotion-in-Motion training procedure succeeded in modifying patterns of attentional bias, as intended. Moreover, the participants who were allocated to the attend-positive condition of the Emotion-in-Motion attentional training task showed reduced anxiety reactivity to the subsequent lab-based

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stressor as compared with participants who were allocated to the attend-negative condition of this task. These results suggest that our novel attentional training task appeared capable of modifying both patterns of attentional bias and causally influencing anxiety vulnerability.

A subsidiary aim was to permit comparison with the conventional probe-based attentional bias training procedure. Under equivalent laboratory conditions, the conventional probe-based attentional training approach failed to induce differential patterns of attentional bias, and the 2 probe-based training conditions did not lead to participant differences in anxiety reactivity to the subsequent stressor. In recent years, several studies (including 3 out of our lab) have reported similar failures of the conventional probe-based attentional training task to successfully modify patterns of attentional bias [28,47-51]; therefore, it is reasonable to conclude that the probe-based ABM procedure may be a nonoptimal way of achieving bias change.

Candidate Explanations for the Effectiveness of the Emotion-in-Motion Task

In reflecting on the reasons for the capacity of our novel Emotion-in-Motion paradigm to induce differential patterns of attentional bias, under conditions where the conventional probe-based training did not, several candidate factors can be considered. First, the Emotion-in-Motion task presents 8 stimuli simultaneously, whereas the conventional probe task displays only 2 stimuli. There is some evidence that attentional bias is more pronounced when assessed using visual displays that contain more stimuli [52,53], but as yet, it is unknown whether more robust ABM effects can be obtained using paradigms that present more stimuli. Although some training procedures that involve more complex stimulus displays already exist [41,54], so far no direct comparison between the effectiveness of training tasks using simple versus complex stimulus displays has been made. In future research, the Emotion-in-Motion paradigm can be easily be adapted to present simple displays (eg, 2 rectangles) versus complex displays (eg, 8 rectangles), to enable such comparison.

A second candidate factor that could have contributed to the findings observed with the Emotion-in-Motion approach is the dynamic nature of the stimulus presentation. In the Emotion-in-Motion task, all stimuli move dynamically around the display, whereas in other attentional training paradigms, stimuli are presented in a static manner. It is possible that the dynamic nature of Emotion-in-Motion enhanced concentration and engagement with the task, thereby increasing its capacity to deliver the intended attentional bias change. In future research, the potential contribution of this dynamic component could be examined by contrasting task variants that employ the present dynamic approach with variants that instead present the same number of stimuli in static grid.

A third candidate reason for its efficacy may be the provision of enriched performance feedback in the Emotion-in-Motion task compared with the rudimentary trial-by-trial error feedback given in the conventional probe-based attentional training task. Moreover, block feedback in the Emotion-in-Motion task was encouraging, whereas trial-by-trial feedback in the probe-based

task penalized participants for making errors by delaying the next trial for 3 seconds, which may have elicited increased negative mood. Block feedback of the type delivered in the Emotion-in-Motion task has been shown to enhance learning in simple repetitive tasks [55], whereas negative mood has been shown to impair learning [56]. As such, this difference in feedback may have also contributed to enhanced performance in the Emotion-in-Motion task. Future research could further examine the contribution of enriched performance feedback to the efficacy of ABM procedures by comparing conventional probe-based training with and without such block feedback or by manipulating whether or not the presently provided block feedback is delivered within the Emotion-in-Motion task.

Moreover, in the conventional probe-based training task, images depicting different emotional expression of the same identity were paired, whereas in the Emotion-in-Motion task, each image depicted a different identity. As such, participants performing the probe-based training only needed to discriminate emotional expression on the same person, whereas participants performing the Emotion-in-Motion tasks needed to discriminate emotional expressions between different identities. There is some evidence to suggest that emotion classifications are affected by variations in identity [57]. It is, therefore, possible that this increased demand on emotion classification contributed to the Emotion-in-Motion task being more challenging. The more challenging emotion classification, enhanced performance feedback, as well as the complex and dynamic nature of the task could have resulted in greater engagement with the Emotion-in-Motion task, relative to the conventional probe task. Task engagement can be conceptualized as a combination of energy, motivation, and concentration and can be measured using self-report as well as through task performance indicators [58]. In the Emotion-in-Motion task, we did not obtain self-report measures of task engagement, and the difference in the nature of the tasks leaves us unable to compare performance indicators of engagement. However, future research may usefully examine whether individuals show a difference in engagement with the Emotion-in-Motion task relative to the probe task and whether task engagement moderates the procedures' impact on attentional bias and anxiety vulnerability [36].

An additional difference between the 2 training procedures concerns participants' responses. The tracking response required in the Emotion-in-Motion task is continuous, whereas the probe task only requires a response every couple of seconds. It is likely that as a result, participants in the Emotion-in-Motion task spend more time attentionally engaged with the target valence (positive or negative, depending on training condition) as compared with participants in the conventional probe task. However, it is also possible that this continuous response would be harder to sustain over time as it is more motorically demanding. As such, future research may usefully examine the acceptability of this response format in multi-session training designs. It is also relevant to note that in the Emotion-in-Motion task, the mouse cursor only disappears behind the target rectangle. As such, it is possible that participants could ignore the content of the rectangle and simply see on which rectangle the mouse cursor would disappear. Although given the speed and complexity of the task

this strategy is unlikely to have occurred, importantly, this strategy would have reduced the efficacy of the attentional training. Future research could, therefore, evaluate whether modification to the task (eg, making the cursor disappear behind every image) would further increase the effectiveness of the task. It will be important to establish, however, whether such modifications that render participants' awareness of the position of the cursor more uncertain cause unwanted frustration or disorientation in participants.

Strengths and Limitations

It is important to consider the potential limitations of this study. One such limitation is that the capacity of the Emotion-in-Motion training task and the capacity of the conventional probe-based training task to modify attentional bias were each established using a different method of assessing attentional bias. For both training tasks, the assessment approach involved delivering the same task but with the training contingency removed. This design critically allows for comparable demonstration of near transfer across the 2 training tasks. However, it does preclude direct comparison of attentional bias change observed in response to each of these 2 candidate attentional training approaches. It is possible, for example, that the assessment version of the Emotion-in-Motion task is more sensitive to individual differences in attentional bias than the probe-based attentional bias assessment task (of potential relevance to this, note that the SDs for Emotion-in-Motion ABI scores are smaller than those for the probe-based ABI scores). If this is the case, then the results of this study could be explained by the Emotion-in-Motion training task producing a greater modification of attentional bias, the Emotion-in-Motion assessment task more sensitively assessing group differences in attentional bias, or both. Future research could circumvent this limitation by employing the same attentional bias assessment approaches for all ABM tasks under evaluation.

A second potential limitation is that this study was carried out on an undergraduate nonclinical participant sample. Although this design allowed us to examine whether the Emotion-in-Motion procedure can induce differential patterns of attentional bias and consequently test the causal impact of these differential patterns of attentional bias on anxiety vulnerability, it does limit conclusion concerning either the acceptability or the efficacy of our novel Emotion-in-Motion

ABM approach when used with a clinical sample. Although the complex and dynamic nature of the Emotion-in-Motion task can be expected to enhance face validity of and engagement in the task, future research using clinical cohorts will be necessary to determine whether this novel ABM task is more acceptable to patients than the conventional probe-based training task.

It is also important to consider some potential limitations of using gamification for bias modification. Some of the potential drawbacks are discussed by Boendermaker et al [31]. These authors note that some gamification elements designed to increase motivation (such as visible scores) may be distracting and impair training. Second, implementing intrinsic motivators may be costly and difficult, and the intrinsically motivating value of such elements may vary across individuals. In addition, even if a game is intrinsically motivating, it may need to be combined with a motivation to change in participants before adherence to multi-session training is improved. Most importantly, however, given the strong link between change in attentional bias and change in emotional vulnerability, it is important that in any gamified ABM procedure, the core mechanism underlying ABM (encouraging a change in attentional bias) remains intact [24,59].

Conclusions

In the meantime, we hope that the Emotion-in-Motion task, which this study has shown to be capable of modifying attentional bias to emotional information and altering anxiety vulnerability as indicated by anxiety reactivity to a stressor, will be of interest and potential value to researchers investigating the potential anxiolytic benefits of directly manipulating maladaptive patterns of attentional bias. To facilitate further research using this task and to encourage independent replication of the findings of this study, we made our Emotion-in-Motion task software freely available [60]. While we look forward to the future evaluation of this novel ABM approach in other cohorts and settings, we also encourage fellow researchers to develop and refine new and innovative ABM paradigms that further enhance our capacity to modify the attentional bias to negative information implicated in anxiety vulnerability and dysfunction. Such continuous improvement in our ABM approaches will optimize the prospect of developing future ABM protocols that prove capable of delivering robust and reliable therapeutic benefits within the clinic.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Further detail on the methods and data handling.

[PDF File (Adobe PDF File), 68KB - games_v6i4e10993_app1.pdf]

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Abbreviations

ABI: attentional bias index
ABM: attentional bias modification
ANOVA: analysis of variance

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<u>Original Paper</u>

Creating a Theoretically Grounded, Gamified Health App: Lessons From Developing the Cigbreak Smoking Cessation Mobile Phone Game

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Abstract

Background: Gaming techniques are increasingly recognized as effective methods for changing behavior and increasing user engagement with mobile phone apps. The rapid uptake of mobile phone games provides an unprecedented opportunity to reach large numbers of people and to influence a wide range of health-related behaviors. However, digital interventions are still nascent in the field of health care, and optimum gamified methods of achieving health behavior change are still being investigated. There is currently a lack of worked methodologies that app developers and health care professionals can follow to facilitate theoretically informed design of gamified health apps.

Objective: This study aimed to present a series of steps undertaken during the development of Cigbreak, a gamified smoking cessation health app.

Methods: A systematic and iterative approach was adopted by (1) forming an expert multidisciplinary design team, (2) defining the problem and establishing user preferences, (3) incorporating the evidence base, (4) integrating gamification, (5) adding behavior change techniques, (6) forming a logic model, and (7) user testing. A total of 10 focus groups were conducted with 73 smokers.

Results: Users found the app an engaging and motivating way to gain smoking cessation advice and a helpful distraction from smoking; 84% (62/73) of smokers said they would play again and recommend it to a friend.

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Conclusions: A dedicated gamified app to promote smoking cessation has the potential to modify smoking behavior and to deliver effective smoking cessation advice. Iterative, collaborative development using evidence-based behavior change techniques and gamification may help to make the game engaging and potentially effective. Gamified health apps developed in this way may have the potential to provide effective and low-cost health interventions in a wide range of clinical settings.

KEYWORDS

Introduction

The Health App Revolution

Mobile phone use is increasing rapidly in both developed and developing countries, and by 2020, 70% of the world's population will be using mobile phones [1,2]. Three billion people globally currently use mobile health apps [3-5], with over 165,000 health apps available worldwide [2].

Health apps are in high demand. A recent study reported 800,000 downloads per month of smoking cessation apps worldwide [6]; there were 400 smoking cessation apps available on app stores in 2013 when Cigbreak development began [6]. However, most health apps are not developed from a theoretical basis that draws on evidence-based behavior change techniques (BCTs), and there is little evidence that public health practitioners or users have participated in design [6-10]. To date, there have been few rigorous evaluations of the effectiveness of health apps [2,11-14] although pilot studies and small trials have shown promising results [9,11,13,15,16].

Using Gamification to Change Health Behavior

Maintaining users' engagement with health apps is not easy, with 77% of apps going unused only 72 hours after being installed [10,17,18]. One potential solution to this problem is gamification, which aims to harness the motivational power of *gaming elements* such as badges, leaderboards, competitions, rewards, and avatars to increase user engagement and hence improve effectiveness [2,19]. Gamification shares key elements with established health BCTs and behavior change theory [20,21], and there is growing evidence that gamification increases engagement with health apps [10,18,22,23]. Despite this, a recent review found that only 4% of top-rated health apps on the Apple and Android stores made use of gamification principles [2].

Health App Development

In recent years, standards have been established for health app development [24], and there are some examples of well-developed health apps that are evidence- and theory-based with expert design [9,13,15,25,26]. The British Standards Institution has formulated a code of practice for health and wellness apps, providing app developers with quality criteria to consider during the development process [24]. However, there is a lack of worked methodologies that app developers and health care professionals can follow to aid development and incorporation of appropriate features.

The Cigbreak App

In 2013, a group of clinicians, researchers, and game developers set out to build a dedicated smoking cessation app *Cigbreak*, developed in collaboration with potential end users. Gamification and theoretically validated BCTs were included, including those shown to be beneficial in smoking cessation [27,28], with the goal of creating an engaging, scientifically grounded health app.

The current version of Cigbreak involves players swiping their screen to break cigarettes as they dance upward from a generic cigarette pack, providing a distraction from cravings. Smokers progress along a path through a garden to a smoke-free finish line (Figure 1). Along the way, players can complete diary entries and overcome specific daily missions. Players are rewarded for both real-life smoking cessation behavior and progress through the game with health messages, coins, and trophies and are given personalized feedback. Player's progress can be monitored and shared on Facebook, providing social support. Nicotine replacement therapy (NRT) power-ups inform players of the different kinds of NRT available, encouraging pharmacological support.

This paper documents the development process in a series of steps, providing a worked example for future development of gamified health apps.

Figure 1. Screenshots of Cigbreak.

Methods

Agile Development Process

Principles of agile development were adopted [29] where prototypes were developed rapidly and systematically modified according to user feedback. The methods adopted in Steps 1 to 7 are described below. We aimed first to gain an understanding of the research problem (why do people still smoke?) and to identify key user preferences for app functions. Doctors, health psychologists, and researchers worked closely with app developers to incorporate established smoking cessation methods and validated BCTs. Feedback from users was obtained following each iteration to refine app functions or features. At all stages of development, the focus groups involved participants using actual prototypes of the app, having hands-on experience on mobile handsets that we provided in the 10 focus groups.

Focus Groups

Focus groups were held throughout the development process (step 2 and step 7). Participants were recruited through pharmacies in Tower Hamlets, London; Eurogamer (Europe's largest gaming show); a community development charity in East London, Social Action for Health; Kick-it the smoking cessation scheme facilitated through the Tri-borough Council, London. Moreover, 10 focus groups were conducted in total with 73 participants (male [n=34] and female [n=39]). In total, 2 focus groups were conducted at Chapel Hill, University of North Carolina, to understand the differences in smoking/ cessation culture between the United Kingdom and the United States, which might affect design requirements when making the app available globally. Furthermore, of the 10 focus groups, 3 (n=26) were conducted during early development as documented in step 2. There was a wide range of ages (15 to 67 years) and ethnicities (Bengali, Turkish, Russian, Polish,

British, American, or African-American) represented in the focus groups, which included smokers who may find it difficult to access standard smoking cessation services (NRT and behavioral support [individual and group]), for example, routine and manual workers and adolescents.

All focus groups were conducted over a 90-min period and led by a trained facilitator (EAE) and assisted by 1 other team member (HC, LS, CR). Participants were asked to use the app for a 30-min period. The remaining 60 min were used for discussion. A basic structure was followed; however, content was also guided by participants. Questions in the first 3 focus groups differed and focused more on participants' smoking behaviors and ideas for smoking cessation app content. The later focus groups focused more on providing user feedback on the various iterations. Participants were also asked to complete a questionnaire at the end of each focus group. Tobacco dependence was measured using the Fagerström test for nicotine dependence [30,31], and participants were asked about any current treatment they were using to help them stop smoking. Questions were also asked regarding the appearance of the app, enjoyability, and usability, and participants were asked if they would recommend the app to a friend.

Participants were given £20 to show appreciation for their time. Voice recordings of the focus groups were taken and transcribed, and observational notes were made. Thematic analysis of the data used a framework approach [32,33]. A trained researcher (EAE) independently analyzed the focus group transcripts; however, any uncertainties were discussed with the study team. We did not double code because we were coding for concrete themes to aid app development rather than conceptual themes; the second researcher in each focus group was able to check themes against their own perceptions. Moreover, 5 interconnected stages were followed in the analysis: (1) familiarization with the data, (2) identifying thematic frameworks for themes arising, (3) indexing—highlighting relevant quotes, (4) charting—arranging the quotes under themes, and (5) mapping and interpretation [32-34]. Furthermore, focus groups were conducted until a saturation period was reached in which no other new themes emerged. No software was used to conduct coding or identify themes.

Step 1: Forming an Expert Multidisciplinary Design Team

A multidisciplinary design team with appropriate experience and expertise was formed to aid in the design and construction of the app. The team included a senior app developer (HC), computer scientists (YP and DG), clinical doctors (EAE and RTW), a senior health psychologist (LS), a senior medical sociologist (CR), and several smoking cessation advisors from the London Kick-it smoking cessation scheme. The membership of the design team was consistent over the development period. Extensive input from the public and potential app users was sought throughout development.

The team brainstormed extensively before any coding began, to establish key concepts and constructs to be included in the app. The design team met once per week throughout the development period. Meetings were chaired by a facilitator (RTW), and decisions were documented and logged.

Step 2: Defining the Problem and Establishing User Preferences

First, we set out to define the problem, exploring factors influencing nicotine addiction and successful quit attempts, and we then explored user preferences with our main goal to establish app components required to create user engagement, resulting in a smoking cessation app likely to be retained by users. In total, 3 focus groups with 26 smokers were conducted.

Step 3. Incorporating the Evidence Base

Cigbreak development was guided by the Medical Research Council framework for complex interventions [35] following the British Standard Institute Code of Practice for Health and Wellness app development [24]. The latest guidelines for effective smoking cessation were also considered [36-39].

Cigbreak was designed with 30 game levels, which were estimated to take an average user 28 days to complete. Evidence suggests that being abstinent for 28 days increases the chance of successfully quitting [9], and hence Cigbreak can support its users through the most critical period of their smoking cessation attempt.

Step 4: Integrating Gamification

There are several taxonomies or frameworks of gamification available [21,40-43]; however, there is a recognized lack of high-quality studies [22] and only 1 taxonomy has been validated [40,44]. Given the lack of empirical guidance in this area, we relied on the experience of our expert multidisciplinary design team aiming to create an engaging and entertaining game.

Having gamified the app, we then turned to one of the more popular taxonomies to deconstruct Cigbreak in an effort to understand how the game might address various aspects of motivation and to optimize features. Cugleman and colleagues identified 7 key gamification strategies: goal setting, capacity to overcome challenges, providing feedback on performance, reinforcement, comparing progress, social connectivity, and fun and playfulness [21].

Step 5: Incorporating Behavior Change Techniques

A BCT is "an observable, replicable and irreducible component of an intervention designed to alter or redirect causal processes that regulate behavior; that is, a technique is proposed to be an 'active ingredient' (eg, feedback, self-monitoring, reinforcement)" [45]. BCTs have been clearly defined and classified into an internationally recognized taxonomy [45]. It was understood that if our intervention was to be effective, it would be important to make good use of BCTs. Therefore, in addition to providing distraction from cravings, the game would become part of a causal pathway for health behavior change.

This development phase of Cigbreak involved close collaboration with a health psychologist, who advised on BCTs on the basis of strong empirical evidence for their efficacy [27,28] and feedback gained in earlier focus groups. A systematic review of BCTs in existing health apps was also conducted [2]. Self-regulatory BCTs (*feedback & monitoring* including *self-monitoring of behavior*) have been commonly used in gamified apps to promote physical activity, healthy eating, and alcohol reduction [2,12,46,47]. These specific BCTs

were effective in achieving behavior change in previous studies [48-53], and therefore, they were an obvious choice for inclusion.

Step 6: Developing a Logic Model and Investigating Causal Pathways

A logic model to describe the program theory behind the intervention was formulated, and methods of representing and examining the operation of the intervention in mathematical models were researched.

Step 7: User Testing

Cigbreak was built in *Unity for Android* [54] by Healthy Games Ltd. The use of a preexisting game engine facilitated rapid development of app prototypes, which could be circulated among the team and focus groups of smokers.

Results

Defining the Problem and Establishing User Preferences

Personal experiences, concerns about ill health, financial pressures, and family/friends were key motivational themes for stopping smoking. Environmental factors and mood played an important role in whether smokers continued to smoke. Smokers identified a need for extra support and distraction from the action of smoking in certain environments. As their thoughts at these times were overwhelmingly related to smoking, a game including cigarettes that involved *swiping* them was felt to be helpful. It was this key finding together with brainstorming in the team that led us to develop the initial concept that the app could be used as a distraction from cravings. These focus groups drove inclusion of many other features such as giving information on health and finances and using family members to provide motivational cues. The key themes identified in motivational factors are shown in Table 1.

Smokers perceived that health information including benefits of quitting and harms of smoking was important. However, smokers preferred more focus on positive outcomes and emotions rather than negative. Smokers felt that personalization was an important feature, including ability to set personal quit dates, plans, record relapses, and receive tailored text messages. The idea of a personalized diary to incorporate these aspects was popular among the smokers as were links to local pharmacies/quit services.

The appearance of the app was identified as an important factor, with smokers wanting a bright, colorful app that was interactive and entertaining. Several smokers felt that gaming elements would aid in this goal.

At the conclusion of this phase, there was a good understanding of user preferences, and the appearance of the app was beginning to take shape. The challenge was then to deliver an app that met user requirements in addition to using evidence-based smoking cessation advice and BCTs. The key themes identified for important features for a smoking cessation app are shown in Table 2.

Integrating Gamification

Game elements were incorporated by game developers and computer scientists (Table 3) [21].

Incorporating Behavior Change Techniques

At the end of this phase, our design for Cigbreak included 36 BCTs (see Figure 2 and Table 4 for a full list). Two researchers trained in BCT coding (EAE and JL) coded Cigbreak independently in accordance to the (V1) BCT taxonomy [45].

Screenshots of the Cigbreak app are shown with examples of BCTs highlighted. Note some screenshots may show multiple BCTs, which have not been highlighted but would have been coded accordingly.

Table 1. Key themes identified in motivational factors affecting smoking and quitting.

Themes	Subthemes	Quotes
Financial	Financial factors are an important motivational factor in quitting	• *If I'm short of money one month, that definitely stops me smoking.*
Mood	Stress/boredom/unhappiness contribute to motivation to smoke	• *I smoke when I am stressed.*
Family and friends	Family, especially children, can be a motivation to quit	• *Children can be powerful.*
Experience of illness and health concerns	Personal experiences of ill health secondary to smoking in family/friends would affect motivation to quit	• *When my mum was unwell with her chest, it definitely made me think of stopping.*
Environmental factors	More likely to lapse if socializing may need more support during these activities; Job stops people smoking during the day time; Being on holiday encourages people to smoke more; Alcohol encourages people to smoke more; Government bans have been very useful	• *I would smoke if others smoked around me.* • *Interestingly when you know smoking not a possibility don't really get cravings e.g. on 10 hour flight.*

Table 2. Key themes identified for important features for a smoking cessation app.

Themes	Subthemes	Quotes
Health information	To know the harms of smoking and the benefits of quitting	• *I think what you need to hear is that stern image you have on the back of cigarettes of what it is doing to you.* • *Maybe it could give you an explanation of how your health is improving.*
Distraction from craving	To keep your hands busy; To help you know what to do when you get cravings; To have a craving button	• *I am craving so idea of a craving button which could be pressed when needed and links to a page with different management strategies e.g. play game, prompt to go for walk, speak to friend.*
Personalization or related to real time quitting	To be personalized to the individual; To receive personalized texts and messages at times of craving; To be able to enter personalized quit date and plan; To be able to record relapses	• *Being personalized is definitely important.* • *Maybe you could put dates in for your stop date.* • *If you had a relapses you could put it in there too, so it is tied to your real time quitting.* • *You could have it so when you wake up it says good morning this is your 11th day, that would be motivating, that would make me stop smoking.* • *Maybe you could set it so it gave you little motivations reminders at times that you need them.*
Bright in color	To be bright in color	• *Being colorful is important.*
Interactive	To be interactive	• *It has to be interactive to work.*
Gamification	To contain gaming elements; To be fun	• *Having a game and having to do something with your hands does work because you will spend an hour on that game before you have realized it and that an hour you have not smoked a cigarette.* • *Games are very good, candy crush is brilliant, I was playing it at 3am when I wanted a cigarette, doing something quick with your hands takes your mind off it.*
Diary	To contain a personal dairy	• *Like for example I want to do something in my diary, like today I have stopped and I really fell like a cigarette, so I would write down I have saved x amount by not going out and buying cigarettes.*
Financial saving	To contain information on the financial savings of quitting	• *I would like to know I have saved x amount by not going out and buying cigarettes* • *After a week if would be good to tot up how much money you have saved.*
Links to local services, pharmacies	Links to local quit smoking services or phone lines or local pharmacies	• *That would really help, or it could give locations of stop smoking places.*
Information about NRT[a]	To contain information about different NRT products available and how to use them	• *I would like to know more about the different products available.*
Emotional content	To have an emotional content, would prefer focus on positive not negative emotions; To promote feelings of relaxation and happiness	• *It needs to have an emotional content, but I think more focus on the positive rather than the negative.* • *I want it to help me relax.*

[a]NRT: nicotine replacement therapy.

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Table 3. Gamification strategies in Cigbreak, including their location in the app.

Gamification strategy	Description	Location in the app
Goal setting	Players are asked to set or agree on goals and to set a quit date	Diary
Capacity to overcome challenges	The diary contains missions and challenges, for example calling a quit line or contacting their local pharmacy for advice on using approved medications; The game involves players increasing speed and avoiding objects when slicing cigarettes	Diary; Game
Feedback	Players are given feedback on outcomes of their behavior, for example, the number of days smoke-free and number of cigarettes smoked; Players are provided with a score for number of cigarettes sliced	Diary; Game
Reinforcement	Players are rewarded with trophies for setting quit date and for not smoking	Diary; Game
Comparing progress	Players are asked to share their scores with their friends on Facebook. Friends can compare scores and trophies	Game; Diary
Social connectivity	Players can connect with friends for social support via Facebook	Diary; Game
Fun and playfulness	Players break cigarettes that dance upward from a generic cigarette pack while trying to avoid breaking any vegetables. Players are rewarded with gold, silver, and bronze stars for breaking the required number of cigarettes	Game

Figure 2. Example of embedded behavior change techniques in Cigbreak.
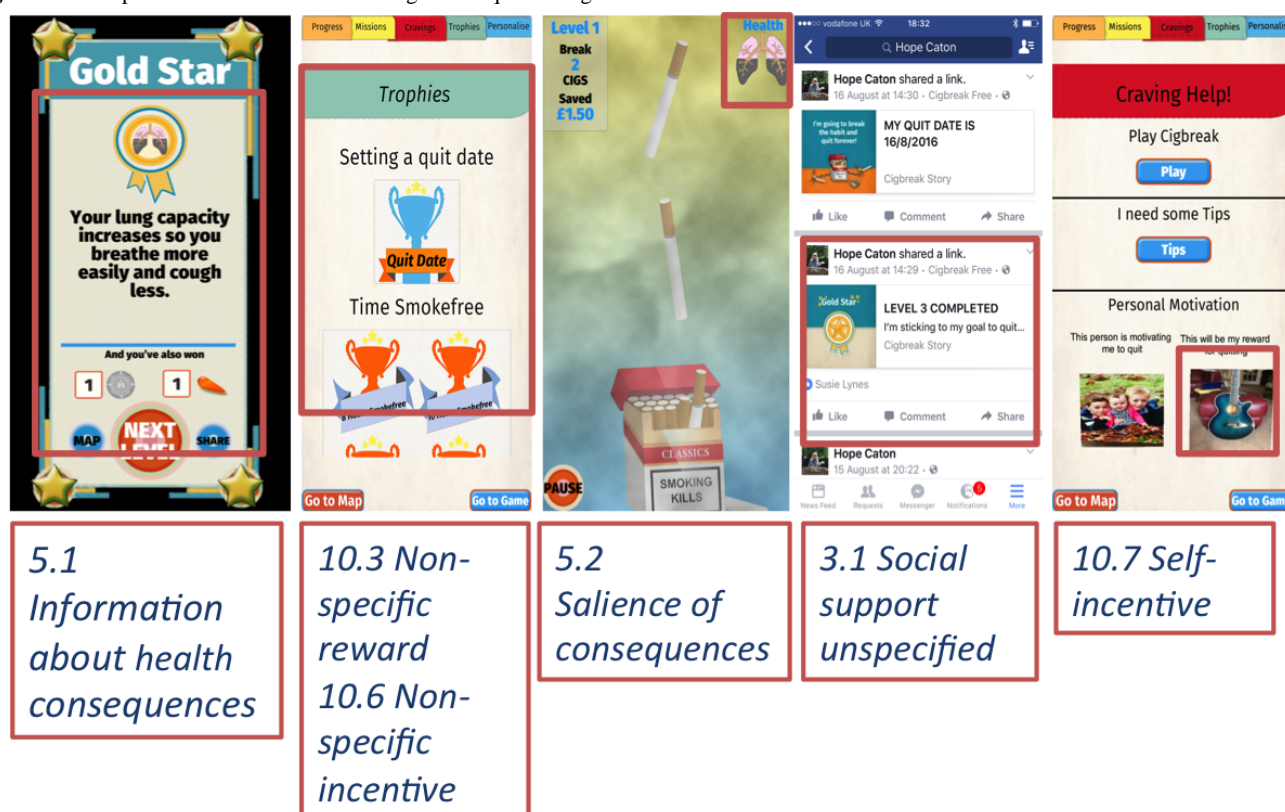
Table 4. Behavior change techniques (BCTs) in Cigbreak with location in the game.

BCT	Description	Location in the game
1.1 Goal setting (behavior)	Players are asked to set goals, for example, a quit date	Diary
1.2 Problem solving	Players are asked to identify specific triggers that generate the urge to smoke and develop strategies for avoiding environmental triggers	Diary
1.3 Goal setting (outcome)	Players are asked to set goals, for example, to save money as a result of the money saved from not smoking to pay for a holiday	Diary
1.6 Discrepancy between current behavior and goal	If players continue to smoke after their quit date, they are provided with feedback on the discrepancy between current smoking and their previously set outcome goals	Diary
2.2 Feedback on behavior	Players are given feedback on their behavior, for example, number of cigarettes smoked since starting the app	Diary
2.3 Self-monitoring of behavior	Players are asked to monitor their smoking daily in a diary in the app. Players are also asked daily in pop-up questions the number of cigarettes smoked and whether players have remained smoke-free	Diary
2.7 Feedback on outcomes of behavior	Players are given feedback on the number of days smoke-free and what this means for their health	Diary
3.1 Social support (unspecified)	Players are asked to share their scores and smoke free status with their friends on Facebook	Game
3.2 Social support practical	Players are provided with practical advice in the diary on how to gain support from friends or colleagues or staff to help them to quit; for example, players are provided with information on support from community pharmacies	Diary
4.2 Information about antecedents	Players are prompted in the diary to record situations or circumstances in which they are more likely to get cravings or experience the urge to smoke, for example, being at a bus stop	Diary
5.1 Information about health consequences	Players are provided written, audible, and visual information on the health consequences of smoking and the health benefits of quitting; Health reward badges inform of the health consequences of smoking	Game
5.2 Salience of consequences	The avatar's lungs become blackened and cough as cigarettes are not destroyed, thus highlight damage to lungs from not stopping	Game
5.3 Information about social and environmental consequences	Players are provided with written and visual information regarding social and environmental consequences of smoking	Game
5.6 Information about emotional consequences	Players are provided with written information regarding emotional consequences of quitting smoking, for example, that quitting smoking increases happiness and life satisfaction	Game
7.1 Prompts or cues	Players are prompted to play the game at times of cravings via the crave button	Game or Diary
8.2 Behavior substitution	Players are prompted to substitute smoking with an alternative behavior; For example, players are prompted to play the game via the crave button when they have a craving to smoke or prompted to go for a walk	Diary
8.7 Graded tasks	Tasks or missions set to help players to quit smoking become increasingly more difficult, but achievable, until players have quit	Diary
9.1 Credible source	The app is cocreated by doctors, health psychologists, and smoking cessation advisors. Players are made aware of this on the app store, website, and in the app	Diary
9.2 Pros and cons	Players are asked to list the pros and cons for quitting smoking in the diary	Diary
9.3 Comparative imagining of future outcomes	Players are asked to imagine and compare possible outcomes following quitting smoking, imagining themselves as nonsmokers and document this in the diary	Diary
10.3 Nonspecific reward	Players are provided with trophies, stars, and virtual coins for staying smoke-free	Game
10.4 Social reward	Players are congratulated by friends on social media or Facebook	Game or Diary
10.6 Nonspecific incentive	Players are incentivized to stay smoke-free	Game
10.7 Self-incentive	Players are encouraged to plan to reward themselves in the future for staying smoke free	Diary
10.9 Self reward	Players are encouraged to reward themselves at the present time if they have stayed smoke free	Diary
10.10 Reward (outcome)	Players are provided with in-game rewards for remaining smoke-free; for example, they are provided with trophies and health reward badges	Game

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BCT	Description	Location in the game
11.1 Pharmacological support	Players are encouraged to use NRT[a] and to obtain this from their pharmacy. There are also NRT power-ups in the game, which allow players to progress to higher levels in the game. This encourages the use of NRT and also informs players of the different NRT available	Game
11.2 Reduce negative emotions	Players are given advice on reducing negative emotions to quit smoking; for example, using stress management skills	Diary
12.1 Restructuring the physical environment	Players are advised how to change their physical environment to help themselves to quit, for example to remove cigarettes from their home and to remove ash trays	Diary
12.2 Restructuring the social environment	Players are advised and given tips on how to change their social environment to help them to quit, for example, avoiding contact with friends who smoke	Diary
12.3 Avoidance or reducing exposure to cues for the behavior	Players are advised and given tips on how to avoid exposure to specific social and contextual or physical cues with regard to smoking, for example, avoiding pubs and bars that have been associated with smoking	Diary
12.4 Distraction	The gameplay involves players breaking cigarettes acting as a distraction from smoking	Game
12.5 Adding objects to the environment	Players are provided with the app and written or visual information to aid smoking cessation	Diary
13.5 Identity associated with changed behavior	Players are advised to construct or articulate a new self-identity as an ex-smoker	Diary
15.1 Verbal persuasion about capability	Players are encouraged that they can quit smoking, arguing against self-doubts and asserting that they can and will succeed	Diary
15.3 Focus of past success	Players are asked to list previous successes, for example, when they have resisted smoking	Diary

[a]NRT: nicotine replacement therapy.

Developing a Logic Model and Investigating Causal Pathways

The logic model (Figure 3) describes basic assumptions on which the intervention is based, together with channels through which smokers are invited to use the app, for example, social media advertisements and recommendations by clinicians. The recruitment methods are designed to reach people who find conventional health care services difficult to access.

The app is designed to record user engagement with BCTs and subsequent changes in smoking behavior to allow detailed temporal analysis of causal pathway assumptions. Frameworks and graphical models for exploring causal relations are well established [55-57], and causal methodologies to account for confounding by covariates are now sufficiently developed to enable effects of new public health interventions to be evaluated from observational studies [58-67]. The relatively unexplored approach of the Cigbreak app for improving public health holds exciting possibilities to form a defining example for the development of testing of causal assumptions and pathway analysis suited to app design. This would provide the framework for a more refined analysis of complex interventions with a dynamic longitudinal treatment regime resulting in long-term health benefit.

User Testing

Changes to Cigbreak From Direct User Feedback

Key themes were identified in a framework analysis (Table 5), and the app was redesigned accordingly. For example, players wanted the app to be more personalized. In response, a personalized diary for players was introduced, which allowed players to set personal goals and quit dates and to add pictures of the item or person motivating them to quit. At this stage of app development, the thematic analysis was oriented toward more concrete app features and design elements rather than abstract concepts.

From Prototype to Product

Players found the prototype app to be an engaging and motivating way to deliver smoking cessation advice, providing a useful distraction from smoking (Table 6), and 84% (62/73) said they would play again or recommend to a friend. Those with higher tobacco dependence as defined by the Fagerström test for nicotine dependence [30,31] and difficult-to-reach smokers appeared to be more engaged. Engagement was measured as both flow (focused attention and enjoyment) and usage (frequency, duration, and depth of usage) [18]. Players said they would be happy to obtain this app from their pharmacy or general practitioner.

The game was completed in 2015 with funding from the London Tri-borough Smokefree Alliance and is commissioned in 5 London boroughs. Following the final focus groups, Cigbreak was released on both Apple and Google Play stores in January 2016.

Figure 3. Cigbreak logic model describing the intended operation of the intervention.
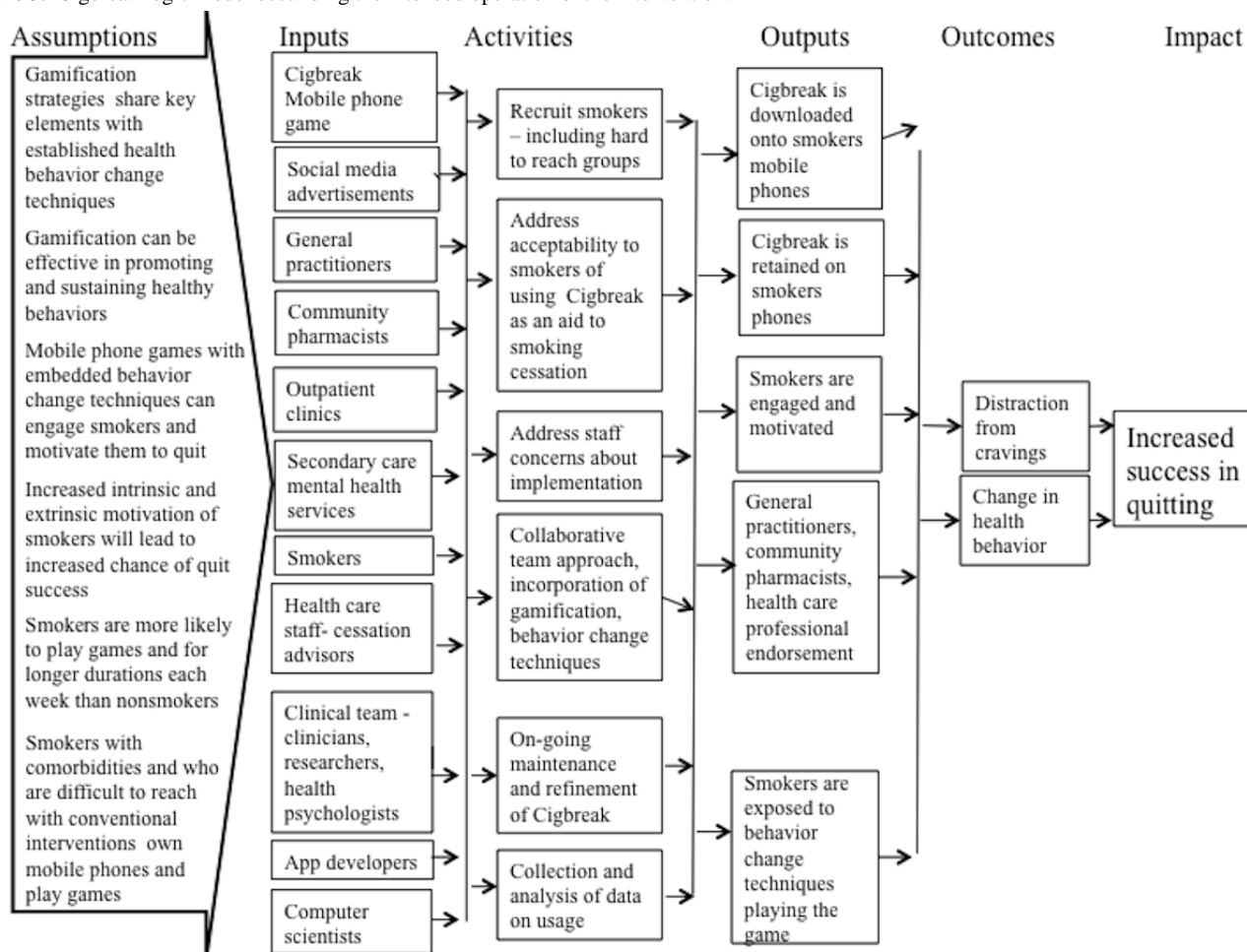
Table 5. Key themes identified by Cigbreak users to aid app development.

Theme	Subthemes	Quotes
Health	Players wanted more emphasis on health gains; Players wanted more hard health facts and graphic imagery; Players wanted the characters' lungs to be linked to reality	• *I want to know the other benefits.* • *I like the lungs in the corner but they need to be linked to reality. I need fear to motivate me.*
Personalization	Players wanted the game to be more personalized and wanted a personalized avatar	• *I want the game to be personalised to me.* • *I like the character in the corner, but I want to personalise him.*
Goals	Players wanted goal setting linked to real life behavior	• *I want to go on holiday so my goal is to save £x.*
Levels or graphics	Players wanted more variation in the levels; Players wanted the game to become increasingly more difficult; Players wanted more interactive graphics; Players wanted brighter colors and graphics	• *Needs more variation to keep you interested.* • *It needs to get harder and harder and needs to be more engaging.* • *Needs to be more interactive and enticing.* • *Needs to be brighter in color.*
Financial	Players wanted the financial rewards more related to real life	• *It would be good to see what I have saved per week.*

Table 6. Key themes identified using Cigbreak as a smoking cessation tool.

Themes	Subthemes	Quotes
Distraction	Players felt the game would work as a distraction	• *I think it could work, candy crush saga was my life when I was quitting, so if it was related to smoking that would be even better.* • *It's a good distraction.* • *It definitely stops me thinking of cigarettes.*
Cravings	Players felt the app could be used at times of cravings	• *I would pick this up and play when I had a craving.* • *I could use this at the bus stop when I get cravings.*
Availability	Players would be happy to obtain from their pharmacy or GP[a]	• *Every GP should know about it, to give it to their patients.*

[a]GP: general practitioner.

Discussion

Principal Findings

A qualitative approach working directly with the target population at an early stage was key to the design process. Feedback on early prototypes helped us to gain an understanding of the problem [24], establish user preferences, and ensure desired functions were included [24,68].

Forming an expert development team was vital to ensure that our app was evidence based and potentially effective [69]. Computer scientists and app developers were included to implement game elements and health psychologists, clinicians, and researchers for incorporation of BCTs. Careful consideration of which BCTs to include was needed, with a clear understanding of which techniques are theoretically linked to the required mechanisms of action [70].

It was found that including imagery of cigarettes and smoking-related cues did not act as a trigger to smoke. Feedback from the qualitative work suggested that a smoking-related game would be more engaging compared with a nonsmoking–related game as attentional bias is toward smoking when craving occurs. The literature also supports this finding. A randomized controlled trial compared Nicot, a video game in which players crush virtual cigarettes in a 3D game environment, with a balloon popping game. Nicot was found to improve smoking cessation rates by 13% [70]. Sanders-Jackson and colleagues found along with Due and colleagues, Hogarth and colleagues, and Meinke and colleagues that individuals who have chemical addictions are more likely to attend visually to objects associated with their addiction [71-74].

It was found that participants wanted to have positive rather than negative messaging and imagery. Gain-framed messages shift smoking-related beliefs, attitudes, and behaviors toward the direction of avoidance and cessation [75,76]. However, Mayes and colleagues found that a combination of both might be beneficial, specifically in younger smokers [77]. Moorman and Putte found that a positive frame is preferable when nicotine dependence or quitting intention is lower, and conversely, a negative frame worked better when nicotine dependence and quitting intention are both high [78].

Comparison With Prior Work

There are currently no published frameworks for production of gamified health apps with systematic inclusion of BCTs or use of behavior change theory.

Several nongamified health apps use an iterative user-centered design process [9,13,79-136]. Most apps are designed by an expert multidisciplinary team. However, only 3 explicitly used agile development [137-140], although this form of technology development is gaining in popularity, and it is anticipated that there will be greater use in the future.

There are several published frameworks for developing nongamified health apps [26,139,141-147]. The Schnall and colleagues framework uses the Information Systems Research framework [141,148]. The Goyl and colleagues framework [143] combines knowledge to action [149] and the MRC framework for complex interventions [33]. The Tombor and colleagues framework [26] is also guided by MRC framework for complex interventions and Multiphase Optimization Strategy [35,150]. Moreover, 6 frameworks also consider the incorporation of behavior change theory. Curtis and colleagues adopted the behavior change wheel (BCW) [144,151]. Tombor and colleagues also uses the BCW and the BCT taxonomy version 1 [26,45,151]. Wilhide and colleagues consider behavioral models [142], whereas Goyal and colleagues and Whittaker and colleagues incorporate social cognitive theory [143,146,152]. Mummah and colleagues combine use of both theory and a taxonomy [145]. Of the frameworks, 3 do not incorporate any form of behavior change theory [139,141,147].

As this area of research is still nascent, it is unclear if any of the above approaches are superior to the approach adopted. The framework recommend is based on our experience in having a successfully developed gamified health app rather than empirical evidence. Recent frameworks including our own are designed around guidelines for complex interventions involving a systematic development process with an iterative user-centered approach based on theory and evidence. It is likely that these elements are key for the development of health apps that may be effective at modifying health behaviors.

Strengths and Limitations

Although there are smoking cessation apps that incorporate gamification techniques, to date, there is no publicly available dedicated game to promote smoking cessation or guidance for

the development of gamified health apps. Raiff and colleagues have developed a prototype smoking cessation mobile phone game using the concept of contingency management (delivering rewards contingent on objective evidence of smoking abstinence) with virtual in-game rewards and social connectivity. The prototype game differs from Cigbreak in concept and mechanic, with the prototype game involving swiping pollen-gems, not including imagery of cigarettes or smoking-related cues. In addition, 71% of participants in a small usability study reported that the program would help them personally to quit smoking [153]. The prototype has not yet been released on app stores and is still in development.

In this study, an example is provided of a systematic approach for developing a gamified smoking cessation app with systematic use of BCTs and evidence-based practice guided by user input. This could provide a potential methodology for development of other gamified health apps. However, the framework proposed has not been evaluated, and thus it cannot be concluded that apps developed using this framework are superior or that the methods adopted are superior to other methods. Future work could include a comparison of usability or acceptability outcomes and behavior change outcomes for apps developed using this framework compared with apps that have not used this framework. The rapidly changing technological landscape and change in sophistication of users may limit the applicability of the findings to future app development.

There are further limitations to the methods adopted. Focus groups can be subject to group bias; however, in turn, small focus groups can generate a natural open discussion, providing fruitful feedback as to usability. Participants were given different iterations of the app to use during the focus groups, which may potentially have biased participants to focus on the functionality of the app presented to them. However, this is a natural consequence of agile iterative development. Only 1 trained researcher independently analyzed the focus group transcripts, which may have led to bias; however; any uncertainties found were discussed with the study team.

Although Cigbreak has been made available to the public on a small scale, the app has not yet been formally evaluated against clinical endpoints. A rigorous evaluation to assess impact on short- and long-term quit rates is being planned.

Implications for Clinicians and Policy Makers

Mobile phone games could provide a potentially cost-effective platform for health promotion and thus have a substantial public health impact. However, developers of digital interventions need to adhere to existing regulatory frameworks and emerging standards [24,69] to develop games that health practitioners can feel confident to recommend to patients.

Questions remain as to the best way to evaluate health apps in this rapidly changing field, without stifling innovation. Michie and colleagues present recent consensus from experts at an international workshop on digital interventions in relation to health behaviors, concluding that evaluations should be made during all phases of the development cycle and need not rely solely on traditional methods [69]. New experimental methods and adaptive research designs such as A/B testing and N-of-1 studies may be used to make best use of rich data streams and assess outcomes within shorter time frames [69]. There is considerable scope for using emerging methods of analyzing observational data in this context [60].

Unanswered Questions and Future Research

Further work is needed to identify potential causal pathways and mechanisms in health apps in general and specifically for Cigbreak. Existing methods such as structured equation modeling and pathway analysis can be applied to study short-to medium-term effects such as Cigbreak engagement. However, current methods only explore assumed causal relations between limited numbers of variables and are not well adapted to complex models or digital interventions. Thus, there are exciting possibilities for future development of more refined analysis of applications and for generating ecologically valid, real-time objective data.

Game analytics provide a rich source of data, and machine learning techniques can be used to make changes to the game design to improve the users' experience and potentially to modify health outcomes. The key is to ensure that the correct metrics are captured during gameplay and then to use the techniques to identify patterns in the data. It should then be possible to change gameplay adaptively to optimize some chosen criteria. These methods could be used to change health behavior if this is being captured as one of the metrics. Bauckhage and colleagues [154] discuss a number of the methods in clustering game behavior data, and use of such techniques in Cigbreak is currently being explored. Future research also aims to ascertain which components of a multicomponent intervention such as Cigbreak are accounting for what effects.

Authors' Contributions

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Conflicts of Interest

HC is a mobile phone game developer and director of Healthy Games.

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Abbreviations

BCT: behavior change technique
BCW: behavior change wheel
NRT: nicotine replacement therapy

<u>Original Paper</u>

How LGBT+ Young People Use the Internet in Relation to Their Mental Health and Envisage the Use of e-Therapy: Exploratory Study

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Abstract

Background: Lesbian, gay, bisexual, and transgender (LGBT) youth and other young people diverse in terms of their sexuality and gender (LGBT+) are at an elevated risk of mental health problems such as depression. Factors such as isolation and stigma mean that accessing mental health services can be particularly challenging for LGBT+ young people, and previous studies have highlighted that many prefer to access psychological support on the Web. Research from New Zealand has demonstrated promising effectiveness and acceptability for an LGBT+ focused, serious game–based, computerized cognitive behavioral therapy program, Rainbow Smart, Positive, Active, Realistic, X-factor thoughts (SPARX). However, there has been limited research conducted in the area of electronic therapy (e-therapy) for LGBT+ people.

Objective: This study aimed to explore how and why LGBT+ young people use the internet to support their mental health. This study also sought to explore LGBT+ young people's and professionals' views about e-therapies, drawing on the example of Rainbow SPARX.

Methods: A total of 3 focus groups and 5 semistructured interviews were conducted with 21 LGBT+ young people (aged 15-22 years) and 6 professionals (4 health and social care practitioners and 2 National Health Service commissioners) in England and Wales. A general inductive approach was used to analyze data.

Results: LGBT+ youth participants considered that the use of the internet was ubiquitous, and it was valuable for support and information. However, they also thought that internet use could be problematic, and they highlighted certain internet safety and personal security considerations. They drew on a range of gaming experiences and expectations to inform their feedback about Rainbow SPARX. Their responses focused on the need for this e-therapy program to be updated and refined. LGBT+ young people experienced challenges related to stigma and mistreatment, and they suggested that strategies addressing their common challenges should be included in e-therapy content. Professional study participants also emphasized the need to update and refine Rainbow SPARX. Moreover, professionals highlighted some of the issues associated with e-therapies needing to demonstrate effectiveness and challenges associated with health service commissioning processes.

Conclusions: LGBT+ young people use the internet to obtain support and access information, including information related to their mental health. They are interested in LGBT-specific e-therapies; however, these must be in a contemporary format, engaging, and adequately acknowledge the experiences of LGBT+ young people.

Introduction

The Mental Health of Lesbian, Gay, Bisexual, and Transgender Young People

Lesbian, gay, bisexual, and transgender (LGBT) young people and other young people diverse in terms of their sexuality and gender (LGBT+) are thought to form up to 12% of the adolescent population [1,2]. Recent systematic reviews have indicated that LGBT+ young people are more likely to experience mental health problems such as depression, self-harm, and suicidality than their age-matched peers [1,3]. For instance, in a meta-analysis of population-based studies, lesbian, gay, bisexual, and other sexuality diverse youth were almost 3 times more likely to have depressive symptoms or a depressive disorder in comparison with heterosexual youth [1]. These greater mental health risks are hypothesized to be caused by minority stress, whereby it is mistreatment and high levels of stress that places LGBT+ young people at greater risk [4,5]. In particular, experiencing mistreatment and stress results in LGBT+ individuals frequently internalizing the negativity associated with anti-LGBT+ messages. This, in turn, can lead to self-loathing and a range of unhelpful cognitions, which are then thought to place LGBT+ young people at greater risk of mental health problems, such as depression [6]. Moreover, it is not unusual for LGBT+ young people to face the challenge of navigating multiple stigmas related to differences such as being LGBT+ and having mental health problems [7] or being an ethnic minority and LGBT+ [8]. In addition to being different and having greater mental health needs, LGBT+ youth are frequently required to manage antagonistic environments in an ongoing manner while simultaneously struggling with a general lack of social support [7]. Given these challenges, it would be logical to assume that there has been a strong focus on providing psychotherapeutic supports for LGBT+ young people. Unfortunately, to date, this has not been the case. Research in the area of psychotherapeutic interventions for this unique population is limited, and LGBT+ young people report difficulties accessing face-to-face professional help for their emotional concerns [9].

Lesbian, Gay, Bisexual, and Transgender Young People and the Internet

The internet has opened up a range of possibilities for LGBT+ young people, including psychosocial support and self-care for mental health problems. This assistance may be especially pertinent for LGBT+ young people, where parental support, a crucial protective factor in adolescence, may be lacking [10]. For example, LGBT+ young people can readily connect with others on the Web, irrespective of where they reside, and as such, the internet has become an important source of support, information, and connection [11,12]. LGBT+ young people can also obtain informal help on the Web to assist them in managing

LGBT+ specific mistreatment (such as homophobia) and in coping with emotional distress [7].

To date, little has been published on how LGBT+ young people use the internet to successfully support their mental health. However, research from Canada and the United States has highlighted that LGBT+ young people are particularly active internet users [13] and use a wide range of Web-based media for information, resources, and support [13,14]. Work from Australia has also highlighted the relative importance of social media for LGBT+ young people, especially for transgender young people [15]. For example, 75% of transgender young people in a study by Strauss et al (n=711) reported that social media use was the most common Web activity participants engaged in to help them feel better [15]. In England, McDermott et al have conducted a Department of Health–commissioned mixed-methods study focused on suicidality, self-harm, and help-seeking in LGBT+ young people [16]. Most LGBT+ young people in their study reported a preference for accessing help through the internet, followed by face-to-face and then text messaging forms of support [16]. Young people in their study had the most positive experiences when asking for help on the Web, as well as from friends, or from LGBT+ youth groups. In contrast, primary care general practitioners and mental health services delivered by the National Health Service (NHS) received low ratings in terms of their perceived helpfulness by LGBT+ young people with mental health problems [16]. Although McDermott et al found that LGBT+ young people value internet-based supports, little detail about the types of e-therapy or on the Web help that could be provided were outlined. Instead, they advocated for "...a more imaginative approach to providing support and help" (p. 170) for LGBT+ young people, and they suggested that services be situated in nonclinical settings such as online [17].

Lesbian, Gay, Bisexual, and Transgender Young People and Electronic Therapy

Formal online mental health interventions have become far more accessible in the last decade; in particular, in the form of computerized cognitive behavioral therapy (cCBT), which has become an effective and recommended form of e-therapy for the treatment of depression [18]. As an intervention, cCBT is particularly promising for LGBT+ young people as it offers opportunities to increase access to treatment. This is because it does not necessarily require therapist support; it can be made freely available to end users; it can be completed in privacy; and it can be made accessible to socially and geographically isolated individuals via the internet [6].

Although LGBT+ young people are an underserved population in terms of their mental health needs, few therapies, online [19] or offline, have been developed for them. A recent systematic review of psychosocial interventions for mental health problems among LGBT+ young people stated that only "A few promising

psychological therapies adapted to meet the needs of LGBTQIA [Lesbian, Gay, Bisexual, Transgender, Queer, Intersex, and Asexual] individuals have emerged in recent years" (p. 2) [10]. This review from Van Der Pol-Harney and McAloon [10] and another review, conducted by Hobaica et al [20], identified only 1 computerized intervention to support the mental health of LGBT+ young people, which was not focused on addressing drug usage, specifically the program Rainbow Smart, Positive, Active, Realistic, X-factor thoughts (SPARX) [10,20]. This intervention is a 7-module cCBT program created for sexual minority young people in New Zealand [21] and is delivered in the English language. Rainbow SPARX has been evaluated in an open trial with LGBT+ young people [21,22] but to date has not been trialed nor appraised for use in the United Kingdom or anywhere other than New Zealand.

It is perhaps surprising that, to date, no e-therapies have been developed or tested for LGBT+ young people in the United Kingdom. This is particularly noteworthy, given that LGBT+ young people have indicated a preference for Web-based help, and there is a strong policy push toward providing more e-therapies in the United Kingdom. For instance, one of the key recommendations when planning services from 2016 to 2021 from the Mental Health Taskforce to the NHS in England was that the NHS "...should expand work on NHS Choices [the main patient-facing website] to raise awareness and direct people to effective digital mental health products..." (p. 42) [23]. Using e-therapies that have already been developed and tested elsewhere could enable health services in the United Kingdom to provide a range of effective treatment options, including for LGBT+ young people.

This Study

This study sought to explore the acceptability of a non-United Kingdom-developed intervention, Rainbow SPARX (Figure 1), for use in British settings. At present, Rainbow SPARX is the only e-therapy focused on addressing depression in LGBT+ youth. Rainbow SPARX is an adapted version of SPARX [21], which is a serious game and form of cCBT for the treatment of depressive symptoms. It uses the medium of a fantasy world, where the user's avatar is faced with a series of challenges to rid a virtual world of gloom and negativity [21,24]. SPARX uses computer graphics and interactive exercises to engage users. Each of the program's 7 modules takes approximately

30 min to complete, and modules have a direct teaching component where the skills from the fantasy world are applied to real life [21]. A randomized controlled trial (RCT) of SPARX was conducted in New Zealand in a general population of young people seeking help for their mental health issues [24]. Per-protocol analyses (n=143) showed that SPARX was not inferior to treatment-as-usual, and postintervention results showed a mean reduction of depressive symptoms [24]. SPARX is now freely available on the Web to anyone with a New Zealand internet protocol address. Following feedback from LGBT+ young people about the importance of refining SPARX for this population, Rainbow SPARX (or SPARX: The Rainbow Version) was made in consultation with LGBT+ young people [6]. An open trial of Rainbow SPARX (n=21) was conducted with LGBT+ young people in New Zealand [21]. This preliminary research highlighted that Rainbow SPARX was a promising intervention in terms of effectiveness by showing a significant reduction of depressive symptoms. This research also showed that it was deemed by participants to be an acceptable form of therapy and was judged to be feasible to deliver [21,22]. However, the cultural relevance of an e-therapy designed in New Zealand needs to be examined in terms of its suitability to young people in a different cultural context. This is because mental health interventions frequently need to be modified to best meet their users' needs across cultural contexts [25,26], and SPARX includes various Māori (ie, indigenous New Zealand) and other South Pacific references. Furthermore, the acceptability of the program to professionals (including mental health practitioners) and commissioners is important to assess, as their views are key to ensuring the funding and promotion of e-therapies is achieved within health services.

Building on prior mixed-methods research related to Rainbow SPARX [6,21,22,27], in this study, we had 2 key research objectives: (1) to explore how and why LGBT+ young people use the internet to support their mental health and (2) to consider the extent to which LGBT+ young people, their parents (or guardians), and professionals think an e-therapy, such as Rainbow SPARX, could be a useful tool to assist in supporting the mental health of LGBT+ young people.

The consolidated criteria for reporting qualitative research [28] were used to guide reporting in this study.

Figure 1. Rainbow SPARX image. SPARX: Smart, Positive, Active, Realistic, X-factor thoughts.

Methods

Ethical approval for this study was obtained from The Open University's Human Research Ethics Committee (reference HREC/2017/2507/Lucassen/1).

Participants

For inclusion in this study, participants needed to be living in the United Kingdom and to be:

- An LGBT+ young person aged 12 to 22 years,
- The parent or guardian of an LGBT+ young person, or
- A professional with either expertise in working with LGBT+ young people or in adolescent mental health service provision or commissioning.

Young people who were exclusively heterosexual and cisgender (ie, those who experience congruence between their gender identity and the sex they were assigned at birth) were not eligible to participate.

Recruitment

Recruitment of LGBT+ young people in research projects is often fraught with challenges and ethical issues [6,27]. For example, many LGBT+ young people are not *out* to their parents, and for those aged less than 16 years, written parental consent is almost always required if they wish to participate in mental health–related studies. In light of the challenges associated with conducting research in this field, we took a pragmatic approach to recruitment in 2 key ways. First, the age inclusion criterion for young people was initially set to be up to 19 years, but because there was considerable interest from LGBT+ young adults (who were already existing members of the youth groups involved in this study), the age range was extended. Hence, participants in this study included young people who were existing members of an LGBT+ youth group. Second, 1 young person who was not a member of any LGBT+ youth groups, but was very keen to take part in the study, was offered an individual interview (with ML and RS present).

Potential participants who were LGBT+ young people and parents of LGBT+ young people were informed about the study via advertising on social media (eg, on closed Facebook groups for LGBT+ individuals and their allies) and from networks of LGBT+ organizations known to or recommended to the authors. For instance, key LGBT+ youth organizations with a Web presence in major cities in the United Kingdom were contacted in London, Cardiff, Manchester, Edinburgh, and Belfast, and staff in these organizations were informed about this research. Primarily, young people heard about the study from staff supportive of this project at relevant LGBT+ youth groups. Potential participants who were professionals were known to the authors and were approached by either ML or LW.

Procedures

The interviews and focus groups were led by ML (a gay and queer male-identified academic experienced in youth mental health work) with assistance from fellow academics (ie, RS and LW). Written parental and participant informed consent was obtained from those LGBT+ young people aged between 12 and 15 years. Adult participants and LGBT+ young people aged

16 years or older provided written consent for themselves. Each interview and focus group began with personal introductions (eg, names and correct gender pronouns) and confirmation of the research objectives and processes; ML explained that he led the development of Rainbow SPARX and also highlighted his interest in supporting the mental health of LGBT+ young people. The semistructured interview guide used in the focus groups and interviews was developed by the authors and reviewed by colleagues independent of this study. See Multimedia Appendix 1 for the focus group guide (the focus group questions were adjusted for the interview format). The questions were open-ended (eg, *What are the main reasons why LGBT+ young people use the internet?* and *In what ways should Rainbow SPARX be adapted to meet the needs of LGBT+ young people in the United Kingdom?*), and discussion was actively encouraged. During the interview or focus group, participants were shown module 1 of Rainbow SPARX, with a single participant controlling the game at any one time while others watched and commented. Participants did not need to have any prior knowledge of this program, serious gaming, or e-therapy. Young people were offered a £20 gift voucher as a gratuity. Interviews and focus groups were digitally audio-recorded and professionally transcribed. The transcripts were thoroughly checked against the digital recordings by ML for accuracy before data analysis began.

Participants completed a brief demographics questionnaire at the end of the interview or focus group. Specifically, young people were asked questions, which included open-response items asking their age, gender or gender identity, and ethnicity. They were also asked about their sexuality (ie, *Please circle below which applies for you: Lesbian, Gay, Bisexual, Questioning, Queer, Not heterosexual, Other [for other, please explain...]*), a closed question about whether they would use Rainbow SPARX and another closed question about whether or not they had suffered from feeling down or low for more than a few days. Professionals were asked their designation (ie, *Please circle below which applies for you: Mental health professional, Commissioner, LGBT Stakeholder, Other[for other, please explain...]*), gender or gender identity, ethnicity, and if they would recommend the use of Rainbow SPARX. Despite considerable attempts to recruit parents of LGBT+ young people, none enrolled in this study (ie, no parents completed the brief questionnaire or participated in an interview or focus group).

In total, 3 focus groups (which were young people and the LGBT+ staff members responsible for these groups only) and 5 interviews (1 LGBT+ young person interview and 4 interviews with professionals) occurred during 2017. They lasted between 51 min and 1 hour and 24 min (mean length 62 min).

Data Analysis

We used a general inductive approach for data analysis [29,30]. This approach focuses on eliciting views and perspectives of participants using preexisting research objectives, rather than generating new theories. A thematic analysis was used because the aim was to explore common themes and interrelationships between themes [30]. Focus group and interview transcripts were read and reread with the research objectives in mind by

ML, RS, and II. Initial codes were independently developed by ML, RS, and II for a focus group and 2 interviews, and after discussion, a common coding framework was developed. This framework was applied by ML and RS to all interviews and focus groups. Codes were then reviewed for redundancies and overlap before higher-order units were created and clustered together. Themes and subthemes were developed and agreed on in consultation with all authors. Microsoft Excel 2013 was used to manage the data and support analyses.

Results

Participants

A total of 21 LGBT+ youth participants took part and they were aged between 15 and 22 years (mean age 17.9 years) (see Tables 1 and 2 for details). Moreover, 6 health and social care professionals participated: 2 were NHS commissioners (1 managerial and 1 clinical), 3 professionals had expertise in LGBT+ youth mental health, and 1 participant was experienced at developing e-therapies.

Figure 2 provides an overview of the study's results. There were 3 main overarching domains: specifically, using the internet and being on the Web, computer games and serious gaming, and the well-being needs and support of LGBT+ young people. Each domain included 2 or 3 themes and then several associated subthemes.

Using the Internet and Being On the Web

The domain of *using the internet and being on the Web* consisted of 3 themes: perceptions of technology and the internet today; the internet as a resource and tool; and digital and personal connections.

Perceptions of Technology and the Internet Today

Several LGBT+ young people and professionals highlighted that the internet is ubiquitous and influential:

> *I think we have grown up and been shaped by the internet, so we know it intrinsically in a way that*

> *perhaps older generations don't...* [YP16, young person, focus group 2]

> *It's fast; it's there; they [LGBT+ young people] have access to [the]internet practically everywhere.* [P5, professional, interview 4]

In contrast, the minority of young people who do not have ready access to the internet were viewed by participants as being socially excluded.

It would appear that from an early age, youth participants begin to discern Web-based resources in terms of their acceptability, and this is then used to assess the suitability of Web-based solutions for different aspects of their lives:

> *...there's online counselling or online suicide helplines, so if you're feeling suicidal or depressed or whatever or you're going to relapse on drugs or self-harm then you can have like this, either you can call a number, you can find that on the internet, or you can do an online chat, which I think is really good, because most people, calling someone makes you feel quite anxious and stuff and I think a lot of people don't want to call, because it's a lot of effort.* [YP20, young person, focus group 3]

Web-based environments were viewed as being unhealthy or unhelpful in several ways by a range of participants. For instance, LGBT+ youth participants cited *Pro-ana* and self-harm sites that *glamorize* mental health problems, such as anorexia and self-harming, as problematic. Professionals also described ways in which the internet creates difficulties for young people in either a more general sense (eg, by young people spending too much time on the Web, and hence, avoiding the *real world*) or in very specific ways. For example, considering how Web-based pornography can generate issues for LGBT+ young people:

> *[it] can maybe make people feel less confident about their bodies, less confident about their sex and their relationships as a result...* [P3, professional, interview 2]

Table 1. Participants' demographic information (grouped by interviews).

Format (researchers present) [setting[a]]	Participant number	Participant category	Age (years)	Sexuality	Gender/Gender identity	Ethnicity
Group interview 1 (ML and LW) [participant's workplace]	P1	Professional (commissioner)	__[b]	—	Male	White British
Group interview 1 (ML and LW) [participant's workplace]	P2	Professional (commissioner)	—	—	Female	White Other
Individual interview 2 (ML) [participant's workplace]	P3	Professional (LGBT[c]+ stakeholder)	—	—	Male	White British
Individual interview 3 (ML) [participant's workplace]	P4	Professional (mental health)	—	—	Male	White British
Individual interview 4 (ML) [participant's workplace]	P5	Professional[d] (LGBT+ stakeholder)	—	—	Male	White British
Individual interview 5 (ML and RS) [city library]	YP12	Young person	19	Gay	Male	White British

[a]Interviews and focus groups were conducted in private spaces.

[b]Not asked.

[c]LGBT: lesbian, gay, bisexual, and transgender.

[d]This professional attended 2 focus groups and participated in an individual interview.

Table 2. Participants' demographic information (grouped by focus groups).

Format (researchers present) [setting[a]] and participant number	Participant category	Age (years)	Sexuality	Gender/Gender identity	Ethnicity
Focus group 1 (ML) [LGBT[b]+ youth center]					
P5	Professional[c] (LGBT+ stakeholder)	—[d]	—	Male	White British
P6	Professional[e] (mental health)	—	—	Female	Black British
YP1	Young person	18	Gay	Male	White British
YP2	Young person	19	Not heterosexual	Male	White British
YP3	Young person	19	Questioning	Male	White British
YP4	Young person	21	Queer	N/A[f]	White Irish
YP5	Young person	18	Gay	Male	White British
YP6	Young person	21	Queer	Nonbinary	White British
YP7	Young person	22	Pansexual	FTM[g]	White British
YP8	Young person	16	Gay	Male	Mixed
YP9	Young person	18	Gay	Male	White British
YP10	Young person	18	Bisexual	Female	White British
YP11	Young person	19	Gay	Male	White British
Focus group 2 (ML) [community center]					
YP13	Young person	17	Bisexual and questioning	Slightly queer	Caucasion (sic)
YP14	Young person	20	Lesbian	Female	White Welsh
YP15	Young person	15	Not heterosexual and asexual	Trans female	Caucasian
YP16	Young person	17	Queer	Queer	White British
YP17	Young person	17	Pansexual	Woman	White Welsh
YP18	Young person	16	Lesbian	Female	White British or Welsh
Focus group 3 (ML) [LGBT+ youth center]					
P5	Professional[d] (LGBT+ stakeholder)	—	—	Male	White British
P6	Professional[e] (mental health)	—	—	Female	Black British
YP19	Young person	15	Transgender or pansexual	FTM transgender	White British
YP20	Young person	15	Gay, questioning, queer, and not hetero	Male cisgender	White British
YP21	Young person	15	Gay, questioning, queer, and not hetero	Male	Black British

[a]Interviews and focus groups were conducted in private spaces.

[b]LGBT: lesbian, gay, bisexual, and transgender.

[c]This professional attended 2 focus groups and participated in an individual interview.

[d]Not asked.

[e]This professional attended 2 focus groups.

[f]N/A: not available.

[g]FTM: female-to-male.

XSL•FO

RenderX

Figure 2. Overview of results. the letter "a" indicates subthemes of particular salience to professionals, and "b" indicates subthemes of particular salience to LGBT+ young people. LGBT: lesbian, gay, bisexual, and transgender; SPARX: Smart, Positive, Active, Realistic, X-Factor Thoughts.

Using the internet and being on the Web

Perceptions of technology and the internet today
- Ubiquitous access to the internet
- Acceptability and engagement
- Problematic aspects of the internet
- Internet safety and security

The internet as a resource and tool
- Seeking information on the Web
- Finding and accessing 'good information' on the Web
- Empowerment enabled online
- Widening access via technology [a]

Digital and personal connections
- Digital communities and interpersonal communication
- Online media and company
- Online interpersonal support

The wellbeing needs and support of LGBT+ young people

Recognizing and acknowledging the experience of LGBT+ young people
- Stigma and dual stigmas
- Isolation and visibility
- Young people accessing professional help
- Establishing online LGBT+ communities

Preferences and requirements for therapy and e-therapy
- Keeping up with technological developments
- Demonstrating effectiveness [a]
- Supervised self-help [a]
- Overt versus stealth therapy
- Overcoming commissioning challenges [a]

Computer games and serious gaming

Drawing on gaming experiences
- Gaming audience
- Technical expectations [b]
- Varied gameplay preferences [b]

Rainbow SPARX as a resource for LGBT+ young people
- Purpose of Rainbow SPARX [b]
- Niche audience
- Avatar representation [b]
- LGBT+ specific content [b]

Look and feel of Rainbow SPARX
- Look and presentation [b]
- Feel and experience

For professional and LGBT+ youth participants, internet safety and security issues were important, including the risk of LGBT+ young people being outed on the Web, challenges around how suicidality was safely managed in a Web-based context, and how LGBT+ young people can be specifically targeted for sexual exploitation. For these reasons, digital privacy and confidentiality appeared to be of fundamental importance. As described in focus group 2, with many LGBT+ young people adapting how they used technology for reasons of self-preservation and avoiding harassment:

It's like you can get stalked on Snapchat now. [YP13, young person]

Yeah. [YP17, young person]

That's the other thing. You can also put the ghost mode on so you can't be followed. [YP13, young person]

> *Yeah, because I've only chosen a few people that can see my location and [YP16 is] one of them.* [YP17, young person]

The Internet as a Resource and Tool

LGBT+ youth participants sought resources and material on the Web for reasons such as job searching, obtaining information, and to acquire health-related information (eg, *...how to put a condom on*). Some young people were aware of various organizations that had websites that they could access to support their mental health, and cited national examples such as ChildLine, MIND, and Stonewall. YouTube was also mentioned as a resource for mental health by several LGBT+ youth participants, for example:

> *...YouTube videos of like, because I have anxiety and my counsellor suggested doing something called, well, they suggested doing something called mindfulness, so like there are just some good videos on the internet of guided meditation and stuff which helps me through my anxiety.* [YP20, young person, focus group 3]

A common challenge mentioned by several professionals and LGBT+ youth participants was finding and accessing *good information* on the Web. As a professional highlighted:

> *...the issue with the internet is you have to know which of these multitude of sites is the one for you.* [P4, professional, interview 3]

Several participants shared examples of how the internet was an empowering tool or force for LGBT+ young people. For instance:

> *RUComing Out [a LGBT+ website], which shares celebrities but also real people's experiences of coming out...And through that as a means to actually learn, discover, feel like there's someone like them out there is really good.* [P3, professional, interview 2]

Professionals, in particular, highlighted that the internet was a valuable medium by which access to mental health services could be widened to potentially include *24/7* support. However, LGBT+ young people were acknowledged as being one of the *hard to reach groups*, and there would be some people who would not be comfortable accessing mental health services on the Web. Professionals also reinforced that any help on the Web should be blended with face-to-face therapy treatment options.

Digital and Personal Connections

Social media enabled LGBT+ young people to communicate freely with others and to be part of Web-based communities, something that was especially important to several youth participants:

> *I think with LGBT people it's different, because I'd say we're a more, what's it called, a hated group by some people, and a bullied group so we would need more support.* [YP20, young person, focus group 3]

LGBT+ young people can also usefully connect with others who share their experiences and provide support online in ways that would be difficult for them to do in person:

> *...[The internet is] a really big support system...because not all, but most of the LGBT community have had hard times and they can all identify and relate with each other, so for the older [members of the]community they help out the younger [LGBT+ people] that are struggling.* [YP19, young person, focus group 3]

The internet was used for entertainment purposes (eg, to watch sports, shop online, and listen to music) as well as for other reasons. For instance, pornography was viewed as being both fun and for *sex education*, whereas selected forms of Web-based media provided helpful distraction (or company).

One LGBT+ young person said:

> *Yeah and I also use the internet, when I'm feeling low and depressed I also use it to distract myself. It's a good coping mechanism, because it's better than self-harming or getting too deep into my thoughts and having all these suicidal thoughts in my head, I can watch YouTube videos or I can go on Instagram or Tumblr or whatever...* [YP20, young person, focus group 3]

Computer Games and Serious Gaming

The domain of *computer games and serious gaming* consisted of 3 themes: drawing on gaming experience; Rainbow SPARX as a resource for LGBT+ young people; and the look and feel of Rainbow SPARX.

Drawing on Gaming Experiences

Most of the LGBT+ youth participants reported playing a range of commercial games (eg, Rage, Skyrim, Mortal Kombat, and The Sims). They also outlined a variety of gameplay preferences: the game's style of graphics; whether the game had a prologue; the amount of dialog that was used; and the degree of violence portrayed.

Some participants could see the therapeutic value of commercial games for mental health, as outlined by an LGBT+ young person:

> *I play a lot of the Lego games, just because they're all the same controls and it's easy and they're so not stressful...I can just sit there and just zone out and just do anything, because they're meant for like five-year-olds, so it's fantastic.* [YP17, young person, focus group 2]

However, despite serious games being seen by some as valuable for those uncomfortable engaging with face-to-face therapy, challenges were identified for developing a serious game that would be acceptable to a range of LGBT+ young people. For instance, participants noted that such games would need to work for those of different abilities, levels of maturity, and stages of acceptance and understanding of their LGBT+ identities.

LGBT+ youth participants, in particular, highlighted that a mental health serious game should be available across a range of Web-based platforms (eg, on mobile phones, computers, and tablets). Moreover, a mobile serious game should not take up too much data storage.

The Rainbow Smart, Positive, Active, Realistic, X-Factor Program as a Resource for Lesbian, Gay, Bisexual, and Transgender Young People

After trialing module 1 of Rainbow SPARX during their interview or focus group, LGBT+ and professional participants recognized the purpose of the program (ie, it was intended to be a mental health tool for LGBT+ young people). However, several youth participants really wanted a more explicit focus on them and their particular needs, and some participants felt that Rainbow SPARX was inadequate as an LGBT+ resource:

> ...they don't focus on the LGBT side of it, point blank, it is just mental health and I think if you were to do that it needs to be marketed as such. You can't just change a few words around and have a slightly different message at the start and say "oh yeah it's a completely different game for LGBT people." [YP16, young person, focus group 2]

Several LGBT+ youth participants also indicated that the language used in Rainbow SPARX was sometimes problematic:

> ...it mentions guys who like guys, like why don't they just use the proper term? [ie, gay]. [YP18, young person, focus group 2]

In contrast, professionals appeared less concerned about whether the program had sufficient LGBT+ content and appeared more focused on whether Rainbow SPARX was too niche to be viable for a rollout:

> I think there would be, given we're talking about already a minority group. I think a minority of that minority group would find that platform quite attractive to use perhaps. [P1, professional, interview 1]

Some LGBT+ youth participants also raised concerns about the avatar in Rainbow SPARX, in particular, the forced sex binary inherent in the program (ie, the user can only customize a male or female avatar with *no in-between* option). Although the avatars could already be customized in gender nonconforming ways (eg, the male avatar can have a *girl haircut* and wear luminous pink clothes), it was thought to be especially important to some youth participants to have nonbinary options for gender diverse users of the program.

Look and Feel of Rainbow SPARX

Several LGBT+ youth participants liked the *concept* of Rainbow SPARX, and they appeared to enjoy using the program:

> Do you know, I'd definitely play that... [YP1, young person, focus group 1]

Furthermore, the affective experience for some youth participants using the program was positive:

> I really liked it. I would play it if it was released. I think it's good, like it's entertaining just as a game like if you were feeling stressed or bored or sad it would just take your mind off of it because it's quite fun to do and then also I think it is good just the messages and stuff, I don't know, it just cheered me up. [YP12, young person, interview 5]

By contrast, a few young people reported that Rainbow SPARX was *patronizing*, and it would not be helpful for LGBT+ young people. In addition, participants also suggested that Rainbow SPARX was dated or needed refining in terms of the graphics:

> ...I don't know exactly how it all plays out in the computer game world. But I think it's pretty cutting edge...and that if you're competing with that then that's [Rainbow SPARX] going to look I think quite basic in comparison... [P3, professional, interview 2]

They also highlighted issues in terms of speed:

> It needs to be faster, it's far too slow. [P1, professional, interview 1]

And the controls:

> I feel like maybe the actions and the freedom to move and what you could do on the game could be developed, like the movement was quite simple and stuff like just playing it and fighting the bad spirits... [YP12, young person, interview 5]

There was also some discussion between LGBT+ youth participants about whether the spoken dialog in Rainbow SPARX was always understandable. There were times when young people seemed to struggle with the Māori (New Zealand indigenous language) phrases used in the program and a character's accent. For example, the term takatāpui (a traditional Māori term meaning *intimate companion of the same sex*) was used in Rainbow SPARX, and this was a new word for participants in this study.

The Well-Being Needs and Support of Lesbian, Gay, Bisexual, and Transgender Young People

This domain consisted of 2 themes: recognizing and acknowledging the LGBT+ youth experience and preferences and requirements for therapy and e-therapy.

Recognizing and Acknowledging the Experience of Lesbian, Gay, Bisexual, and Transgender Young People

LGBT+ youth participants described forms of mistreatment and other challenges that their heterosexual peers would not face. In particular, their family not accepting them because they are LGBT+ and the difficulties associated with accepting oneself, in part, because of internalized negativity:

> ...So when I was sprouting into the blossom that I am now, that part of the conflict came from not knowing what it [my own LGBT-specific identity] was. And the only context I'd ever heard of it being in-between was in like a promiscuous context like "oh that's what people do if they have loose morals or anything" [YP17, young person, focus group 2]

Furthermore, being transgender was described as being more stigmatized and resulting in increased mistreatment by a few participants, compared with those who were diverse in terms of their sexuality:

> I think trans people are probably more at risk than LGB people, because it's less normalized...So it's like really overwhelming and stuff and I feel like, I don't know, I feel like there's more people on the internet

preying on T people than LGB generally, because it's easier to spot someone out and there's more trans people who are like excluded from their families and stuff. [YP12, young person, interview 5]

LGBT+ youth participants recognized that dual stigma could be an issue for LGBT+ young people, whereby they could be faced with the stigma associated with having mental health problems as well as the stigma linked to being LGBT+. Being isolated was also reported to be an issue, with this being *probably the worst thing.* To combat this, participants mentioned the value of LGBT+ characters on television and LGBT+ celebrity role models who were *completely unapologetic* about who they are (eg, Stephen Fry and Sir Ian McKellen), as a way to increase visibility.

Professionals also recognized that stigma creates barriers to LGBT+ young people getting help:

I think almost this group has double stigma because you would have the one around disclosing that you might have some mental health difficulties, and then the additional stigma of being, lesbian, gay, or transsexual on top of that. So there would be quite a lot of barriers for you to come out and start talking about how you feel about things. [P2, professional, interview 1]

Developing and maintaining LGBT+ communities on the Web was especially important for youth participants. This allowed them to date other LGBT+ young people and engage in leisure activities with other LGBT+ youth (eg, an online friendship had the potential to lead to face-to-face activities), and it provided a sense of LGBT+ community and belonging.

Preferences and Requirements for Therapy and Electronic Therapy

Participants reinforced that CD-ROMs and websites were viewed as outdated means by which to offer an intervention. Access issues would also need to be taken into account; for instance, Wi-Fi is not always freely available to young people, so it was recommended that Web-based e-therapies have a downloadable option. Serious games presented their own set of problems in terms of the need to move in line with expectations based on commercial games:

I think what you need to think about as well is the life span of the game. So gaming in general will have updates every single year because there is quite a lot of competition. [P2, professional, interview 1]

Some professional participants were particularly concerned with the effectiveness of an e-therapy. RCTs were cited as a means to provide the evidence required to demonstrate that an e-therapy was effective, and so the focus was on demonstrating effectiveness at a population level although their limitations were recognized:

I suppose it's a question about a rigorous evaluation, you know, like an RCT, versus something which is, I don't know, a sort of user-experience evaluation where we're not going to randomize people because if people want to use it then they should be able to

use it, you know, rather than saying well, fine but we're going to randomize you to a waitlist control now. [P4, professional, interview 3]

In contrast, LGBT+ youth participants seemed to evaluate cCBT interventions (such as Rainbow SPARX), more generally, in terms of their ideas about the perceived usefulness of the CBT content:

...where it [Rainbow SPARX] said things that you can do or ways you can think to change how you feel. Which is a concept that works but sometimes it's really not helpful to hear. And it's obviously not that exciting. [YP4, young person, focus group 1]

Professional participants were especially concerned that any e-therapy has sufficient moderation and guidance to ensure risk is managed effectively. There was a consensus among professionals that an e-therapy should be provided in a blended way so that LGBT+ young people always had the option of face-to-face therapy, if required.

Among LGBT+ youth participants, there was some debate about how explicit therapy should be in a serious game, with some suggesting that this should almost be achieved by stealth:

So do you think there's a way that you could innovate the game to where it's not therapy talk...it's just, it's a way of not thinking that it's therapy talk. [YP4, young person, focus group 1]

Commissioning e-therapies on the NHS requires certain criterion be met, specifically around effectiveness and safety, as explained by a commissioner:

...in our specification we will have a standard sentence around that it has to be evidence-based. And you sort of hang all sorts of things off that really. So in the procurement process we went through they had to show us evidence of how that particular sort of online service was going to work and that it was going to be safe. [P2, professional, interview 1]

However, commissioning was acknowledged by some professionals to involve further challenges; in that, for an e-therapy to be *attractive* for a health service commissioning body, it would need to be relevant to *a huge group* of young people for each commissioning body to support its implementation.

Questionnaire Responses

Of 21 LGBT+ youth participants, 18 (18/21, 86%) indicated that they had felt down or low in the past (based on the single question: *have you ever suffered from feeling down or low for more than a few days in a row?*). The remaining 3 participants (YP8, YP9, and YP11) reported having not previously suffered from feeling down or low. Most professionals said that they would recommend Rainbow SPARX to an LGBT+ young person who was *feeling down* (4/6, 67%), whereas only 38% (8/21) of the youth participants reported that they would use Rainbow SPARX if *feeling down* themselves. Most participants provided comments about why they would or would not use (or recommend) the program (see Table 3).

Table 3. Participants' written responses.

Would recommend use of Rainbow SPARX[a]	Comments
Professionals	
Yes (n=4)	• "I would recommend that they try it, but would follow up to see if they felt their needs were met, or if further assistance was required." [P1, professional, interview 1] • "Yes in principle, but would like to see final version [ie, all 7 modules] first before recommending." [P2, professional, interview 1] • "As part of or accompanying face-to-face intervention." [P3, professional, interview 2] • I think it's a great, accessible self help tool" and "Lovely game, very useful, accessible." [P5, professional][b]
Possibly (n=1)	• "Possibly – depends on whether they feel the internet intervention would be helpful. Many prefer face to face interventions." [P4, professional, interview 3]
No (n=1)	• "I think they need someone to talk to face to face" and "It will provide extra support." [P6, Professional][b]
Young people	
Yes (n=8)[c]	• "I enjoyed it." [YP12, individual interview 5] • "It's awfully good." [YP17, focus group 2] • "For anxiety and when my mood is especially low." [YP 19, focus group 3] • "For anxiety." [YP20, focus group 3] • "I think it could help up to a poin[t] [sic]." [YP21, focus group 3]
No (n=13)[d]	• "I have nothing to add." [YP2, focus group 1] • "Would rather develop skills when better." [YP4, focus group 1] • "Bit too basic and CBT for my liking." [YP6, focus group 1] • "I'd see my care coirdinator [sic] instead." [YP7, focus group 1] • "I don't require a game to make me feel better I have [P5, Professional – LGBT+ stakeholder] and [P6, Professional – Mental health]." [YP8, focus group 1] • "I don't think it would help me." [YP13, focus group 2] • "More of a distraction than how to solve a problem." [YP14, focus group 2] • "Outdated system/terms." [YP15, focus group 2] • "No thanks." [YP16, focus group 2] • "Skims over topic at hand." [YP18, focus group 2]

[a]SPARX: Smart, Positive, Active, Realistic, X-factor thoughts.

[b]The same participant completed 2 surveys.

[c]Participants YP1, YP3, and YP11 did not provide a written comment, for reasons unknown to the authors.

[d]Participants YP5, YP9, and YP10 did not provide a written comment, for reasons unknown to the authors.

Discussion

Principal Findings

This study sought to explore 2 main research objectives. First, to explore how and why LGBT+ young people use the internet to support their mental health. This is important to consider to minimize the risks of developing interventions that do not address LGBT+ users' needs or do not fit-in well with how LGBT+ young people use the internet. Notably, rather than accessing existing e-therapies developed for the general youth population, young people in our study created personal pathways to use the internet for enhancing their mental health (eg, by locating resources on mindfulness via YouTube). Their apparent lack of knowledge about e-therapies, combined with the challenges associated with finding and accessing *good information on the Web*, suggests that even if LGBT+ e-therapies were made available, they would be difficult for LGBT+ young people to locate. Therefore, it is not simply the development of e-therapies and demonstrating their effectiveness that needs consideration but also their dissemination and

ensuring they are adequately and appropriately supported in the real world [31]. Another issue of relevance for LGBT+ young people was cyberbullying and stalking. Professional participants, in particular, were concerned about the safety and the personal security of LGBT+ young people on the Web and described concerns about the risk of Web-based sexual exploitation. Hence, e-therapies for LGBT+ young people will need to carefully consider these issues in their development, evaluation, and implementation.

The second objective of this study was to elucidate whether LGBT+ young people and professionals consider an e-therapy, such is Rainbow SPARX, as a useful tool to assist in supporting the mental health of LGBT+ young people. Most of the professionals indicated that they would recommend the program to an LGBT+ young person who was *feeling down*, whereas only 8 of the 21 LGBT+ young people indicated that they would use Rainbow SPARX in this context. In part, usefulness will be about effectiveness, but another important factor to consider is acceptability. A key means by which to enhance acceptability is to use codesign or coproduction processes. This study found

diverse attitudes to gaming preferences as well as different opinions about the appeal of Rainbow SPARX and factors related to LGBT+ identities. It will be important that future e-therapy codesign approaches for this population pay special attention to ensuring that a range of LGBT+ individuals take part in these processes, in particular, transgender young people [32]. Rainbow SPARX was originally developed using codesign methods [6]. However, these processes occurred some years ago and in a different cultural context (that of New Zealand). As LGBT+ young people are coming out at increasingly early ages [33], they are now even more likely to require content that is specific to their experiences as LGBT+ individuals, especially because the majority of existing LGBT+ services are provided for adults in large urban centers. Another challenge relates to the use of serious games as a therapeutic medium. In particular, the pressure to remain as up-to-date as possible relative to commercial games, as these games appear to be the base of comparison from which young people draw on when critiquing an e-therapy delivered in a game-like format.

Comparisons With Prior Research

A considerable body of research has been published, which reinforces that LGBT+ young people are an *at-risk* population in terms of their mental health. However, to date, very few studies have focused on the means by which to address the mental health problems that arise from hostile environments [4] from which LGBT+ young people may not be able to escape. For instance, in a recent systematic review of empirically based psychological treatments conducted with LGBT+ young people, Hobaica et al identified only 8 such interventions [20]. Of the 8 interventions, 3 were Web-based, specifically: Rainbow SPARX; *Queer Sex Education* (an inclusive sex education intervention); and a Web-based drug abuse prevention intervention [20]. Another similar systematic review, conducted by Van Der Pol-Harney and McAloon [10], highlighted only one e-therapy for mental health problems (ie, Rainbow SPARX). However, the e-therapy field is rapidly evolving, and the developers of AFFIRM (a group-based CBT intervention for LGBT+ young people, cited in both reviews) [34] have highlighted their intention to expand their program. In particular, it is hoped that, in the future, AFFIRM can be delivered in Web-based format [35]. We identified another e-therapy intervention in the field of LGBT+ mental health called TODAY. This tool is a mobile phone intervention for the treatment of anxiety and depression and was developed in the United States. TODAY has been subjected to usability testing [36]. However, to date, it has been exclusively evaluated to inform further development among gay-identified young men (aged 18-20 years) [36]. Given that Web-based psychosocial tools are valued by LGBT+ young people [16] and that they can be made accessible to socially and geographically isolated individuals [5], effective and acceptable e-therapies should be made available to LGBT+ young people in the United Kingdom and elsewhere. It is probable that funders of e-therapies may argue that the target population is not large enough to justify the investment. But given the extent of the problems [1,3], that LGBT+ young people are coming out earlier [33], and that therapy access issues have previously been identified [9], early intervention is warranted. Rollout is also likely to be more cost-effective if LGBT+ resources can be funded across several clinical commissioning groups or public health departments.

For e-therapies to be used meaningfully by LGBT+ young people, they will need to include relevant content. Although e-therapies are demonstrably important tools in addressing mental health problems, the vast majority are designed for a general population [37]. But these *mainstream* tools do not address the needs of LGBT+ individuals. For instance, Rozbroj et al reviewed Web- and app-based interventions for the prevention and treatment of depression and anxiety in relation to the degree to which they would meet the needs of lesbians and gay men (of note, the review was not inclusive of bisexual or transgender individuals). They found that the tools largely neglected core issues for lesbians and gay men [37], such that more than half (14 of 24 interventions) contained instances that assumed or suggested the user was heterosexual. Moreover, only 1 intervention explicitly addressed homonegativity, and only 1 tool referred to same-gender relationships [37].

Given the findings from this study, which indicated that a minority of LGBT+ young people who participated in this study would use Rainbow SPARX, but that discussions revealed others might if the content and format were improved, this research suggests that adapting existing resources designed for LGBT+ youth can be a worthwhile endeavor. Nonetheless, whether new LGBT-specific e-therapies are created or whether they are modified from existing interventions, to ensure they are up-to-date, all e-therapies need to be more rapidly tested and implemented [38].

Implications

In this exploratory study, we have highlighted that LGBT+ young people are interested in mental health support via the internet and that e-therapies should be tailored for LGBT+ young people and their cultural context. We have further identified that the needs and preferences of LGBT+ young people are diverse and, in some cases, polarized. For example, the affective experience with Rainbow SPARX included those LGBT+ young people reporting positive emotions associated with the program and others, in contrast, who felt patronized by the language used within the game. It may not be as simple as developing 1 tool or approach that suits all LGBT+ young people. However, there could be future scope to develop multiple *layers* within the same e-therapy (game-based or otherwise) that are tailored to appeal to different developmental or maturity levels. This is an approach we intend to explore in the future. An approach that is personalized in this way could allow for the customization of language and design that is deemed acceptable for a wide range of LGBT+ young people. This would be useful because choice and control are obviously important considerations in the design of serious games for adolescents [39]. Furthermore, this study has shown that timeliness or recency of approach is important because internet intervention's date and the expectations of LGBT+ young people appear high.

Limitations

This is a small-scale exploratory study, and as is not uncommon in research conducted in the area of LGBT+ mental health, recruitment had its challenges [27]. The study included 4

LGBT+ young people aged older than 19 years (whereas Rainbow SPARX was designed for young people up to this age) with the oldest participant being aged 22 years. However, these participants were established members of their youth group, they were keen to take part in a focus group, and they provided useful insights, as young people just outside of the initial target age range.

This study's sample was not representative of all LGBT+ young people in the United Kingdom or the professionals working with them. Furthermore, not all LGBT+ youth organizations in the United Kingdom are likely to have been contacted, especially those organizations that do not have a Web presence outside of London, Cardiff, Manchester, Edinburgh, and Belfast. Some young people from the organizations contacted may not have heard about this study. Regardless of our attempts to recruit them, no parents or guardians of LGBT+ young people took part in this study. Despite this, we had a range of LGBT+ young people and professionals taking part in this study, including young people questioning their sexuality and those who were nongender binary. We had a strong sense that no new concepts or ideas were raised on the conclusion of focus group 3. Transcripts were not returned to LGBT+ youth or professional participants for comment or for participants' feedback on the findings. No field notes were taken.

When using Rainbow SPARX in focus groups, only 1 young person played the game at a time while others watched and commented. However, Rainbow SPARX was designed for use in a single player format. It is, therefore, possible that using the program in this manner influenced how much participants were able to engage with this e-therapy. Moreover, participants knew that ML led the development of Rainbow SPARX, and as such, young people may have felt reserved in relation to expressing criticisms of the program. To attempt to remedy this, every participant was explicitly asked to comment on what they did not like about Rainbow SPARX. Nonetheless, it is possible that the results are skewed toward a more positive view of the program. In focus groups 1 and 3, the professionals responsible for these youth groups chose to attend these focus groups. The inclusion of these professionals in 2 youth focus groups is a limitation, as their presence may have influenced what young people said. However, professionals' data from the focus groups were not included in analyses, and our impression is that having these professionals present made young people feel at ease.

Conclusions

LGBT+ young people frequently experience stigma and isolation, and they also have high mental health needs. The internet is an important source of information and support for these young people, and e-therapies appear particularly valuable for this unique population. In this study, the first where Rainbow SPARX was used outside of New Zealand, LGBT+ young people emphasized that e-therapies must be appealing, up-to-date and inclusive of LGBT-specific content. Professional participants reinforced the need for proof of efficacy and that an e-therapy appeals to a sizeable proportion of a population. LGBT-specific e-therapies, such as Rainbow SPARX, show promise, but only those that are tested sufficiently should be made available to support the mental health of LGBT+ young people. To reduce costs and increase access, these tested interventions should be considered for implementation by commissioners across wide geographical areas.

Conflicts of Interest

The intellectual property for SPARX is held by UniServices at the University of Auckland. Any proceeds from licensing or selling SPARX outside of New Zealand will be shared in part with UniServices and KS, TF, MS, and ML. LW is a nonexecutive director of the health service where recruitment of commissioners took place for this study.

Multimedia Appendix 1

Focus group guide.

[PDF File (Adobe PDF File), 33KB - games_v6i4e11249_app1.pdf]

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Abbreviations

cCBT: computerized cognitive behavioral therapy
e-therapy: electronic therapy
LGBT: lesbian, gay, bisexual, and transgender
LGBT+: LGBT and other people diverse in terms of their sexuality and gender
NHS: National Health Service
RCT: randomized controlled trial
SPARX: Smart, Positive, Active, Realistic, X-factor thoughts

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<u>Original Paper</u>

A Web-Based Serious Game on Delirium as an Educational Intervention for Medical Students: Randomized Controlled Trial

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Abstract

Background: Adequate delirium recognition and management are important to reduce the incidence and severity of delirium. To improve delirium recognition and management, training of medical staff and students is needed.

Objective: In this study, we aimed to gain insight into whether the serious game, Delirium Experience, is suited as an educational intervention.

Methods: We conducted a three-arm randomized controlled trial. We enrolled 156 students in the third year of their Bachelor of Medical Sciences degree at the University Medical Centre Groningen. The Game group of this study played Delirium Experience. The Control D group watched a video with explanations on delirium and a patient's experience of delirious episodes. The Control A group watched a video on healthy aging. To investigate students' skills, we used a video of a delirious patient for which students had to give care recommendations and complete the Delirium Observations Screening Scale and Delirium Rating Scale R-98. Furthermore, students completed the Delirium Attitude Scale, the Learning Motivation and Engagement Questionnaire, and self-reported knowledge on delirium.

Results: In total, 156 students participated in this study (Game group, n=51; Control D group, n=51; Control A group, n=55). The Game group scored higher with a median (interquartile range) of 6 (4-8) for given recommendations and learning motivation and engagement compared with the Control D (1, 1-4) and A (0, 0-3) groups (*P*<.001). Furthermore, the Game group scored higher (7, 6-8) on self-reported knowledge compared with the Control A group (6, 5-6; *P*<.001). We did not find differences between the groups regarding delirium screening (*P*=.07) and rating (*P*=.45) skills or attitude toward delirious patients (*P*=.55).

Conclusions: The serious game, Delirium Experience, is suitable as an educational intervention to teach delirium care to medical students and has added value in addition to a lecture.

Introduction

Delirium is an acute neuropsychiatric syndrome often experienced by older hospitalized patients. It is characterized by altered attention, awareness, and cognition. Delirium has serious consequences such as increased length of hospital stay, functional decline, institutionalization, and mortality [1]. Adequate delirium recognition and management are important to reduce the incidence and severity of delirium [2,3]. To improve delirium recognition and management, training of

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medical staff and students is needed [4] as timely recognition is crucial [2]. Lack of delirium awareness, knowledge, and education were the most commonly reported barriers to improving the recognition of delirium (risk) and the hospital care for delirious patients [5]. Current educational interventions focus merely on increasing knowledge and skills in recognition of delirium but do not seem to be effective enough [6,7]. It was suggested that educational interventions on delirium should have a broader scope to target (1) the attitude of the medical staff and students toward delirious patients; (2) the understanding of patients' needs; and (3) the translation of this knowledge into the practice of offering good health care to delirious patients [7,8]. Future educational interventions on delirium should not only have a broader scope addressing these 3 objectives but also focus on teaching methods with students actively involved and supportive technologies with sufficient feedback loops [6,7].

Serious games may be an opportunity to meet this demand for new educational interventions. Serious games are games developed and intended to provide playful learning experiences, which can be transferable to or applicable in real-life settings [9]. Serious games are often more effective compared with regular health care educational interventions [10] or assessments [11]. However, there is a lack of effect studies [12] and assessment [13] of good quality on serious games.

Delirium Experience is a recently designed serious game that uses video simulation [14], which is intended to train and educate medical students on how to take better care of delirious patients. As both serious games [15] and simulation-based learning [16,17] provide learning spaces in which learners can safely practice, Delirium Experience might serve as a new educational intervention by addressing the need for a focus on caregiver attitude and the application of knowledge to the care of delirious patients.

In this study, we aimed to gain insight into whether Delirium Experience is suited as an educational intervention for medical students regarding skills in advising care for delirious patients, skills in screening and rating of delirium symptoms, and improving the attitude toward delirious patients. Additionally, we aimed to gain insight into the possible effects of Delirium Experience on learning motivation and engagement, as well as self-reported knowledge on delirium.

Methods

Design and Study Population

We conducted a three-arm randomized controlled trial. The study population consisted of undergraduate medical students at the University Medical Centre Groningen (UMCG). To be included in this study, participants had to (1) be in their third year of preclinical education in December 2016; (2) sign up for the practical on delirium; and (3) sign the informed consent form. The UMCG offers an undergraduate program of 6 years—3 years of preclinical and 3 years of clinical education. Preclinical medical students at the UMCG select 1 of 4 different learning communities with different, in-depth focus during their medical education (global health, sustainable care, intramural

care, and molecular medicine). At the moment, the UMCG third-year preclinical medical curriculum on delirium is based on lectures and literature. However, educators of the UMCG emphasize the need for a more practice-based education before students enter their clinical education.

Students started with the conventional lecture on delirium. Thereafter, students could voluntarily sign up for the practical on delirium, in which the study conditions took place. The practicals were given in three separate classrooms of the University of Groningen. Each study condition had a separate classroom. All students had the opportunity to join the practical on delirium, including students who did not wish to participate in the study. Students were informed about the study in the description of the practical. This practical description explained that the practical was divided over 3 different groups for research purposes but did not explain the different study conditions. Students were not aware that the serious game, Delirium Experience, was one of the study conditions, in order not to influence the motivation to sign up for the practical. All students were provided a license of Delirium Experience after the practical so they could play the serious game. Data were collected and analyzed anonymously.

We used SPSS 23.0 (IBM Inc) for stratified block randomization (block size of 6) to allocate participants into one of the three research groups [18]. Learning communities represented the 4 different strata used. All participants who signed up for the practical were randomly allocated to one of the groups. They subsequently received an email indicating the classroom in which they were expected. As our research subjects consisted of medical students who could voluntarily sign up for both the practical and the study, registration of the trial was not necessary in accordance with the ICMJE (International Committee of Medical Journal Editors) recommendations. Multimedia Appendix 1 shows the CONSORT-EHEALTH checklist.

Intervention and Control Groups

We designed three different practicals on delirium, which represented the study conditions. Only the intervention group, the Game group, played Delirium Experience [14]. Delirium Experience is a serious game focusing on delirium both from a patient's and a caregiver's perspective (watch the trailer in Multimedia Appendix 2). The goal of Delirium Experience is to allow players to learn how to take better care of delirious patients. The game tries to achieve this by giving players insight into what a patient experiences during delirious episodes and how your actions as a caregiver influence the experience of the patient. Delirium Experience was based on the delirium guidelines used in the United Kingdom [19] and the Netherlands [20] and on stories of patients who suffered from delirious episodes. The game was developed with personnel who were specialists in developing serious games, designing education, and treating delirium, all working closely together. Usability was tested by a group of care professionals during the development. Based on their suggestions and feedback, the final version of the game was made. Completing the game once takes approximately 20 minutes; in these 20 minutes, one experiences 4 days as a caregiver and the corresponding 4 nights as the patient. During the daytime, as a caregiver, the player has to

take care of a delirious patient and can choose different actions. Depending on the actions one chooses, the delirious episodes of the patient differ in severity, and one gets different actions to choose from the next day. Hence, if one performs poorly as a caregiver, the severity of delirious episodes increases, and the next day, one has fewer actions to choose from compared with a caregiver who performed well. Players who perform poorly have their actions limited to only the most important actions to decrease the level of difficulty. Furthermore, players receive feedback every other day in the game on how they performed and how they could improve as a caregiver before they switch to the patient's perspective.

We compared this Game group with two other groups, one with and one without information about delirium. The first control group, Control D group, watched a video on delirium, which explained delirium causes, symptoms, diagnosis, treatment, and pathology. Contrary to the serious game, the video did not ask for active involvement of students; thus, students were not able to try different scenarios. Furthermore, this group watched a second video of a patient's experience explaining his suffering from delirious episodes.

The second control group, Control A group, watched a more general video on healthy aging. This video did not have any specific information on delirium and how to take care of delirious patients; each session took 20 minutes.

Outcome Measurements

At baseline, before the intervention started, all participants completed a form including questions on sex, age, experience with older and delirious patients, learning community, self-reported knowledge on delirium, *Which mark (0-10) would you give your knowledge on delirium?*, and attendance at the lecture. Primary and secondary outcome measures were assessed directly after the intervention or control condition.

The primary outcome of this research was assessment of the skills acquired by students in advising care for delirious patients, in which students describe how they would manage delirium in practice. In this outcome, students could show their understanding of patients' needs and be able to translate this knowledge into practice [7,8]. To measure skills in advising care, all participants observed an interview of a delirious patient and were asked to give 3 written recommendations for the care of this patient. A predefined rubric-form was used to assess all given recommendations as rubric-forms can enhance the reliability of assessors' scoring [21]. The rubric-form was based on the Dutch delirium guidelines [20]. Recommendations were assessed independently by two researchers, and a weighted kappa was calculated. To ensure blinding of the assessors, data on intervention and control groups were removed from the assessed recommendations. Each recommendation could receive 0 (incorrect or not mentioned), 1 (topic mentioned), 2 (nonspecific recommendation), or 3 (specific recommendation) points from the 10 different domains of the Dutch delirium guidelines (range, 0-9 points) [20].

Subsequently, several secondary outcomes were measured. First, use of screening and rating instruments for delirium was measured. Participants completed the Delirium Observations Screening Scale (DOSS) [22] and Delirium Rating Scale R-98 (DRS-R-98) [23,24] for the patient in the observed interview. Both scales are widely accepted and applied tests for the recognition and severity assessment of delirium. Second, attitude toward delirious patients was measured using the Delirium Attitude Scale. The Delirium Attitude Scale is based on the Dementia Attitude Scale [25]. Items regarding creativeness, enjoyment of life, and coping skills were replaced by items focusing on the experiences of delirium. This resulted in a 19-item 7-point Likert scale (range, 19-133 points). *I feel confident around people with delirium* and *I would avoid an agitated person with delirium* are examples of statements used in the Delirium Attitude Scale. Third, learning motivation and engagement were measured using the Motivation and Engagement Questionnaire to evaluate learning experiences [26], a 9-item 5-point Likert scale (range, 9-45 points). Examples of statements used in this questionnaire are as follows: *It was challenging to perform well in this practical* and *I liked this way of learning.* Finally, participants were asked to self-report their knowledge on delirium (range, 0-10 points).

Statistical Methods

We checked data for normality by judging histograms, skewness, and kurtosis. We analyzed discrete variables using chi-square test. Furthermore, continuous variables were analyzed using one-way analysis of variance (ANOVA) in case of normal distribution and Kruskal-Wallis in case of a nonnormal distribution. $P<.05$ was considered statistically significant for the results of the chi-square and one-way ANOVA or Kruskal-Wallis tests. In case of significant results regarding outcome measurements, specific post hoc or Mann-Whitney U tests were performed to investigate differences between the (1) Game group and Control D group or (2) Game group and Control A group. Furthermore, a Bonferroni correction for two tests was used for the Mann-Whitney U test; therefore, $P<.025$ was considered statistically significant for the results of the Mann-Whitney U test.

Results

In total, 176 of 387 students subscribed for the practical on delirium in December 2016. Of these 176 students, 156 signed the informed consent form and participated in the study (Figure 1). The 20 students who declined to sign the informed consent form still participated in the practical but were not included in the study. Students did not have to give a reason why they declined to sign the informed consent form. We compared playing a serious game (Game group) to either watching a video on delirium in combination with a video of a patient's experience (Control D group) or watching a video on healthy aging (Control A group). Data on students' characteristics and outcome measures were not normally distributed. The median age (interquartile range [IQR] 25-75) of all participants was 20 (20-21) years, and 75% (117/156) participants were females. No differences were found between the research groups regarding baseline variables, as presented in Table 1.

Figure 1. Flowchart of approached students and participants.
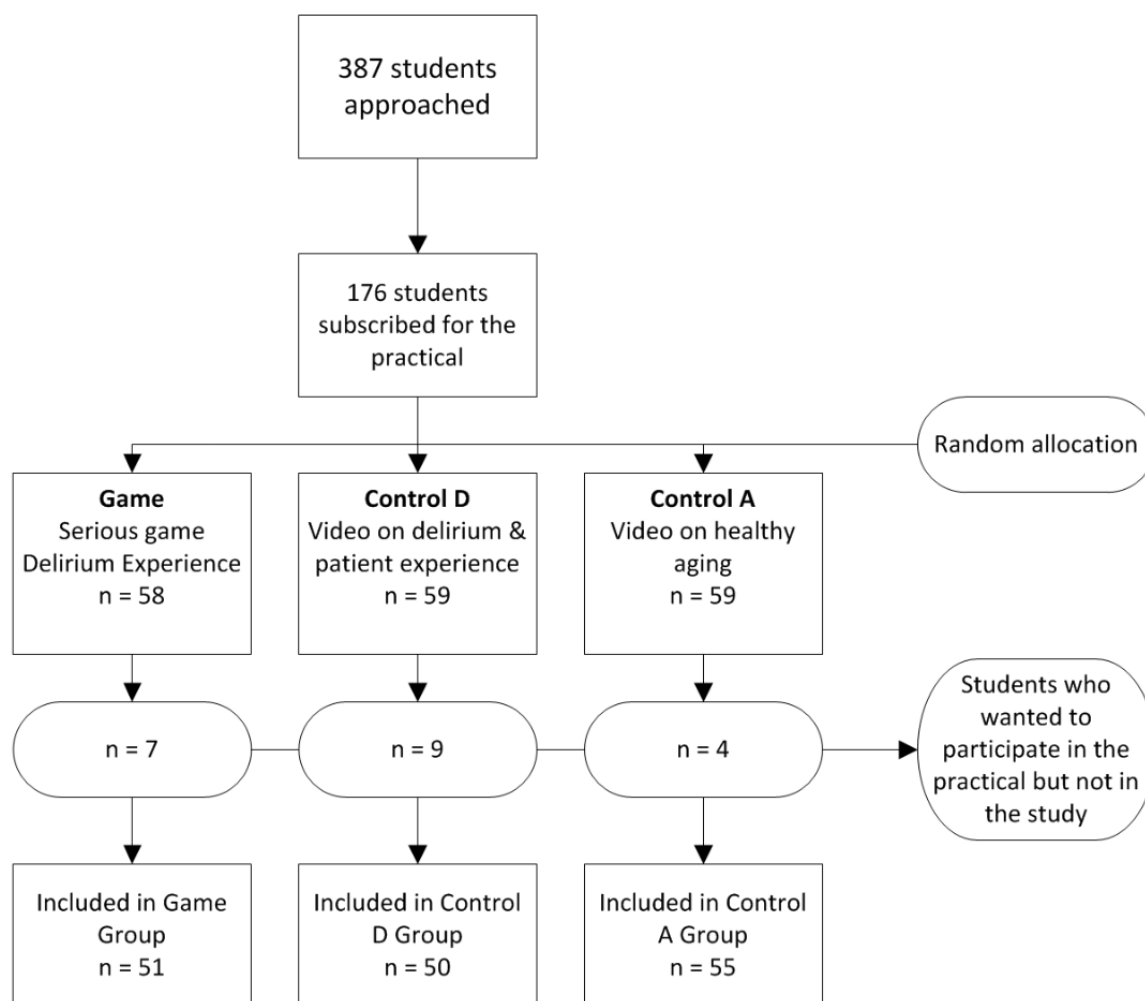
Table 1. Baseline variables.

Characteristics	Total participants (N=156)	Game[a] (n=51)	Control D[a] (n=50)	Control A[a] (n=55)
Age in years[b], median (IQR[c])	20 (20-21)	21 (20-21)	20 (20-21)	21 (20-21)
Female[d], n (%)	117 (75.0)	37 (72.5)	40 (80.0)	40 (72.7)
Experience older patients[d], n (%)	118 (75.6)	36 (70.6)	38 (76.0)	44 (80.0)
Experience delirious patients[d], n (%)	48 (30.8)	17 (33.3)	15 (30.0)	17 (30.9)
Learning community[d], n (%)				
Global health	45 (28.8)	19 (37.3)	15 (30.0)	12 (21.8)
Molecular medicine	39 (25.0)	11 (21.6)	14 (28.0)	14 (25.5)
Sustainable care	31 (19.9)	11 (21.6)	7 (14.0)	11 (20.0)
Intramural care	40 (25.6)	10 (19.6)	14 (28.0)	18 (32.7)
Attended lecture, n (%)	129 (82.7)	44 (86.0)	43 (86.0)	43 (78.2)
Self-reported knowledge on delirium (0-10)[b], median (IQR)	5 (4-6)	5 (4-6)	5 (4-6)	5 (4-6)

[a]Game: Delirium Experience; Control D: video on delirium with a patient experience video; Control A: video on healthy aging.

[b]Data compared using Kruskal-Wallis test, *P*>.05.

[c]IQR: interquartile range.

[d]Data compared using chi-square test, *P*>.05.

Table 2. Kruskal-Wallis and Mann-Whitney *U* tests for primary and secondary outcomes for the Game (n=51), Control D (n=50), and Control A (n=55) groups.

Outcome	Game[a]	Control D[a]	Control A[a]	*P* value[b]	*P* value (G-D)[c]	*P* value (G-A)[d]
Recommendations	6 (4-8)	1 (1-4)	0 (0-3)	<.001	<.001	<.001
DOSS[e]	10 (9-11)	9 (8-10)	9 (8-11)	.07	N/A[f]	N/A
DRS-R-98[g]	14 (12-16)	13 (12-15)	14 (11-16)	.45	N/A	N/A
Attitude	92 (88-96)	94 (90-100)	92 (85-96)	.55	N/A	N/A
Learning motivation[h]	36 (32-38)	27 (24-30)	20 (15-25)	<.001	<.001	<.001
Delirium knowledge[i]	7 (6-8)	6 (6-7)	6 (5-6)	<.001	.03	<.001

[a]Data are presented as median (interquartile range 25-75); Game: Delirium Experience; Control D: video on delirium with patient experience video; Control A: video on healthy aging.

[b]Kruskall-Wallis test to compare the three groups.

[c]Mann-Whitney *U* test to compare the Game group and the Video Delirium group (*P*<.025 considered statistically significant).

[d]Mann-Whitney *U* test to compare the Game group and the Video Aging group (*P*<.025 considered statistically significant).

[e]DOSS: Delirium Observation Screening Score.

[f]N/A: not applicable.

[g]DRS-R-98: Delirium Rating Scale R-98.

[h]Learning motivation and engagement.

[i]Self-reported knowledge on delirium.

The primary outcome of this study, skills in advising care for delirious patients, was measured on the basis of the given care recommendations. The independently assessed recommendations, which were scored using the rubric-form, had a weighted kappa of .835. Disagreements were resolved through discussion.

Kruskal-Wallis tests showed differences between the three groups regarding given recommendations, *H(2)*=54.5*, P*<.001, learning motivation and engagement, *H(2)*=91.5, *P*<.001, and self-reported knowledge, *H(2)*=26.0, *P*<.001, as presented in Table 2. No differences were found regarding delirium screening, *H(2)*=5.2, *P*=.07, and rating *H(2)*=1.6, *P*=.45, scores or in attitude toward delirious patients, *H(2)*=5.8, *P*=.55.

Furthermore, Mann-Whitney *U* test to compare the Game group and the Control D group showed differences regarding given recommendations (*U*=466.0, *z*=− 5.58, *P*<.001) and learning motivation and engagement (*U*=302.5, *z*=− 6.61, *P*<.001) but not for self-reported knowledge (*U*=967.5, *z*=−2.18, *P*=.03). The comparison of the Game group with the Control A group showed differences in given recommendations (*U*=363.0, *z*=−6.77, *P*<.001), learning motivation and engagement (*U*=110.5, *z*=−8.18, *P*<.001), and self-reported knowledge (*U*=651.0, *z*=−4.91, *P*<.001). Participants in the Game group scored a median score (IQR 25-75) of 6 (4-8) on recommendations, whereas the Control D group had a median score of 1 (1-4), and Control A group had a median score of 0 (0-3). With regard to learning motivation and engagement, participants in the Game group had a median score of 36 (32-38) compared with a median score of 27 (24-30) for the Control D group and 20 (15-25) for the Control A group. The median mark on self-reported knowledge of the Game group was a 7 (6-8) compared with a 6 (5-6) for the Control A group.

Discussion

Principal Findings

In this study, we investigated the effects of a serious game, Delirium Experience, as a new educational intervention. We compared playing a serious game with watching a video with delirium explanation in combination with a patient experience video or a video on healthy aging. The results showed that the serious game had a positive effect on students' skills in advising care for delirious patients, learning motivation and engagement, and self-reported knowledge on delirium. However, the serious game did not influence skills in screening and rating the severity of delirium. In addition, it did not affect the attitude toward delirious patients.

Although students in the group playing the serious game and the group watching the video on delirium got more familiar with the behavior of delirious patients, they were not explicitly trained in the use of the DOSS and DRS-R-98 or recognizing the delirious behavior. Furthermore, the design of Delirium Experience allows players to practice caring for a delirious patient and manage delirium instead of recognizing it. The DOSS and DRS-R-98 are used and applied in a real-life setting over 24 hours by trained and experienced health care professionals [22,24]. This might explain why we did not find differences in delirium screening and rating scores, as the medical students did not get training and patient information of 24 hours, nor did they have clinical experience with delirious patients. All participants received high scores on their attitude toward delirious patients, which could have been caused by a ceiling effect or by students answering in a socially desired way. Furthermore, attitudes can be influenced by intense emotions [27]. As participants played the game as well as they could, they probably did not see the more severe delirium scenarios,

as these scenarios are only shown when the game players perform poorly.

Implications

Conventional simulation-based educational interventions have proven to be effective but are costly owing to a large number of teachers, role-play actors, and time and space required [17]. By using Delirium Experience as a simulation-based educational intervention, students could play without the need of teachers and role-play actors. Development of serious games is costly. Delirium Experience was developed by an unrestricted grant of NutsOhra, and development costs were covered and, therefore, not relevant for educational institutes as they only pay for a license to use the game. Delirium Experience provides students with a safe environment to practice and apply attained knowledge and can be used as an educational intervention on delirium to improve skills in advising care for delirious patients. As simulation-based assessment seems to predict the clinical performance [28], this safe simulation environment might prepare preclinical students in advance for their clinical education. In addition, this study supports earlier research on the importance of including objectively obtained measurements instead of self-reported measures [12,29]; we did not find differences in the self-reported knowledge between playing the serious game and watching the delirium video, but we did find differences between these groups regarding skills in advising care for delirious patients.

Limitations

This study has a number of limitations. First, skills in advising care for delirious patients were measured using a video of a delirious patient and using written answers instead of a real clinical situation, which would involve both the responsibility of caring for a delirious patient and the demonstration of the correct skills. However, simulation-based assessment seems to be a suitable tool for predicting clinical performances [30]. Second, there might have been selection bias in the recruitment of students, as more highly motivated students were more likely to sign up for the practical. However, due to the design of this randomized study, this could not have influenced the differences between the research groups. Furthermore, there is a slightly skewed number of students that declined to sign the informed consent form in the different groups. We cannot explain this, because students did not have to explain why they declined, nor do we have any information on these students because they were never included in the study. However, as there was only a small percentage of students that declined to sign the informed consent form, we do not expect this to influence the results. Finally, we did not perform a sample size calculation beforehand. We

approached all third-year medical students. If we had not found statistically significant results due to a too low sample size or power, the study would have been extended in 2017. However, as we found significant results, the power was sufficient.

Further Research

Further research should be performed as to whether it is possible to improve attitudes toward delirious patients with Delirium Experience. If the change in attitude can be established by more emotional and intense patient scenarios [27], Delirium Experience might improve attitudes when students are allowed to play Delirium Experience several times, including "dark play." In a dark play situation, players show behavior in the game that in a normal care situation would be problematic [31] and increases the intensity of the delirium. In Delirium Experience, this results in adverse events and scenarios with an extremely frightened patient. Showing immoral behavior, such as dark play, in video games has already been proven to lead to improved awareness of moral norms [32]. Subsequently, it would be interesting to investigate the effect of dark play on learning outcomes such as advising care for delirious patients. Because Delirium Experience increases learning motivation, it would be interesting to investigate whether students might be more motivated to use Delirium Experience as self-study material [28] and whether the increased motivation also influences learning outcomes. Furthermore, player characteristics might influence the effectiveness and use of games and should be taken into account in future studies [33]. In addition, future studies should take into account other health care professionals and trainees to generalize the results and use of interdisciplinary games, such as Delirium Experience, and investigate whether Delirium Experience can improve timely recognition of delirium. Finally, it is important to look at long-term effects of playing a serious game and ascertain our interest in whether it can influence the strain of care in experienced health care professionals working with delirious patients.

Conclusions

Playing Delirium Experience increases medical students' skills in advising care for delirious patients, learning motivation and engagement, and self-reported knowledge on delirium. However, in this study, we could not show an effect on improving delirium screening and severity rating skills or on attitudes toward delirious patients after playing Delirium Experience. The serious game, Delirium Experience, is suitable as an educational intervention to teach delirium care to medical students and has added value in addition to that of a lecture.

Editorial notice: This randomized study was not prospectively registered. The editor granted an exception from ICMJE rules mandating prospective registration of randomized trials because, according to ICMJE rules, registration of the trial was not necessary as the research subjects consisted of medical students who could voluntarily sign up for both the practical and the study. However, readers are advised to carefully assess the validity of any potential explicit or implicit claims related to primary outcomes or effectiveness, as the lack of registration means that authors could change their outcome measures retrospectively.

Multimedia Appendix 1

CONSORT‐EHEALTH checklist (V 1.6.1).

[PDF File (Adobe PDF File), 2MB - games_v6i4e17_app1.pdf]

Multimedia Appendix 2

Trailer of Delirium Experience.

[MP4 File (MP4 Video), 217MB - games_v6i4e17_app2.mp4]

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Abbreviations

ANOVA: analysis of variance
DOSS: Delirium Observations Screening Scale
DRS-R-98: Delirium Rating Scale R-98
ICMJE: International Committee of Medical Journal Editors
IQR: interquartile range
N/A: not applicable
UMCG: University Medical Centre Groningen

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Original Paper

Potential of an Interactive Drug Prevention Mobile Phone App (Once Upon a High): Questionnaire Study Among Students

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Abstract

Background: In recent years, drug prevention networks and drug education programs have started using Web-based or mobile phone apps as novel prevention tools, testing their efficacy compared with face-to-face prevention.

Objective: The aim of this study was to assess the potential of an interactive app called Once Upon a High (VoltEgySzer).

Methods: The app approaches drug prevention from 6 different aspects, and it addresses youngsters with 6 different modules: (1) interactive comics/cartoons, telling stories of recovery; (2) quiz game; (3) roleplay game; (4) introduction of psychoactive drugs; (5) information on the somatic and psychological effects of psychoactive substances; (6) list of available treatment units, rehabs, and self-support groups in Hungary. Students of 2 vocational schools and 2 high schools filled out a questionnaire at a baseline (T0) and a 2-month follow-up (T1) data collection session. Students of 1 vocational school and 1 high school downloaded the Once Upon a High app (app group), whereas students from the other vocational school and high school did not (nonapp group). The time points of T0 and T1 questionnaires contained demographic variables, items with regard to substance use characteristics for both legal and illegal substances, including novel psychoactive substance, exercise habits, knowledge about psychoactive substances, attitudes toward substance users and validated instruments measuring the severity of tobacco (Fagerström Test for Nicotine Dependence), alcohol (Alcohol Use Disorder Identification Test), cannabis (Cannabis Abuse Screening Test), and synthetic cannabinoid consumption. Beliefs about substance use (Beliefs About Substance Abuse) and perceived self-efficacy (General Perceived Self-Efficacy) were also measured. At T1, members of the app group provided additional evaluation of the app.

Results: There were 386 students who participated in the T0 session. After dropout, 246 students took part in T1 data collection procedure. Alcohol was the most frequently consumed psychoactive substance (334/364, 91.8% lifetime use), followed by tobacco (252/386, 65.3%, lifetime use) and cannabis (43/323, 13.3% lifetime use). Decreased self-efficacy (beta=−.29, P=.04) and increased daily physical exercise frequencies (beta=.04, P<.001) predicted higher frequencies of past month energy drink consumption, whereas elevated past month alcohol consumption was mainly predicted by a decrease in negative attitudes toward substance users (beta=−.13, P=.04) in the regression models. Once Upon a High was found to be effective only in reducing energy drink consumption (beta=−1.13, P=.04) after controlling for design effect, whereas perceived utility of the app showed correlation with a decreasing alcohol use ($r_{S(44)}$=.32, P=.03). The roleplay module of the app was found to be the most preferred aspect of the app by the respondents.

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Conclusions: The Once Upon a High app can be a useful tool to assist preventive intervention programs by increasing knowledge and self-efficacy; however, its efficacy in reducing or preventing substance use needs to be improved and further studied**.** Additional potential impacts of the app need further testing.

Introduction

Background

The era of contemporary substance use scene is also an era in which Web-based communication influences our daily lives to an increasing extent. Spending an increasing amount of time in virtual spaces is a phenomenon that mostly affects the lifestyle of adolescents [1]. Virtual spaces—such as Web-based fora, blogs, Web markets—serve a significant role as one of the primary sources of gathering either classic or novel psychoactive substance (NPS)-related information as well. The Web-based space not only provides information and means of communication, but Web-based marketing is also responsible for increasing the availability of NPS [2].

Not only the drug market but prevention itself also transformed as one of the many consequences of the rise of information technologies. In recent years, drug prevention networks and drug education programs have started using Web-based or mobile phone apps as novel prevention tools [3]. Such virtual methods may provide an opportunity to access individuals who otherwise might not seek or receive professional help. The anonymity and accessibility of prevention apps often lead to increased self-disclosure with regard to sensitive subjects such as substance consumption [4]. The effectiveness of Web-based interventions providing personalized feedback and mobile phone apps in reducing the intake of psychoactive substances is already supported by empirical evidence [5,6]. According to the findings of previous research, such programs may result in significant decrease in alcohol consumption among heavy drinkers [7], in prolonged smoking cessation as a supplement to nicotine patch therapy [8], or in decrease of marijuana use among college students who show a high level of contemplation to be abstinent [9]. However, there are some contradictory results as well with regard to the efficacy of such programs when implemented in the adolescent population. On the basis of the systematic review of Majeed-Ariss and colleagues [10], some apps *may be considered feasible health interventions* that may increase self-management of chronic health conditions, but on the other hand, there are several apps available on the app market without any evidence-based background. A Web-based prevention program for ecstasy and NPS [11] was reported to be efficient in reducing adolescents' intentions to use NPS; it increased knowledge about both ecstasy and NPS. However, changes in lifetime use of ecstasy or NPS did not differ significantly between the intervention and control conditions.

The result that tailored and interactive sites and apps are more effective than static ones [12] is also essential with respect to our project, although this principle applies not only to apps and websites but also to prevention itself. Interactivity may also increase the subjective feeling of self-efficacy and self-directedness, which might improve the commitment to participate in a prevention program. Self-directedness itself was found to be a relevant protective factor against opiate addiction [13], alcohol addiction [14], cannabis addiction [15], and smoking [16].

As opposed to personal, face-to-face prevention, preventive interventions implemented in the virtual space have distinct advantages as they are available any time, are more cost effective in the long run, are better in providing tailored feedback, and are able to reach more members of the target population [17]. Previous studies have also indicated that mobile phone apps combine the benefits of Web-based and computerized preventive interventions as they provide both interactive and static contents with and without an internet connection [18], even if some apps cannot operate properly offline. Nevertheless, updates concerning eventual content change are usually assured by automatic version refreshments in every case.

With respect to the methodological concept of our project, we followed the concept of gamification. Gamification—when utilized in prevention—is usually defined as the mixture of game design elements and traditional prevention techniques in a nongame context [19]. The aim of gamification is to increase the engagement and motivation of the target group while providing a useful method in supporting learning and problem solving. It is not essential to use any digital technology in gamification, but smartphones make the implementation easier and the outreach wider. With regard to the efficacy of gamification in preventing substance use among adolescents, Boendermaker and colleagues [20] found that game elements (authors label them as *serious games*) can help to motivate youngsters to do a cognitive bias modification training, which might reduce substance consumption. However, research is still lacking to draw further conclusions about the efficacy of gamification.

Objective

The aim of this study was to assess the effectiveness of a mobile phone prevention app, titled *Once Upon a High* (the original name of the app is *VoltEgySzer* in Hungarian). We aimed to target adolescents in an age range that may indicate the existing experiences with substance use but without clinically relevant problems. Therefore, Once Upon a High was tested as a novel tool with embedded game elements (ie, as a form of gamification) for mainly the purpose of secondary prevention. Being such an instrument, we expected this app to be effective—among other goals—in reducing or at least maintaining substance use frequencies. The app, besides being

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a contemporary gadget of providing information on the risks of substance use, was expected to enhance or affect certain skills as well, which might be considered as protective factors against the increasing severity of substance consumption and are as follows: (1) *self-efficacy* is usually seen as a protective resource in prevention or even treatment of substance use disorders (SUD) [21] and as an important determinant of health behavior in general [22]; (2) *increasing physical exercise* is similarly recommended as a potential tool to be utilized in substance use prevention for the youth [23,24] or as a beneficial adjunctive treatment of SUD [25], which may lead to elevated abstinence rates or the ease of withdrawal symptoms [26].

In the study, besides the exploratory analysis of the app's utility, the following hypotheses were tested:

Once Upon a High can be effective in:

> H1: Increasing knowledge about the risks of psychoactive substances
>
> H2: Enhancing perceived self-efficacy
>
> H3: Decreasing or maintaining the frequency of current substance use
>
> H4: Decreasing negative attitudes toward substance users
>
> H5: Increasing the frequency of physical exercise

Although H2, H4, and H5 might also be related to primary prevention, we still considered self-efficacy, physical exercise, and negative attitudes toward substance users as potential protective factors against the exacerbation of substance use among active users; and as such, preferable outcomes of secondary prevention too, potentially leading to decreased substance use frequencies. We further hypothesized that increased knowledge (H1), perceived self-efficacy (H2), physical exercise (H5), and decreased negative attitudes toward substance users (H4) might predict decreased frequencies of substance use (H3).

Methods

Once Upon a High: Introducing the App

Once Upon a High is an interactive drug prevention app targeting the youth and drawing attention to the importance of prevention in a novel way. The app approaches drug prevention from 6 different aspects, and it addresses youngsters with 6 different modules: (1) interactive comics/cartoons, telling stories of recovery (see Animated Comics section); (2) quiz game (see Quiz Game section); (3) roleplay game (see What If? section); (4) introduction of psychoactive drugs (see Substance Store section); (5) information on the somatic and psychological effects of psychoactive substances (see Trans-formation section); (6) list of available treatment units, rehabs, and self-support groups in Hungary (see Where to go? section). The user may choose to use any of the modules from the initial menu. The app unites the experience of usual Web education and computer games. The applied genres—cartoons, videos, and animation—are anticipated to be attractive to the youth by their nature. The app provides anonymity for its users.

The app was designed and developed in a joint project of Nyírő Gyula Hospital, National Institute of Psychiatry and Addictions and the techLab of the Moholy-Nagy University of Art and Design, Budapest. The development of the app was funded from a national tender (invited by the Hungarian Government's Ministry of Human Capacities) supporting the establishment of novel drug prevention programs. More information on the technical details are presented in the Multimedia Appendix 1 as well as on the visual rendering of the app. To increase risk perception, yet to avoid overestimation of the dangers of specific psychoactive substances (ie, avoiding autotelic deterrence), the literature basis for each module contained current papers providing high-quality evidence (ie, mainly systematic reviews and meta-analyses or randomized controlled trials). The literature basis for each module is presented under the detailed characteristics of the app.

Detailed Characteristics and Aims of the Modules

Animated Comics: Interactive Recovery Stories

The first module comprises altogether 4 recovery stories, of which there are stories of 2 males (Adam, the beggar; Adam, the prince) and 2 females (Eve, the beggar; Eve, the princess). These 4 comic-style animated tales (Figure 1) introduce common risk factors of adolescent psychoactive substance use (eg, peer pressure, peer recognition for substance use involvement, social isolation, a dysfunctional family background indicated by symptoms such as familial substance use and either sexual, physical, or emotional victimization) based on the findings of former studies [27,28], as well as potential way outs by presenting 4 types of treatments: (1) art therapy, (2) individual psychotherapy, (3) group therapy including self-support groups and as a combination with family counseling, and (4) animal-assisted therapy. The selection of these therapeutic interventions was based on former findings with respect to their efficacy in addiction treatment. Art therapy is commonly used throughout the process of detoxification and rehabilitation, including 12-step programs and self-support groups [29]. The effectiveness of individual psychotherapy and primarily cognitive behavioral therapy in the treatment of SUD was supported by the results of numerous meta-analyses [30,31]. Group counseling and family therapies were highlighted as the most effective interventions in a study comparing the effectiveness of various treatment methods for adolescent substance use [32]. A systematic review and meta-analysis of randomized controlled trials further confirmed the efficacy of animal-assisted therapy in the treatment of SUD [33]. The interactivity of this module means that the dialogues are triggered by the user, and turns are indicated by a slight movement of the main characters. The module also aims to display different socioeconomic backgrounds of substance users by telling the stories of both socially marginalized youth and youngsters coming from high-income families.

Quiz Game

The second module, a quiz-game, contains a database of 50 potential questions, of which the app randomly generates 15 questions every time the user plays the game. The quiz game is structured by 3 difficulty levels (easy, moderate, and hard). Difficulty levels were determined by assigning an adjustment

weight to the questions based on the results of 98 high school students who gave either correct or wrong answers to all the 50 questions. Many of the quiz questions reflect common misbeliefs about the prevalence and risks of substance use (eg, by asking: "What percentage of high school students in your country have tried an illegal substance at least once in their lifetime?"). As a trend, adolescents often overestimate peer substance use [34], which might legitimize their own substance consumption.

Review of the current literature resulted in the following relevant areas, addressed in the quiz game: the topics of cannabis-induced psychosis [35], effects of energy drink consumption [36], dangers of adolescent alcohol use [37], peer group influence on adolescent smoking [38], or harms of NPS [39]. Less emphasis was placed on the risks associated with the use of substances with low prevalence among adolescents, such as heroin or other opioids, based on the findings of the most recent ESPAD study [40]. To every question, there are 3 potential answers (A, B, and C solutions), of which only one is correct. After every round, the user receives a feedback on his or her answers, which contains relevant citations from the scientific literature as well.

The quiz game has 2 main goals. First, to provide well-established knowledge of the epidemiology and risks of substance use, with respect to both legal and formerly banned "classic" substances (such as alcohol, tobacco, ecstasy, amphetamines, or cannabis) and NPS (in this module, mainly synthetic cannabinoids and synthetic cathinones). Second, the module aims to promote health-conscious behavior. Those users who are able to achieve a 100% quiz result are offered free admission to gyms, dance schools, laser-tag, and paintball facilities or indoor climbing centers. As such, this module might increase physical exercise frequencies as a potential benefit and, therefore, its application was considered to test our H5 hypothesis.

What If? Roleplay Game and Dialogue System

The third module titled "What if?" is an interactive dialogue system, within the confines of a roleplay situation: *What if one of your close acquaintances started to use synthetic cannabinoids*? *What would you suggest*? *How would you help*? During the roleplay game, the user communicates with his or her assumed acquaintance by following a structured dialogue system, in which the virtual "talk partner" makes a specific statement, whereas the user selects a response from 2 optional sentences offered (see Figure 2). The main task within the game is to persuade the virtual acquaintance to change his lifestyle by reducing his substance use, seeking professional help, or starting drug-free recreational activities. Whenever the user selects the better option, the portrayed room gets brighter and brighter and vice versa, in case of a worse option selection, the room goes darker and darker. If the user is able to convince the virtual partner to make a positive change in his life, the game ends positively. However, in case of bad choices during the dialogue (eg, by being too impatient, hypocritical, or arrogant), the game ends with a *game over*. In this case, users receive a feedback on how to improve their communication skills and strategy next time.

The roleplay game, therefore, aims to improve communication skills, decrease stigma, and negative attitudes against people (see H4) who use psychoactive substances and to increase willingness to help peers with substance use problems. As such it targets adolescents with or without any former substance use experiences. Communication style of the virtual partner was based mainly on clinical experiences with substance users as well as the feedback of the co-design group (see Appendix for details). The assumption that peer support might be of utmost relevance was supported by literature evidence as adolescents tend to prefer informal sources of help (eg, friends) rather than professional support [41]. Finally, the risks of synthetic cannabinoid use presented in this module were also collected from published data [42].

Figure 1. Visual appearance of the animated comics module.

Figure 2. Visual appearance of the What if? roleplay game module.
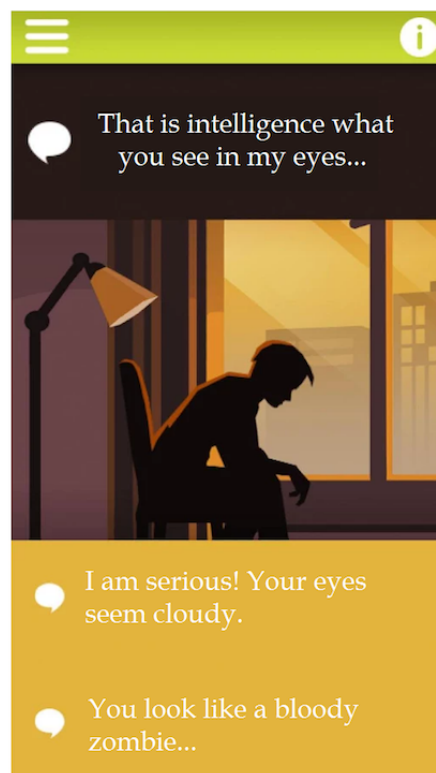
Figure 3. Visual appearance of the Substance-store module.

Figure 4. Visual appearance of the Trans-formation module.
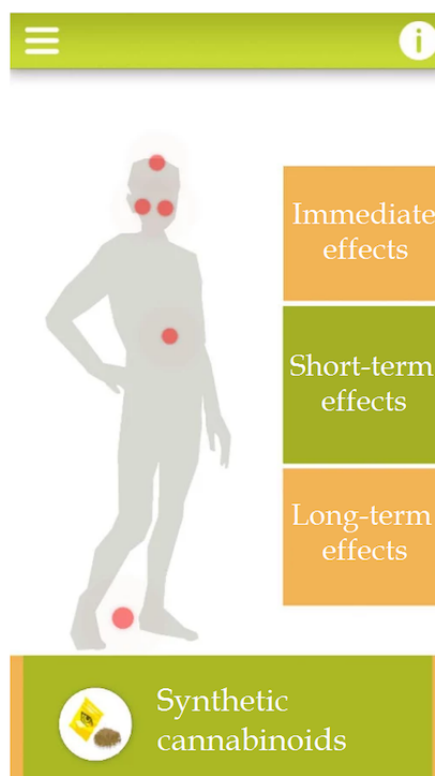
Substance Store: Information About Psychoactive Drugs

The fourth module titled "Substance-store" (Figure 3) provides information on "classic" substances (cannabis, cocaine, ecstasy and amphetamines, lysergic acid diethylamide [LSD], and heroin) and NPS or recently popularized substances (ketamine, gamma-hydroxybutyrate [GHB], Salvia divinorum, synthetic cannabinoids, and cathinones). Users are offered knowledge of the brief history of the selected psychoactive substance, information on the psychoactive compounds, both desired and unwanted or adverse effects of the substance, as well as the dangers of potential overdose. For each substance, an image

helps to recognize the common distribution form. As such, this module's main goal is to educate the users and provide information. Cultural history of substance use and the desired and adverse effects of specific substances were collected from the literature [43-51].

Trans-Formation: Somatic and Psychological Effects of Psychoactive Substances

"Trans-formation" is closely related to the fourth module (Substance store). In addition to that one, this fifth module presents substance-specific somatic and psychological effects in a longitudinal aspect by offering a selection between immediate, short-term, and long-term effects of specific substances. As impulsivity—and especially sensation seeking—usually rise during adolescence [52], for this age group, it is thought to be more relevant to focus on the immediate and short-term consequences of substance use and not just the long-term risks of recurrent psychoactive substance consumption. All the presented somatic and psychological effects are based on the findings of former studies [42,53-55]. These effects are indicated by the red dots located on a picture of a schematic body with the option to touch a dot on the screen (see Figure 4) and, thus, access detailed description of the effects. Here too, we relied on visual clues and active exploration by the user as learning methodology.

Where to Go? List of Available Treatment Units

The aim of the final module was to create a national register of the available treatment units (both inpatient and outpatient), rehabs, and self-support groups. Thus, the purpose of this module is to help youngsters who are already at-risk substance users in finding nationwide professional help, as close to their place of residence as possible. By overviewing the existing national registries and the websites of self-support groups, we created a searchable map with the contact details of each of the treatment units and meeting points. As a result, altogether, more than 300 locations were registered.

Sample and Procedure

The sample of the study consisted of 386 students of 2 vocational schools and 2 high schools from Budapest, Hungary, to analyze outcome variability by school type as well. To examine the impact of age as a covariate on the outcome measures, 9th (approximately 14- to 15-years-olds), 10th (approximately 15- to 16-years-olds), and 11th (approximately 16- to 17-years-olds) graders participated in the study from each school. The age range was 14 to 18 years. Permission from the schools was obtained as well as from the parents in cases where respondents were younger than 18 years. Written informed consents were asked in every case. Our goal was to assess participants in a natural setting, that is, in their schools, with the involvement of those professionals (teachers and school psychologists) who are involved in the everyday life of these students, to model an as realistic arrangement as possible. Randomization was performed at the school level, where participants were nested in classes. Altogether 4 groups were assessed at 2 different time points.

Students of 1 vocational (VS1) and 1 high school (HS1) downloaded the Once Upon a High app, whereas students from the other vocational (VS2) and high school (HS2) did not. Those students who downloaded the app were, therefore, part of the group hereunder referred to as "app group," whereas those who did not download the app were members of the group referred to as "nonapp group." We wanted to avoid assigning students to both app and nonapp groups within the same schools to prevent information sharing between study groups. Schools were selected with the help and involvement of 2 school psychologists who were also involved in monitoring the data collection procedure. Therefore, a nonprobability, convenience sampling method was used. Homeroom teachers were asked to help in organizing occasions of data collection. The app itself had an option to provide further information about its use via a website. Thus, detailed psychoeducation with respect to the use of the app was not necessary. However, homeroom teachers and those colleagues who were responsible for face-to-face data collection answered any questions that might have arisen throughout the study. We additionally provided an email address to receive and answer any incoming questions. We tried to motivate students to participate (and maintain their participation) by ensuring the opportunity of winning recreational activities (ie, free admission to gyms, dance schools, laser-tag and paintball facilities, or indoor climbing centers) in case of a flawless result in the quiz-game module.

As data were collected in 2 phases (baseline and 2-month follow-up data collection), participants received a unique identifier (UID) that helped the pairing of baseline (T0) and follow-up (T1) data. UID was generated by a similar algorithm of treatment demand indicator and consisted of the following 6 characters: (1) the third letter of the participant's surname, (2) the second letter of the participant's first name (3) last number of the participant's birth month, (4) last number of the participant's birth day, (5) third letter of the maiden surname of the participant's mother, and (6) second letter of the maiden first name of the participant's mother. This method was found to be more effective than allowing the students to choose a UID for themselves as they were expected to forget that during the 2 months between the 2 dates of data collection.

Measures

The baseline and follow-up questionnaire was filled by all the participants who remained in the study. Members of the app group responded to additional questions during the follow-up measurement with respect to their experiences with the app. Participants were asked to provide an evaluation on (1) the utility and (2) subjective preference of distinct modules, as well as (3) general impression about the app using a 5-point Likert scale (from 1=not at all, to 5=absolutely). We computed 2 variables ("app preference" and "app usefulness") as a total score of the evaluative response categories with respect to the distinct modules' preference and the app's perceived utility.

The baseline questionnaire contained demographic variables, questions about socioeconomic status, former experiences with other prevention programs, and the family history of either alcohol, tobacco, or illicit substance use. These items were not included in the follow-up questionnaire. Both the baseline and follow-up questionnaire comprised questions with respect to the respondents' physical exercise and sport habits (including

sport types, monthly and daily exercise frequencies, measured in minutes/day), psychoactive substance use experiences (including lifetime, last year, and last month frequencies of the consumption of both legal and illegal "classic" and NPS-type drugs). NPS-type substances included synthetic cathinones (mephedrone, methylenedioxypyrovalerone [MDPV], pentedrone), synthetic cannabinoids, and GHB, as the use of these NPS was found to be relevant among Hungarian school-aged respondents in the ESPAD study [40].

With respect to the measurement of psychoactive substance use, the questionnaire further contained validated instruments such as the 6-item Fagerström Test for Nicotine Dependence (FTND) [56,57], the 10-item Alcohol Use Disorder Identification Test (AUDIT) [58,59], and the 6-item Cannabis Abuse Screening Test (CAST) [60,61]. CAST was also used for the assessment of synthetic cannabinoid use and related problems (and referred to as sCAST). AUDIT, CAST, and sCAST were only included in the first data collection procedure as these instruments screen substance use severity at an annual rate (ie, ask questions about the past 12 months), whereas FTND measures current smoking habits. Beliefs about psychoactive substances were measured by 20-item Beliefs About Substance Abuse [62], including areas such as the ability of controlled substance use or the role of craving in relapse. Knowledge about the risks and prevalence of both legal and illegal classic and NPS-type drugs were measured by 12 items. These true/false or multiple-choice questions (eg, "What is the national prevalence of lifetime cannabis use among high school students in your country?" A=15% to 20%, B=30% to 40%, C=50%, or more) tested the knowledge that the app aimed to provide for its users. A 5-point Likert scale was used for assessing the attitudes toward substance users. Respondents had to evaluate 10 statements on substance users and addiction itself (eg, "Addiction is not a disorder, it is a lack of will-power"), rating how strongly they agree with them (from 1=Absolutely disagree, to 5=Absolutely agree). A total score of negative attitudes was computed. Finally, perceived self-efficacy was measured by the 10-item General Perceived Self-Efficacy Scale [63,64], primarily dealing with self-observed coping skills.

Statistical Analysis

Data were analyzed by SPSS 17 (SPSS Inc) [65]. Descriptive statistics were applied to provide sample characteristics. Mean age and exercise frequencies were compared by independent sample t tests, perceived socioeconomic status as an ordinal variable was compared by Mann-Whitney U test, whereas potential differences in gender distribution and repetition of year rates were analyzed by chi-square statistics. Baseline comparison of the app versus nonapp groups, vocational versus high schools, and compliant respondents versus dropouts was implemented by using independent sample t tests, Mann-Whitney U test, chi-square test, and Fisher exact test. AUDIT, FTND, CAST, and sCAST scores were compared between the app and nonapp groups by using Mann-Whitney U test. Gender differences in substance use frequencies were analyzed by chi-square statistics and Fisher exact test.

To control for the design effect, pre- and postdata comparisons were performed by estimating treatment (intervention) effect

with a series of linear regression analysis. Design effect was calculated by average cluster size and intracluster correlation. Changes in past month frequencies of less commonly consumed substances (including both "classic" and NPS-type stimulants and depressants) and the FTND scores at the postdata setting could not be examined by a regression analysis because of low response rates. The evaluation of the app was examined with descriptive statistics. Spearman rank correlation was applied to measure the connection between the repeated use of the distinct modules and the changes in attitudes, self-efficacy, knowledge, and exercise frequencies. The association between the app's preference and perceived utility and substance use changes was also tested by Spearman rank correlation.

Results

Sample Characteristics

Altogether 386 students participated in the first data-collection (T0) session and 246 students took part in the second data collection procedure (T1). Main reasons of dropouts were lack of motivation to participate further in the study or missing identifiers to pair pre- and postdata. Tables 1 and 2 summarize detailed sample characteristics with respect to respondents with available identifiers.

With respect to both the pre-and posttest setting, the app and nonapp groups differed in age but not in gender distribution. In addition, a significant difference was found with respect to baseline exercise frequencies as members of the nonapp group showed higher means of daily exercise duration. In case of the posttest setting, this difference ceased to be significant. Vocational and high school students differed in perceived socioeconomic status as high school students reported higher living standards (mean 4.8, SD 0.9, U=14,517.5, P=.001) than students of the vocational schools (mean 4.5, SD 0.9). However, the app and nonapp groups did not show significant difference in terms of perceived socioeconomic status and rates of school year repetition because of failure (ie, poor academic performance).

Furthermore, respondents who participated in both data collection phases (ie, compliant participants) were compared with those who dropped out of the study, with regard to gender distribution, age, rates of year repetition because of academic failure, and substance use characteristics (lifetime and past month use of both legal and illegal substances, AUDIT, CAST, sCAST, and FTND scores). On the basis of this analysis, the group of students who dropped out of the study was characterized by a higher rate of male respondents (For N=384, χ^2_1=10.4, P=.001), higher mean age (mean 16.9, SD 0.9, t=–2.72, P=.007), higher rates of lifetime cannabis (For N=323, χ^2_1=4.4, P=.04), ecstasy (Fisher exact test, P=.006), amphetamine (Fisher exact test, P=.001), cocaine (Fisher exact test, P=.001), and LSD (Fisher exact test, P=.005) use; higher rates of last month cannabis (For N=323, χ^2_1=4.7, P=.03), tobacco (For N=252, χ^2_1=4.97, P=.03), LSD (Fisher exact test, P=.02), GHB (Fisher exact test, P=.02), and synthetic cannabinoid (Fisher exact test, P=.03) consumption. There were no differences in AUDIT (U=8296, P=.17), CAST (U=720.5,

P=.92), sCAST (U=264.5, P=.31), or FTND (U=264.5, P=.09) scores, or in the rate of year repetition because of academic failure (N=385, χ^2_1=0.2, P=.70).

Baseline Psychoactive Substance Use

The majority of the students have consumed alcohol at least once in their lifetimes (average rate=91.8%, 334/364), and there was no significant difference in the frequencies of lifetime and past month alcohol use between the subgroups (app vs nonapp groups; vocational vs high schools). However, vocational and high school students differed in the rates of lifetime and last month smoking. Although high school students showed a higher rate of lifetime smoking, last month frequencies were higher in vocational schools. Concerning illegal substances, respondents mainly had experiences with cannabis (average lifetime use rate=13.3%, 43/323), ecstasy (average lifetime use rate=3.1%, 10/319), and LSD or magic mushroom (average lifetime use rate=2.5%, 8/319). The nonapp group and participants from vocational schools showed higher rate of lifetime ecstasy consumption. In addition, lifetime use of cocaine was more frequent among the participants of the nonapp group. With respect to NPS-type substances, synthetic cannabinoids were found to be the most commonly used drugs (average lifetime use rate=6.6%, 21/319), whereas MDPV consumption only occurred among the students of vocational schools. Table 3 presents the results of the applied comparative analyses.

In case of baseline AUDIT, FTND, CAST, and sCAST total scores, there were no significant differences between the app and nonapp groups. However, students of the vocational schools showed higher total scores on both the CAST (mean 2.2, SD 4.3, U=532, P=.02) and the FTND (mean 3.3, SD 2, U=118, P<.001) compared with the CAST (mean 0.3, SD 0.7) and FTND scores (mean 1, SD 1.4) of high school students. Considering the severity of baseline substance use, 64 students

(22.5%) indicated hazardous or harmful alcohol use (based on AUDIT cut-off: a score of 8 or more), 14 students (17.9%) showed moderate or severe cannabis use (based on CAST cut-off: a score of 3 or more), 3 students (5.8%) indicated moderate or severe synthetic cannabinoid use (based on CAST cut-off: a score of 3 or more), whereas 11 students (20.4%) showed risk for moderate or severe nicotine dependence (based on FTND cut-off: a score of 5 or more). With regard to potential gender differences, male students showed higher rates of lifetime ecstasy use (Fisher exact test, P=.04), whereas higher rates of lifetime smoking were found among female students (For N=384, χ^2_1=11.95, P<.001). In case of AUDIT, FTND, CAST, and sCAST, no gender differences occurred.

Pre- and Postdata Comparisons

Among those participants with available and comparable pre- and postdata, potential changes in psychoactive substance use, knowledge about psychoactive substances, perceived self-efficacy, exercise frequencies, beliefs about substance use, and attitudes toward substance users were analyzed and compared between the app and nonapp group. Multimedia Appendix 2 presents pre- and posttest settings' description with respect to the outcome measures for both the app and nonapp groups. Intervention or treatment effect was estimated with a series of linear regression analyses, while controlling for the design effect as well. Significant treatment or intervention effect was observed only in the frequency of past month energy drink consumption. Users of the app showed greater decrease in energy drink consumption after the implementation of the intervention. A trend increase in psychoactive substance–related knowledge and physical exercise frequencies could be seen in the app group but, compared with the nonapp group, these differences were not significant and could not be considered relevant.

Table 1. Sample characteristics and group differences at T0 participation.

Sample characteristics	App group		Nonapp group		Significance[a] (app vs nonapp group)	Effect size, r
	VS1[b]	HS1[c]	VS2[d]	HS2[e]		
T0 participation, N	148	107	71	60	N/A[f]	N/A
Age, mean (SD)	16.7 (0.9)	16.5 (1)	16.9 (1)	17.2 (0.7)	t=−4.31; P<.001	.23
Male participants, n (%)	131 (89.1)	54 (50.9)	70 (98.6)	24 (40)	χ^2_1=0.1	.01
Repetition of year of study because of failure, n (%)	13 (8.8)	1 (0.9)	5 (7)	0 (0)	χ^2_1=0.5	.04
Perceived socioeconomic status, mean (SD)	4.5 (0.9)	4.9 (0.9)	4.5 (1.0)	4.6 (1.0)	U=15,387.5	.06
Exercise frequency (minutes/day), mean (SD)	103.9 (91.9)	92.8 (51.9)	169.5 (250.3)	82.9 (47.4)	t=−2.12; P=.40	.10

[a]Independent sample t-test or Mann-Whitney U test or χ^2 test or Fisher exact test.

[b]VS1: vocational school 1.

[c]HS1: high school 1.

[d]VS2: vocational school 2.

[e]HS2: high school 2.

[f]N/A: not applicable.

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Table 2. Sample characteristics and group differences at T1 participation.

Sample characteristics	App group		Nonapp group		Significance[a] (app vs nonapp group)	Effect size, r
	VS1[b]	HS1[c]	VS2[d]	HS2[e]		
T1 participation, N	90	65	38	53	N/A[f]	N/A
Age, mean (SD)	16.7 (0.9)	16.3 (0.9)	16.7 (0.8)	17.1 (0.7)	$t=-3.29$; $P=.001$	.22
Male participants, n (%)	79 (87.8)	33 (50.8)	37 (97.4)	18 (34)	$\chi^2_1=3.7$	.12
Repetition of year of study because of failure n (%)	9 (10)	1 (1.5)	2 (5.3)	0 (0)	$P=.22$	N/A
Perceived socioeconomic status, mean (SD)	4.4 (0.9)	5 (0.9)	4.3 (1.1)	4.6 (0.9)	$U=6230$	.10
Exercise frequency (minutes/day), mean (SD)	153.2 (208.9)	88.3 (48.5)	191.3 (257.5)	84.6 (135.8)	$t=-0.13$	.01

[a]Independent sample t-test or Mann-Whitney U test or χ^2 test or Fisher exact test.

[b]VS1: vocational school 1.

[c]HS1: high school 1.

[d]VS2: vocational school 2.

[e]HS2: high school 2.

[f]N/A: not applicable.

Table 3. Psychoactive substance use characteristics at baseline measurement.

Category, substance, and characteristics	App group		Nonapp group		Significance[a] (app vs nonapp group)	Effect size, r
	VS1[b]	HS1[c]	VS2[d]	HS2[e]		
Legal substances, n (%)						
Alcohol						
Lifetime use	123 (92.5)	94 (88.7)	60 (92.3)	57 (95)	$\chi^2_1=0.9$	.05
Last month	65 (56)	53 (50.5)	33 (55.9)	40 (67.8)	$\chi^2_1=2.2$	.08
Tobacco						
Lifetime use	77 (52)	84 (77.6)	42 (59.2)	50 (83.3)	$\chi^2_1=2.1$	.07
Last month use	35 (45.5)	20 (24.1)	16 (38.1)	12 (24)	$\chi^2_1=0.4$	.04
Illegal substances, n (%)						
Cannabis						
Lifetime use	14 (13.1)	14 (14.1)	10 (17.2)	5 (8.5)	$\chi^2_1=0.0$	.01
Last month use	2 (1.9)	7 (7.1)	4 (6.9)	1 (1.7)	$\chi^2_1=0.0$	.001
Ecstasy						
Lifetime use	3 (2.8)	0 (0)	6 (10.3)	1 (1.7)	$P=.04$[f]	N/A[g]
Last month use	1 (0.9)	0 (0)	2 (3.4)	0 (0)	$P=.56$	N/A
Amphetamines						
Lifetime use	2 (1.9)	1 (1)	3 (5.2)	1 (1.7)	$P=.26$	N/A
Last month use	1 (0.9)	0 (0)	2 (3.4)	0 (0)	$P=.56$	N/A
Cocaine						
Lifetime use	1 (0.9)	0 (0)	5 (8.6)	1 (1.7)	$P=.01$[h]	N/A
Last month use	1 (0.9)	0 (0)	2 (3.4)	0 (0)	$P=.56$	N/A
LSD[i]/Magic mushroom						
Lifetime use	3 (2.8)	1 (1)	4 (6.9)	0 (0)	$P=.47$	N/A
Last month use	2 (1.9)	0 (0)	2 (3.4)	0 (0)	$P=.63$	N/A
Heroin						
Lifetime use	1 (0.9)	0 (0)	2 (3.4)	0 (0)	$P=.56$	N/A
Last month use	1 (0.9)	0 (0)	2 3.4)	0 (0)	$P=.56$	N/A
NPS[j]-type substances, n (%)						
GHB[k]						
Lifetime use	2 (1.9)	0 (0)	3 (5.2)	0 (0)	$P=.36$	N/A
Last month use	1 (0.9)	0 (0)	3 (5.2)	0 (0)	$P=.14$	N/A
Mephedrone						
Lifetime use	1 (0.9)	0 (0)	2 (3.4)	0 (0)	$P=.56$	N/A
Last month use	1 (0.9)	0 (0)	2 (3.4)	0 (0)	$P=.56$	N/A
Pentedrone						
Lifetime use	2 (1.9)	0 (0)	3 (5.3)	0 (0)	$P=.36$	N/A
Last month use	1 (0.9)	0 (0)	2 (3.5)	0 (0)	$P=.30$	N/A
MDPV[l]						

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Category, substance, and characteristics	App group		Nonapp group		Significance[a] (app vs nonapp group)	Effect size, r
	VS1[b]	HS1[c]	VS2[d]	HS2[e]		
Lifetime use	5 (4.7)	0 (0)	3 (5.2)	0 (0)	$P=.99$	N/A
Last month use	1 (0.9)	0 (0)	2 (3.4)	0 (0)	$P=.56$	N/A
Synthetic cannabinoids						
Lifetime use	6 (5.7)	4 (4.2)	8 (13.8)	3 (5.1)	$P=.16$	N/A
Last month use	1 (0.9)	1 (1)	4 (6.9)	0 (0)	$P=.19$	N/A

[a]χ^2 test or Fisher exact test.

[b]VS1: vocational school 1.

[c]HS1: high school 1.

[d]VS2: vocational school 2.

[e]HS2: high school 2.

[f]$P<.05$.

[g]N/A: not applicable.

[h]$P<.01$.

[i]LSD: lysergic acid diethylamide.

[j]NPS: novel psychoactive substance.

[k]GHB: gamma-hydroxybutyrate.

[l]MDPV: methylenedioxypyrovalerone.

Explaining Changes in Past Month Substance Use

As secondary outcome measures, changes in past month frequencies of psychoactive substance use were examined using the changes in beliefs about substance use, psychoactive substance–related knowledge, perceived self-efficacy, exercise frequencies, and attitudes toward substance users as explanatory variables, applying linear regression models. An increase in past month alcohol consumption was explained by a decrease in negative attitudes toward substance users (beta=−.13, $P=.04$). Changes in past month tranquillizer misuse or overuse, cannabis use, and FTND scores were not explained by any of the predictor variables. An increase in past month energy drink consumption was explained by an increase in exercise frequency (beta=.04, $P<.001$) and a decrease in perceived self-efficacy (beta=−.29, $P=.04$).

Evaluation of the App

Tables 4 and 5 present the results of the app's evaluation as provided by the respondents of the app group.

Respondents highlighted the overall utility of the app and the majority of the participants thought that the app might be an effective tool in providing preventive knowledge. Fewer respondents considered the app to be a useful instrument in decreasing substance use or promoting exercise. When assessing the connection between the use of the app's distinct modules and the main outcome measures, results of the Spearman rank correlation analysis indicated that of the 6 modules of the app, repeated use of the "What if?" roleplay module showed a significant correlation with an increase in psychoactive substance–related knowledge ($r_{S(35)}=.39$, $P=.02$). A significant correlation was also observed between a decrease in negative attitudes toward substance users and the repeated use of the "Where to go?" module ($r_{S(44)}=.31$, $P=.04$). Finally, a significant correlation was found between the app's perceived general usefulness and a decreasing past month alcohol consumption ($r_{S(44)}=.32$, $P=.03$), indicating that those respondents in the app group who found the app useful, showed lower frequencies of alcohol intake at the time of postdata collection.

Table 4. Evaluation of the app's distinct modules by the respondents.

Modules	Utility, mean (SD)	Subjective preference, mean (SD)
Animated comics	3.3 (1.3)	3.5 (1.4)
Quiz game	3.9 (1.2)	3.8 (1.3)
What if?	3.8 (1.3)	3.9 (1.3)
Substance store	3.9 (1.3)	3.8 (1.3)
Trans-formation	3.9 (1.3)	3.7 (1.3)
Where to go?	3.5 (1.4)	3.3 (1.5)

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Table 5. General evaluation of the app by the respondents.

General evaluation of the app	Mean (SD)
"Utilization of the app is easy and clear."	4 (1.2)
"By using the app, I received novel and relevant information."	3.9 (1.2)
"Visual realization fits the topic of substance use."	3.6 (1.4)
"I think that the use of this app can change the user's attitudes toward both legal and illegal substances."	3.6 (1.4)
"The app is intriguing and entertaining."	3.5 (1.3)
"The structure of the app is diverse and captures the user's attention."	3.4 (1.3)
"I think that the use of the app might facilitate treatment seeking among substance users."	3.3 (1.3)
"The quality of visual realization is high."	3.3 (1.3)
"I think that the use of this app helps in decreasing the frequency of substance use."	3.3 (1.4)
"The app helps in the destigmatization of substance users."	3.2 (1.4)
"The app helps in the promotion of exercise."	3.1 (1.4)
"The app increases empathy and tolerance."	3.1 (1.4)

Discussion

Principal Findings

This pilot study identified some potential benefits of the Once Upon a High app and also a considerable amount of flaws that need amendments to further increase the utility of the intervention. Our result that alcohol was the most commonly consumed psychoactive substance is in line with the results of epidemiological studies with respect to the substance use characteristics of the adolescent population [40]. Although we did not assess a representative sample, average lifetime use rate of NPS-type drugs was also comparable with the findings of the ESPAD study. Synthetic cannabinoids were the most popular NPS, especially in one of the vocational schools (VS2). Students of the vocational schools showed higher frequencies of tobacco, ecstasy, and MDPV use as well as higher scores on the CAST and FTND, indicating more severe problems associated with their substance use. As O'Malley and colleagues [66] emphasize in their study, school types and related socioeconomic status may have a significant impact on the students' psychoactive substance use frequencies. Considering the assessed sample, vocational students indeed reported lower living standards than high school students.

With regard to the secondary outcome measures of the regression models, results indicate that a decrease in negative attitudes toward substance users might be a risk factor for an increasing past month alcohol consumption. This finding suggests that the subgoal of the app to destigmatize the population of substance users (those who consume either legal or illegal substances) might miss the aim: instead of facilitating social tolerance, it may indirectly promote an accepting attitude toward substance use itself. According to Hohman and colleagues [67], attitudes toward psychoactive substances—especially ambivalent attitudes—can affect substance use behavior. An increase in past month energy drink consumption was associated with higher frequencies of exercise. This result is in line with the findings of Larson and colleagues [68], namely, that pursuing sports or energy drink consumption

is often related to higher rates of participation in organized sport activities among adolescents; thus, exercise is not exclusively a protective factor with respect to any substance use.

On the basis of both the respondents' evaluation on the utility of the distinct modules and the pre-and postcomparative results of our pilot study, the Once Upon a High app might be overall ineffective in decreasing psychoactive substance use (with the exception of energy drink consumption), increasing exercise frequencies, or enhancing self-efficacy at least under the conditions of this study. When we, however, assessed repeated use of distinct modules of the app (and not the app in general), the What if? module showed significant correlation with an increase in substance-related knowledge, whereas the use of the Where to go? module was associated with decreased negative attitudes toward substance users. The What if? module was also one of the most preferred parts of the app by the responding students. As the "What if?" module contains gaming elements, the fact that it was found to be the most effective and likeable part of the app, once again highlights the benefits of gamification. Johnson and colleagues [69] also conclude that as a result of their systematic review, gamification can have a positive impact on health behaviors, although current literature lacks efficacy studies with respect to the effects of gamification on substance use. Nevertheless, Fleming and colleagues [70] also emphasize that gamification might have considerable potential for increasing the efficacy of mental health–related Web-based interventions.

In terms of hypothesis testing, our study could only partially confirm the H3 hypothesis, as the app appeared to be effective in decreasing energy drink consumption but not in reducing other substance use frequencies. Considering the emerging concerns about the harmful effects of energy drinks with high content of caffeine, sugar, or other ingredients (eg taurine or guarana) and the increasing prevalence of energy drink consumption among adolescents [71], this result might still be relevant. A correlation between the app's perceived usefulness and a decreasing frequency of past month alcohol use was also found, indicating a more motivated subgroup of respondents

who not just downloaded the app but also found it a utilizable tool. It further needs to be addressed that the majority of the respondents did not show severe (or even moderate) substance use problems as indicated by the cut-off scores of AUDIT, CAST, sCAST, and FTND. Furthermore, those students who dropped out from the study, showed higher frequencies of lifetime and past month substance use. Therefore, it is likely that the app could not exert its preventive effects on those students who would have needed it the most. This high-risk subgroup mainly consisted of males and older students. Assessing a sample consisting of adolescents with problematic substance use might better fit the scope of secondary prevention. On the basis of the characteristics of our sample (ie, the majority did not show at risk or hazardous substance use), it was not entirely possible to draw valid consequences in terms of the app's secondary prevention efficacy. Although a significant increase in substance use was not found among the app users, the possibility of iatrogenic harms cannot be neglected in case of the app, as it was already noted in case of other prevention programs as well [72,73]. As Dishion and colleagues [72] pointed out, such harms might be dependent on many factors, including the adolescent target group's homogeneity (eg, containing only at-risk individuals) or the specific phase of adolescence (eg, early vs late adolescence) at the time of the intervention.

Limitations

Our pilot study is not without limitations. We did not use a randomized controlled design. The use of the app was not monitored coherently, even if respondents had to provide answers about their experiences with the app. The sample size for the applied postanalyses—because of the relatively high dropout rate—might be considered to be small for reliable multivariate analysis. Furthermore, a nonprobability, convenience sampling method was used that doubtlessly reduced the external validity of the study. The short period of follow-up time between T0 and T1 occasions (ie, 2 months) could also encumber the valid measurement of change, particularly in terms of substance use. Behavioral and cognitive change can be perceived as the result of a complex process with many unassessed factors in the background, including, but not limited to, family dynamics, peer pressure, other sources of psychoactive substance–related information (eg, internet fora), or motivation. For similar reasons, full causality cannot be assumed in our results.

These first experiences with the Once Upon a High app highlight the relevance of the target population's motivation or the lack of it. We tried to motivate participants by offering them free recreational activities; however, this strategy failed to fulfill its goals. The offered possibility of costless admission to gyms, paintball facilities, or indoor climbing centers, did not show association with an increased frequency of daily exercise, and the dropout rates were still high. Therefore, other strategies need to be tested in the future with respect to their efficacy in motivating adolescents to maintain the use of this or a similar app. As adolescents susceptibly react to peer opinion and judgments, effective dissemination of such an app might be crucial as it may form its perception in the target population. If prevention apps can be presented as exciting or even fashionable tools that promote and help the self-management of various health conditions, the motivation of adolescents to use and share these might increase. As far as we are concerned, tools of extrinsic rewards (eg, money or presents) do not come into question in case of such prevention programs. On the basis of the findings of El-Hilly and colleagues [74], it is intrinsic motivation that may function as a positive drive to engagement in a prevention program and to a positive health behavior as well, whereas external social influences might rather have a negative impact on the overall efficacy of gamification. Similar results were published by Habgood and Ainsworth [75], indicating that in-game intrinsic motivators are more effective than extrinsic ones in case of educational games.

Conclusions

To conclude, Once Upon a High app can be a useful and feasible tool to assist effective preventive intervention programs, as it was originally developed for such purposes as well, not necessarily as a stand-alone prevention instrument. It is likely that the beneficial effects of the app can be maximized when its use is supplemented with personal discussion. As Majeed-Ariss and colleagues [10] emphasize, similar apps that support personal self-management of chronic health conditions are usually implemented with the involvement of health professionals. School psychologists, health visitors, or social workers can also be involved in such projects to improve the effects of the app as well as to increase the target population's commitment to use it.

Further research is needed to assess additional potentials of the app, and it is also necessary to find better ways to motivate the target population to repeatedly use this tool. Preventive effects of the app on substance use itself also need to be explored by using probability sampling and larger effect sizes and increasing the heterogeneity (eg, cross-cultural differences) to find established ways to improve the app so that it can be really called and function as a "prevention" app in the end. This pilot study might function as a basis for future research with such purposes.

Dániel Karasz (programmer), Klára Berczi (project management), and Lívia Lukács (creating the app's logo). The authors also wish to thank members of the co-design group for their contribution.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Technical details of development.

[[PDF File (Adobe PDF File), 251KB](#) - [games_v6i4e19_app1.pdf](#)]

Multimedia Appendix 2

Pre-and posttest description in point of the outcome measures.

[[PDF File (Adobe PDF File), 29KB](#) - [games_v6i4e19_app2.pdf](#)]

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Abbreviations

AUDIT: Alcohol Use Disorder Identification Test
CAST: Cannabis Abuse Screening Test
FTND: Fagerström Test for Nicotine Dependence
GHB: gamma-hydroxybutyrate
LSD: lysergic acid diethylamide
MDPV: methylenedioxypyrovalerone
NPS: novel psychoactive substance
sCAST: Cannabis Abuse Screening Test adapted for synthetic cannabinoids
SUD: substance use disorders
UID: unique identifier

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Original Paper

A Mobile App Delivering a Gamified Battery of Cognitive Tests Designed for Repeated Play (OU Brainwave): App Design and Cohort Study

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Abstract

Background: Mobile phone and tablet apps are an increasingly common platform for collecting data. A key challenge for researchers has been participant "buy-in" and attrition for designs requiring repeated testing.

Objective: The objective of this study was to develop and assess the utility of 1-2 minute versions of both classic and novel cognitive tasks using a user-focused and user-driven mobile phone and tablet app designed to encourage repeated play.

Methods: A large sample of app users (N=13,979 at first data collection) participated in multiple, self-paced sessions of classic working memory (N-back), spatial cognition (mental rotation), sustained attentional focus (persistent vigilance task), and split attention (multiple object tracking) tasks, along with the implementation of a comparatively novel action-learning task. The "OU Brainwave" app was designed to measure time-of-day variation in cognitive performance and did not offer any training program or promise any cognitive enhancement. To record participants' chronotype, a full Morningness-Eveningness questionnaire was also included, which measures whether a person's circadian rhythm produces peak alertness in the morning, in the evening, or in between. Data were collected during an 18-month period. While the app prompted re-engagement at set intervals, participants were free to complete each task as many times as they wished.

Results: We found a significant relationship between morningness and age (r=.298, n=12,755, P<.001), with no effect of gender ($t_{13,539}$=−1.036, P=.30). We report good task adherence, with ~4000 participants repeatedly playing each game >4 times each—our minimum engagement level for analysis. Repeated plays of these games allowed us to replicate commonly reported gender effects in gamified spatial cognition ($F_{1,4216}$=154.861, P<.001, η^2_ρ=.035), split attention ($F_{1,4185}$=11.047, P=.001, η^2_ρ=.003), and sustained attentional focus ($F_{1,4238}$=15.993, P<.001, η^2_ρ=.004) tasks. We also report evidence of a small gender effect in an action-learning task ($F_{1,3988}$=90.59, P<.001, η^2_ρ=.022). Finally, we found a strong negative effect of self-reported age on performance, when controlling for number of plays, in sustained attentional focus (n=1596, $F_{6,1595}$=30.23, P<.001, η^2=.102), working memory (n=1627, $F_{6,1626}$=19.78, P<.001, η^2=.068), spatial cognition (n=1640, $F_{6,1639}$=23.74, P<.001, η^2=.080), and split attention tasks (n=1616, $F_{6,1615}$=2.48, P=.02, η^2=.009).

Conclusions: Using extremely short testing periods and permitting participants to decide their level of engagement—both in terms of which gamified task they played and how many sessions they completed—we were able to collect a substantial and valid dataset. We suggest that the success of OU Brainwave should inform future research oriented apps—particularly in issues of balancing participant engagement with data fidelity.

Introduction

Recent advances in the performance and accessibility of Web technologies have resulted in increasing use of Web platforms to conduct cognitive psychology research. Large, diverse cohorts easily available to researchers are now accompanied by platforms capable of implementing complex tasks and accurately measuring performance [1,2]. Moving on from Web-based data collection, possibilities offered by custom built, natively coded, mobile apps include high levels of stimulus control and enormous flexibility in experimental design and data collection—both frequency of data-collecting sessions and range of data collected [3]. By collecting large sets of cognitive performance data, insights into subtle variations in cognition, both within an individual, as here, or across individuals and cultures [4], are potentially available to researchers. The aspects of tasks included here are prevalent in many everyday skills and activities—from paying attention to all potential threats when crossing a busy road (Track—multiple object tracking), to packing a suitcase efficiently (Spin—mental rotation). Understanding cognitive performance is hugely important. Even if we consider only healthy mental function, only by understanding our cognition's fundamental properties can we design our lives [5], work [6,7], and play [8] to enable our own best performance [9,10].

A key issue for all psychology researchers is recruiting participants. While laboratory-based studies can often rely on departmental participation requirements to ensure a steady flow of—debatably—willing participants, the sample obtained is inevitably limited in demographic factors [11]. Web-based and app-based studies are one possible way of researching with a broader sample of participants, but to achieve this, researchers must ensure their task, or request, is an engaging one, especially if it requires repeated testing sessions for data collection. Embedding the experimental collecting task within an engaging, fun-to-play game is an increasingly popular way of trying to improve participant engagement and retention. A recent systematic review of gamification of cognitive tasks suggested increased engagement as one of the main reasons for gamification [12]. Moreover, this review highlighted additional benefits of gamification, such as reducing anxiety and extending the investigator's reach, while underlining the potential that gamification has to improve data collection without necessarily impairing data's validity.

OU Brainwave is a bespoke app, launched on multiple platforms, designed to collect research data while providing participants with understandable measures of their performances across 5 facets of cognitive ability. The app includes gamified tasks designed to measure performance on aspects of working memory, spatial cognition, sustained attentional focus, split attention, and action learning. Importantly, neither did we set out to "train" participants in any of these aspects of cognitive ability nor does the app make any promise of improvement to

cognitive performance through repeated play. Instead, the app seeks to measure natural variation in performance on such tasks throughout the day [13] and in relationship to an individual's sleep-wake cycle [14]. The app also aims to utilize a large-scale sample to answer the question of whether such variations are related to an individual's Morningness-Eveningness score—ie, whether "Larks" perform better earlier in the day than "Owls" who perform better later [15].

Here, we present in-game data from the app, report our cohort's broad performance across the 5 tasks in relationship to the respective task literatures and any relationships between demographic factors and performance, and discuss broader issues of gamification and task design for use in app-based testing.

Methods

OU Brainwave

The OU Brainwave app was designed and created in collaboration with an external developer (Conjure Ltd, London, UK). Each game included in the app went through numerous rounds of development, with usability and participant engagement given equal weight for essential factors of data validity and experimental design. The app was launched on Android and iOS mobile phone platforms in February 2015. The launch was publicized through blog posts and traditional media coverage. In addition, participants were encouraged to publicize the app through an built-in function of sharing a graph of their individual results to social media.

Ethical approval for this study was obtained from the Open University Human Research Ethics Committee. Immediately upon downloading and opening the app, participants were presented with an informed consent statement, with which they were required to agree via a tick box to continue using the app. Once consent was received, a unique participant ID for each participant was generated to link participant and future session data. Should individual participants wish to withdraw their consent at a later date, they could do so through a settings screen. Doing so deleted all participant data on the device and returned the participants to the app's opening screen, where they had to agree again to the consent statement to reuse the app. At no point was any personal or potentially identifying information collected from the participants.

Participants entered simple demographic information: gender (male or female) and age in years although participants could choose not to answer either of these questions. Participants then completed the 5-item Morningness-Eveningness self-report questionnaire (MEQ) [16]. The MEQ is a well-established and validated research tool which measures whether a person's circadian rhythm produces peak alertness in the morning, in the evening, or in between [13,17,18], and the 5-item variation of the original questionnaire was used here to move participants to the more interactive aspects of the app as quickly as possible.

Using the original scoring of this MEQ implementation, participants were coded into one of 5 types ranging from "strongly morning type" to "strongly evening type." This result was shared onscreen with the participants, and to encourage continued and repeated participation, they were then prompted to continue to the games to "see if your performance matches your belief."

The app also attempted to ameliorate high attrition rates from which mobile phone apps suffer by displaying the participant performance graph only once the participant had completed 3 sessions. This was made clear to participants each time they used the app until they had completed this requirement, at which point a graph of their performance, on each of the games and as an aggregate score, was shown. These graphs were designed to show participants variation in their performances on tasks across day and night, rather than to reveal absolute performance levels. As such, the performance values were normalized for each participant to highlight the best and worst scoring sessions. Accompanying the presentation of these graphs were icons encouraging the participant to share the image on social media.

At the beginning of each session (ie, on each subsequent launching of the app), participants were also asked up to 3 additional questions. A single item of mood rating [19] was included at the start of every session, "How is your mood right now?" to which they responded via a visual analog scale (VAS) slider. If a session was the first on a given day, participants were also asked what time they had woken from sleep and how many hours of sleep they had had the previous night. Participants could opt to skip answering these questions and continue to games. Each session comprised all 5 games, which were presented in a randomized order. Participants could choose to skip any game during a session, but were encouraged to complete them all through game-by-game results graphs of their individual performance within the app. These graphs were shown only after 3 full sessions to encourage a minimum level of engagement and were updated with each play after this point to promote continued play.

Games

Hotspot: Action Acquisition Task

The Hotspot game is a variation on an action discovery and acquisition task [20]. In this task, participants must discover a target area by tilting their phone or tablet to roll an onscreen ball into a target area (Figure 1). The target area is unmarked, and no feedback is given until the target area is "discovered" by the participant rolling the ball over the area, at which point the ball's color changes. Participants must then use this color change to guide them in bringing the ball to rest within the target area. Task difficulty was adjusted in development by including a 100-milliseconds delay between success (ie, entry into the target area) and a feedback signal (ie, ball's color change). The effect of delays of this type and magnitude is to increase task difficulty [21] and was intended to prevent ceiling effects among app participants. The game consisted of 5 attempts, and each attempt presented a new, randomly chosen target area covering 5% of the game arena's total space, with the ball covering half of that area. To succeed in the game, participants had to keep the ball within the target area for 500 milliseconds of a 1-second window. Scores were allocated so that 50% of points available were awarded for finding the target, and the remainder were apportioned according to milliseconds elapsed before the ball remained within the target area for the required time.

Figure 1. Screenshots of OU Brainwave app, showing Hotspot game instructions and play screen.

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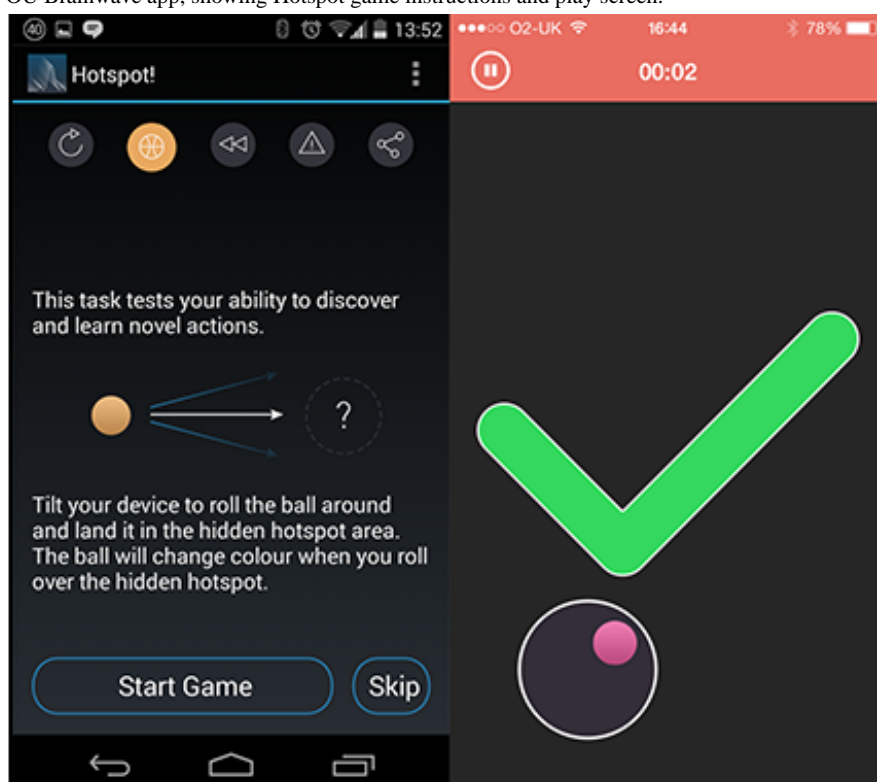
React: Persistent Vigilance Task

The React game was intended to be an implementation of the psychomotor vigilance task [22]. During the design process, it was decided to adjust how the task was operationalized in the game to try to increase participant engagement. This was done by including a simple choice element, which was in addition to the reaction time task and not a standard part of the classic psychomotor vigilance task. Participants were presented with 4 large, red, circular buttons (Figure 2). At a random interval from 2 to 7 seconds, one button changed color to green, and the participant had to tap the appropriate button within a 600-milliseconds window. Auditory and visual feedback was given on both correct and incorrect responses. This was repeated 8 times. Participant scores were essentially simple reaction time measures, with scores reducing according to milliseconds elapsed before a correct response was recorded, after a 100-milliseconds grace period. Responses made before the color change or incorrect button presses scored zero.

Spin: Mental Rotation Task

Spin is a gamified implementation of a spatial rotation task, using the stimulus set developed by Bethell-Fox and Shepard [23], shown in Figure 3. This stimulus set contained 18 possible patterns of filled squares within a 3×3 grid, avoiding excessive simplicity or difficulty and rotational symmetry of pattern. Each pattern contained 1, 2, or 3 groups of filled squares within the grid. While the original paper split these into levels of difficulty, all 18 patterns were presented here in a random order within a given session to provide the participant variation. In the Spin game, participants were required to match the test image with 1 of the 3 options. Feedback was given in the form of ticks and crosses in circles at the top of the screen, and a timer was shown with the remaining time for the task.

Participants were presented with a large image of the target grid and had to correctly identify the rotated version of this grid from 3 alternatives presented below. The correct version was rotated at random by 90, 180, or 270 degrees. Incorrect options consisted of the test pattern reflected either vertically or horizontally. Participants had 45 seconds to make as many correct judgments as they could, up to a maximum of 18, and correct or incorrect auditory and visual feedback was given after each response.

Figure 2. Screenshots of OU Brainwave app, showing React game instructions and play screen.

Figure 3. Screenshots of OU Brainwave app, showing Spin game instructions and play screen.
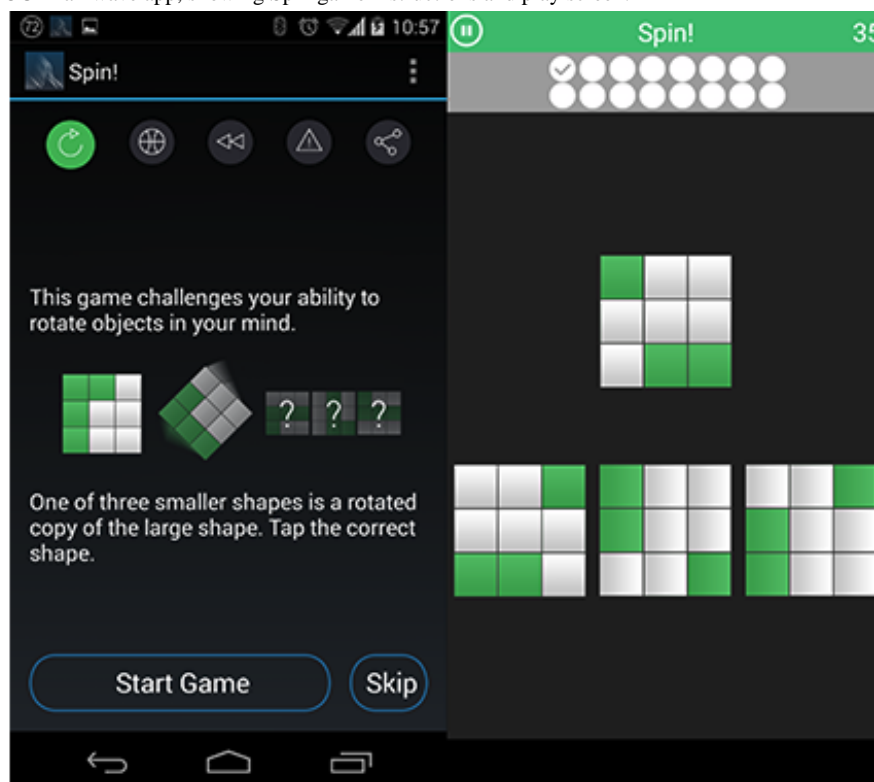
Super Snap: N-Back Analog

A simple implementation of the classic N-back task was used as a test of working memory (Figure 4). The N-back task has a long history of use in studies of working memory [24], see Kane [25] for a detailed discussion of the N-back's construct validity. Here, a series of 6 brightly colored shapes (ie, circle, hexagon, rhombus, square, star, and triangle) were shown onscreen, and participants had to tap the screen to mark when the current shaped matched with previously shown two shapes. Each shape was presented onscreen for 1.5 seconds against a blank black background with an interitem delay of 1.5 seconds. Auditory and visual feedback was given after each response, along with a tick or cross at the top of the gameplay window. Participants were scored by the number of correct responses, and the game continued until 10 matches had been presented or 10 responses (including false alarm incorrect responses) had been made. Participants started each session with a score of 60 and lost 6 points for each incorrect response or miss recorded.

Track: Multiple Object Tracking

The Track game (Figure 5) is a gamified version of a multiple-object tracking task [26]. In this task, participants had to track the location of 3 members of an array of identical moving balls. A subset of balls onscreen was highlighted before the start of the trial, before reverting to white once the trial started and all balls began to move. Participants were first shown a static array of 8, 9, or 11 balls, 3 of which were highlighted in pink, rather than the color white of the other balls. After a 3-second countdown, highlighted balls reverted to white, and all balls began moving on independent, randomly assigned trajectories. Each ball's speed and direction of movement was adjusted randomly between each frame, and collisions between balls or borders were handled such that no ball was ever overlapped or exceeded the playing area. The balls continued in motion for 5 seconds, after which time the entire array stopped, and participants were instructed to tap the 3 balls that had been highlighted at the start of the trial. Two trials of each array size were shown, with set sizes presented in an increasing order. Participants were scored on the number of balls correctly identified with nonresponses counted as incorrect. Each correctly identified ball added a score of 2.5, so a maximum score of 45 across 6 trials was possible. Auditory and visual feedback was given after each trial, along with a tick (for correct identification of all balls) or a cross for each trial, along the top of the gameplay area.
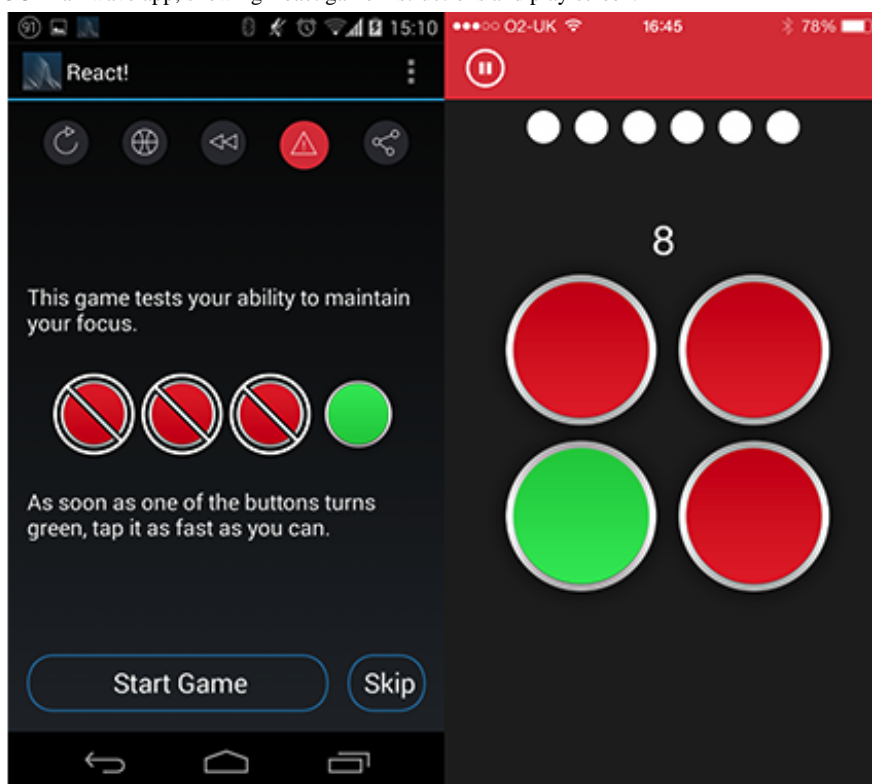
Figure 4. Screenshots of OU Brainwave app, showing Super Snap game instruction and play screen.

Figure 5. Screenshots of OU Brainwave app, showing Track game instruction and play screen.

Results

Demographics

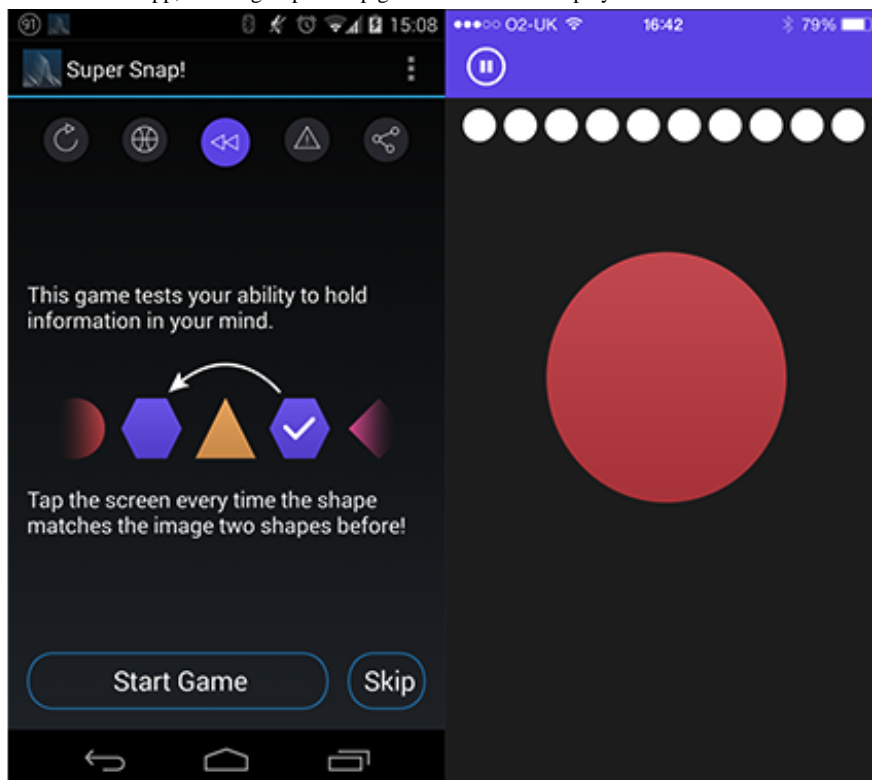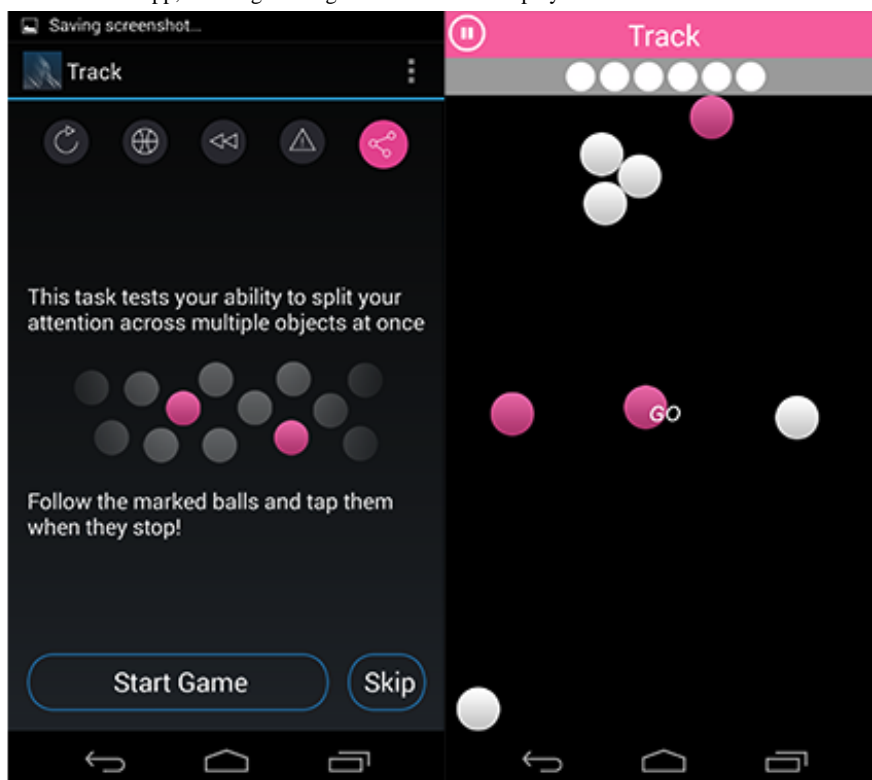### *Number of Downloads and Participants*

The OU Brainwave app was launched on both Apple and Android stores on January 15, 2015. Discovery of the app peaked in its launch month, with 4394 installations during January, with the expected drop-off of installations broken only by smaller peaks in April 2015 and January 2016—both probably due to further publicity. Again, like many apps, OU Brainwave found far more users on the Apple platform than on the Android platform—with roughly two-thirds of 15,890 users across the 18.5-month data collection window using Apple devices.

Separately, and far more importantly than the raw number of downloads, is the number of active app users. As with many mobile phone apps, many downloaders either did not open the app or did not engage with the app sufficiently to be considered active users.

Of 15,890 installations between app launch and July 31, 2016, 13,979 used the app sufficiently to upload some data to the server, meaning almost 2000 downloaders did not open the app after installation. Engaging with the app for a single session only—the most popular decision among downloaders—were 3661 users, contributing at most demographic and MEQ data along with a single session's play to the dataset. Attrition among the remaining 10,319 was predictably steep, with only 5756 users playing for >3 sessions, dropping to 1435 users at ≥10

sessions. Although no contact information was deliberately collected, so precluding any survey of participants who stopped early, potential disincentives may have included technical issues, particularly with the Android app, "pestering" by app notifications, or a perception that the app's demands were too high.

Just over 1000 users played ≥12 sessions, and just over 100 played ≥30 sessions. Additionally, each user was free to play 1, some, or all 5 games during a given session, so while 3556 users completed 5 plays of any single game, only 2780 completed 5 plays of all 5 games. For this reason, later analyses were conducted on a game-by-game level, and no overall performance measure was calculated.

Demographics of Total Participant Cohort

Of 13,979 total participants, 39.47% (5517/13,979) self-reported as male and 58.88% (8231/13,979) as female, with only 1.65% (231/13,979) declining to answer the gender question. Self-report ages of all participants are shown in Figure 6.

Distribution of participants' reported ages shown in Figure 6 reveals a shortcoming of implementation of self-report demographic data collection. While 1033 declined to answer the age question, an exceptionally large number of participants reported their age as 18 years (965, compared with 405 for 27 years, the next most common age). While this might well be an accurate figure, it could potentially be an artifact caused by the requirement for participants to confirm they are over 18 years to use the app and play the games—a stipulation necessary for ethical approval.

Figure 6. Age of participants by gender.
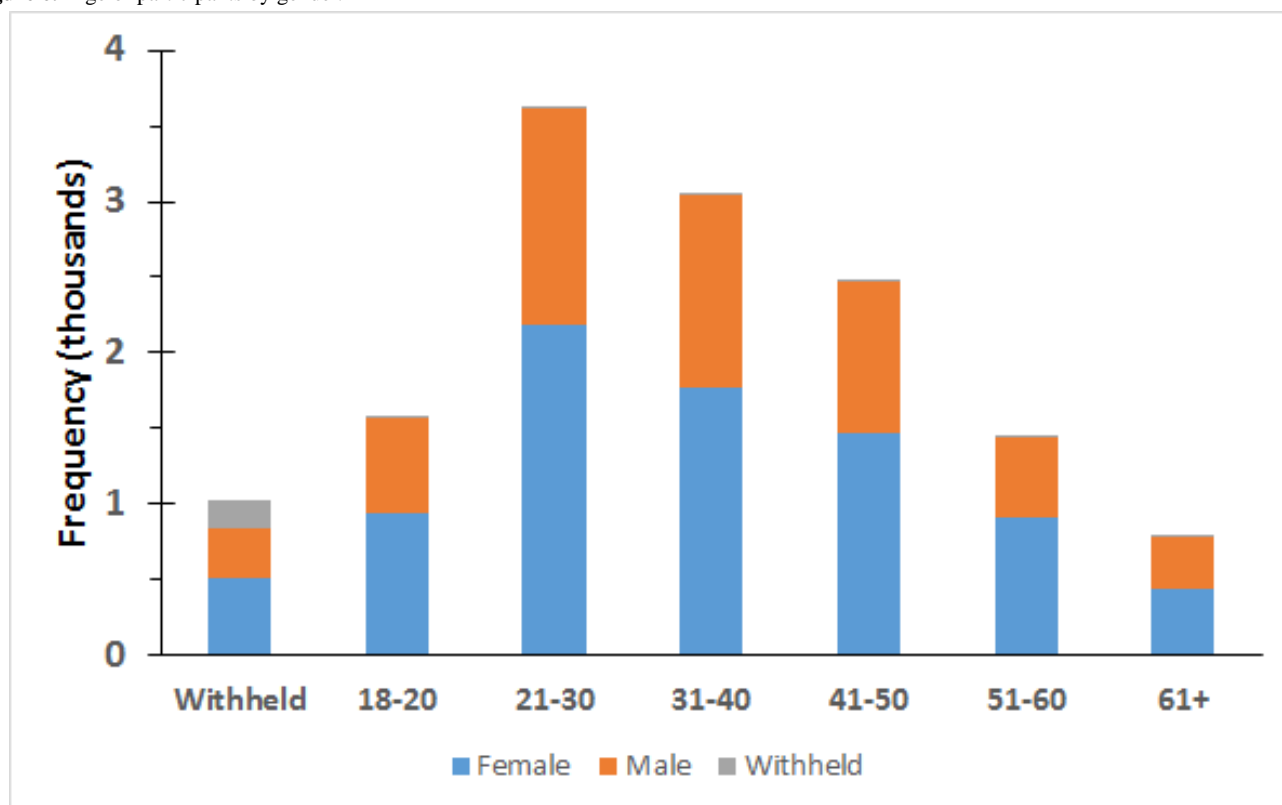
Therefore, 18 years was the lowest selectable age in the self-report question. Unless age controls on downloading and installation of apps—controlled by the developer or app store rather than the end user (or parent)—become a viable option, future apps, especially particularly gamified ones, may consider collecting and subsequently discarding (or filtering not to upload) data from particular age groups, rather than attempting to exclude by self-report of age.

Morningness-Eveningness Questionnaire

The 5-item MEQ [16] that each participant completed produces a score from 4 to 25, ranging between extreme evening type and extreme morning type. Respondents are then traditionally classified into 5 classes by their scores (Definitely evening type: 4-7; moderately evening type: 8-11; neither type: 12-17; moderately morning type: 18-21; and definitely morning type: 22-25). From our original sample, 13,752 participants filled in all sections of the MEQ survey. As is common in studies using the MEQ, approximately half of our overall sample scored within the "neither type," central range of the MEQ (7172/13,752, 52.2% participants). A further third of participants scored in one of the evening type categories (4584/13,752, 33.3% participants), with the remaining 14.5% (1996/13,752) scoring in the morning type categories.

One of the stronger relationships usually found by the MEQ is that between age and morningness [18,27]—greater age is associated with greater morningness scores—and as Figure 7 shows, we replicated that finding here. We found a statistically significant correlation between age and MEQ score for participants who submitted both age and MEQ data (r=.298, n=12,755, P<.001). The greater absolute number of evening types than morning types in the dataset is almost certainly a result of this relationship being expressed in our cohort, which was skewed toward younger participants.

As Figure 8 shows, there was no significant difference between MEQ scores for males and females: mean 13.20 (SD 4.00) versus mean 13.28 (SD 3.99); $t_{13,539}$=−1.036; P=.30. While many studies have reported greater propensity for evening types in males than in females [17], lack of gender differences reported here is not an uncommon finding in the literature [18].

Cognitive Task Results

Comparison of Results to Previous Research and Demographic Effects

Because each participant could choose to play separate games individually, any 2 participants potentially played any given game a different number of times. Additionally, the full participant set includes participants who did not play a particular game sufficiently to become familiar with it. This makes handling data generated by the app very different from handling the usual data generated by tasks in OU Brainwave when conducted in a laboratory setting. To address the issue of participants who did not engage with a task sufficiently even to familiarize themselves with it, we implemented a cutoff minimum of 4 plays of each game for any participant to be included in analysis for that game. The intention was to remove participants who played no more than what would be considered

a "practice trial" set in a laboratory-based experiment. However, this still leaves variability in the number of measures per participant (in terms of sessions played) and the possibility that those participants who played more would register a higher mean score on each game. Therefore, the effect on score of demographic variables was analyzed with the number of plays as a covariate. To remove outlier individuals, the most extreme 1% of average performance scores were identified and excluded before all analyses.

Other Effects

Gender

Gender effects were analyzed using analysis of covariance with the mean score of the participant as the dependent variable, gender as a fixed factor, and the number of plays as a covariate. To ensure gender and number of plays were not confounded, a t test was conducted to confirm no significant difference between the number of plays of a particular game by each gender. For each of the 5 games, this test was nonsignificant. Table 1 shows the mean number of plays across gender for each game and the associated t test statistic.

Track: Multiple Object Tracking

For the Track game, 4188 participants (1455 male and 2733 female) completed ≥4 sessions. Previous studies in using multiple object-tracking paradigms have shown an advantage for male participants [28], and we replicate that finding here. There was significant, but small, effect of gender on performance after controlling for number of times beyond 4 that each participant played the game ($F_{1,4185}$=11.047, P=.001, η^2_ρ=.003). Male participants scored on average 1.2 points more than female participants: male: mean 38.9 (SD 12.0) versus female: mean 37.7 (SD 11.7). Although, it should be noted that variance in score accounted for by gender is very small (~0.3%) and only roughly half that accounted for by the significant effect of the number of plays beyond 4 by a particular participant ($F_{1,4174}$=27.524, P<.001, η^2_ρ=.007).

Super Snap: N-Back Analog

For the N-back analog Super Snap, 4215 participants (1449 male and 2766 female) completed ≥4 sessions. We found no effect of gender on performance after controlling for the number of plays beyond 4 ($F_{1,4212}$=2.711, P=.1, η^2_ρ=.001), although the number of plays beyond 4 was still found to improve performance significantly ($F_{1,4227}$=127.06, P<.001, η^2_ρ=.03).

React: Persistent Vigilance Task

For React, 4241 participants (1460 male and 2781 female) completed ≥4 sessions. We found a small, but significant effect of gender on performance after controlling for the number of plays beyond 4 ($F_{1,4238}$=15.993, P<.001, η^2_ρ=.004), accounting for 0.4% of variance in mean score. Male participants scored an average of 4 points more than female participants: male, mean 409.0 (SD 29.6) versus female, mean 405.1 (SD 29.9). The number of plays beyond 4 was not found to improve performance significantly ($F_{1,4238}$=1.264, P=.26).

Figure 7. Morningness-Eveningness self-report questionnaire (MEQ) scores by age.
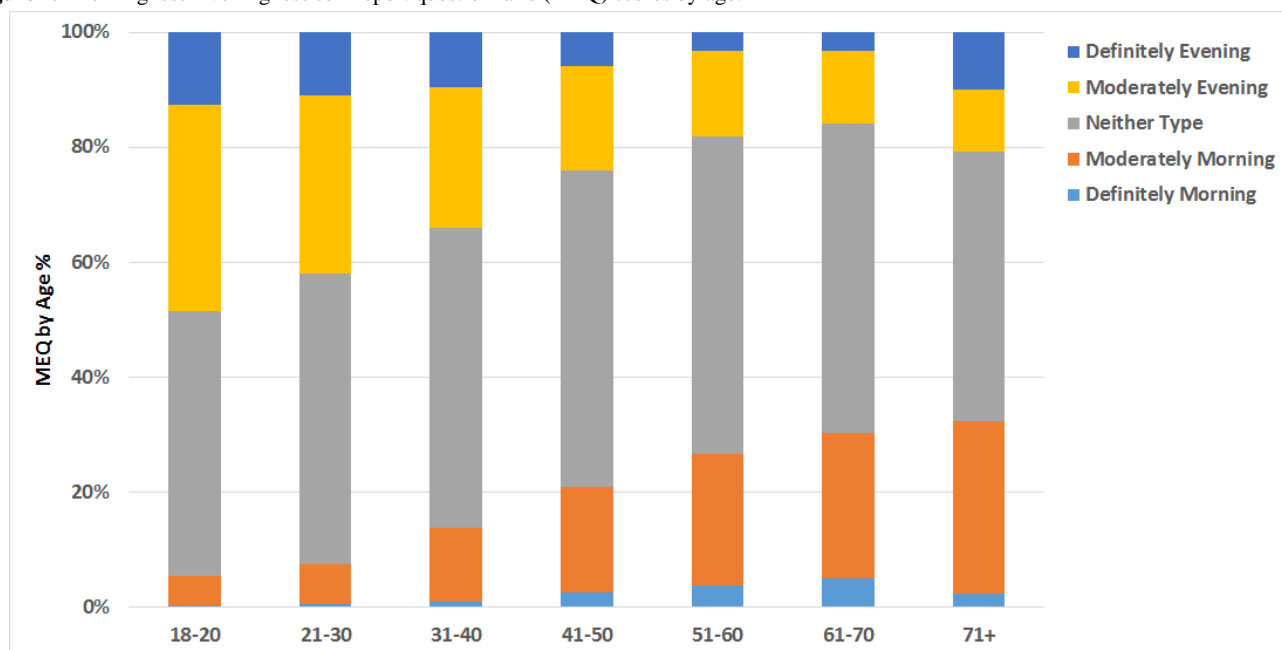
Figure 8. Morningness-Eveningness self-report questionnaire (MEQ) scores (color coded by MEQ category) by gender.
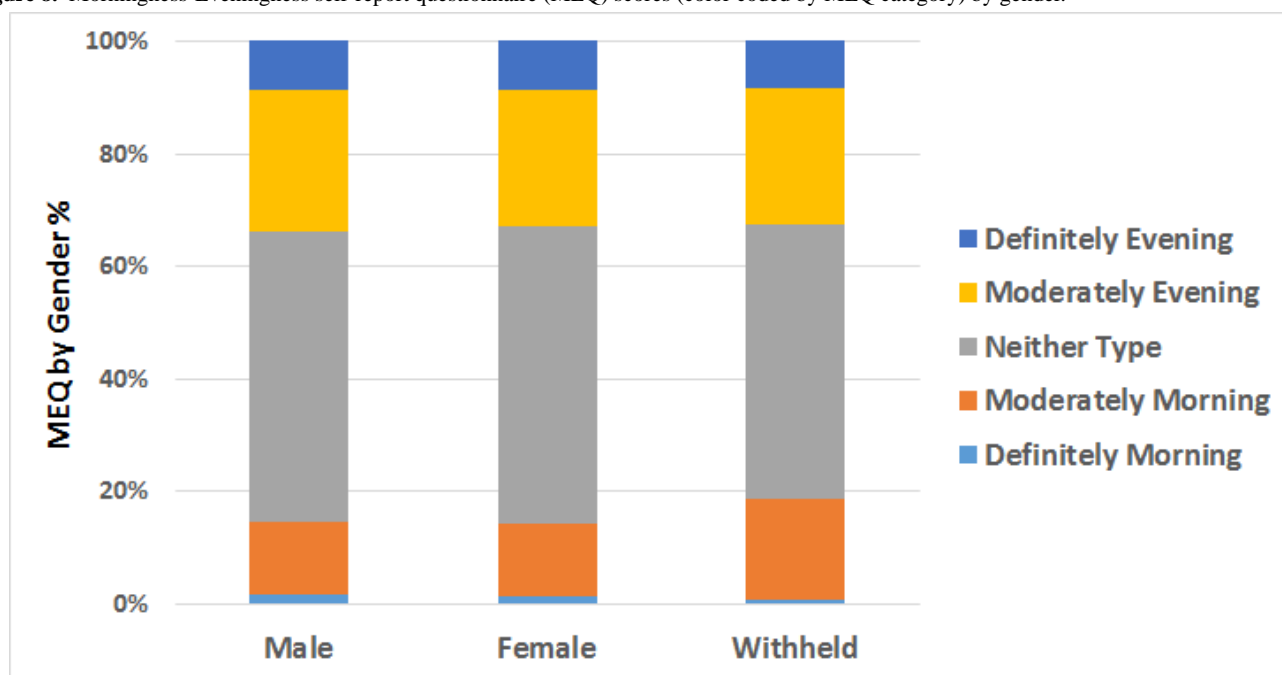
Table 1. Mean number of plays by game and gender.

Game	Number of plays, n		Number of plays, mean (SD)		t test	
	Male	Female	Male	Female	t value	P value
Hotspot	1403	2640	8.07 (8.56)	8.36 (7.12)	$t_{4041}=-1.150$	.25
React	1495	2840	8.09 (8.52)	8.32 (7.16)	$t_{4333}=-0.933$	.35
Super Snap	1459	2773	8.13 (8.52)	8.42 (7.31)	$t_{4230}=-1.175$	.24
Spin	1475	2784	8.16 (8.61)	8.40 (7.36)	$t_{4257}=-0.932$	.35
Track	1457	2735	8.12 (8.57)	8.38 (7.30)	$t_{4190}=-1.038$	.30

Spin: Mental Rotation Task

For Spin, 4219 participants (1455 male and 2764 female) completed ≥4 sessions. We found significant effect of gender on performance after controlling for the effect of number of plays beyond 4 ($F_{1,4216}$=154.861, P<.001, η^2_ρ=.035), accounting for 3.5% of variance in score. Male participants scored on average 3 points more than female participants: male, mean 23.6 (SD 7.7) versus female, mean 20.6 (SD 7.5). The number of plays beyond 4 was still found to have significant, albeit smaller, benefit to performance ($F_{1,4216}$=60.45, P<.001, η^2_ρ=.014).

Hotspot: Action-Learning Task

A total of 3991 participants completed ≥4 sessions of Hotspot (1393 male and 2598 female). We found a small, but significant effect of gender on performance after controlling for the number of plays beyond 4 ($F_{1,3988}$=90.59, P<.001, η^2_ρ=.022), with male participants scoring on average 3.7 points more than female participants: male, mean 31.33 (SD 12.25) versus female, mean 27.64 (SD 12.03) and accounting for 2.2% of variance in mean scores across the cohort. However, the number of plays beyond 4 was also found to have significant effect of similar size on performance ($F_{1,3988}$=105.946, P<.001, η^2_ρ=.026).

In summary, of the 5 games, all but the N-back task showed significant effect of gender, after controlling for the number of plays beyond 4. In each game that showed an effect, male participants scored higher (React, Track, Spin, and Hotspot), with the strongest effect in the mental rotation-based game Spin.

Age Effects

For every game, there was significant positive correlation between the age of participant and the number of plays (React: n=4171, r=.216; Super Snap: n=4081, r=.221; Spin: n=4100, r=.216; Hotspot: n=3896, r=.215; Track: n=4035, r=.266, all significant at P<.001). Older participants played far more sessions than their younger counterparts, possibly due to the cohort's self-selecting nature. Demographically, older people are less likely to either have a mobile phone or use a mobile phone for playing games [29], so it may be the case that for an older person, downloading the app represented greater commitment to engage with it. With such a confounding relationship between the number of plays and age, it was not appropriate to adopt the same approach—analysis of covariance using mean score for each participant—as to analyze gender. Instead, a stratified approach was used to analyze the effect of age on performance, controlling for the number of plays. Rather than calculating mean scores from all sessions of a participant, the mean score for each participant from only their 4th, 5th, and 6th sessions was calculated. These early snapshots provided a measure of each participant's performance before going on to complete differing numbers of sessions and attaining an eventual average performance level.

Using this measure, we then broke participants into 7 age groups by decade (<20, 20-29, 30-39, 40-49, 50-59, 60-69, and >70). This allowed us to analyze any potential age effects with analysis of variance and to compute effect size for each game.

We found significant effect of age in all games except Hotspot. Results from React (n=1596, $F_{6,1595}$=30.23, P<.001, η^2=.102); Super Snap (n=1627, $F_{6,1626}$=19.78, P<.001, η^2=.068); and Spin (n=1640, $F_{6,1639}$=23.74, P<.001, η^2=.080) all align with previous findings that show strong negative associations between age and reaction time [30], age and working memory as measured by the N-back task [31], and age and mental rotation [32]. The Track game, as an implementation of the multiple object-tracking paradigm, might have been expected to similarly replicate a previously found age effect for multiple object tracking [33]. While we did find significant main effect of age on multiple object-tracking performance, it was much smaller than that for React, Super Snap, and Spin (n=1616, $F_{6,1615}$=2.48, P=.022, η^2=.009). There was no relationship between age and performance on the action discovery task—the Hotspot game (n=1519, $F_{(6,1518)}$ = 1.78, P=.10, η^2=.007). These analyses were also conducted with a correlational approach, and the pattern of results was broadly similar.

Mood

Before starting each session of games, participants were presented with a single mood rating to which they responded via a VAS slider. These additional data were collected to investigate the relationship between mood and cognition. Previous research has suggested a complex relationship between emotions, mood, and performance on cognitive tasks [34,35], with both beneficial and detrimental impacts on cognitive performance reported from a single, for example, positive mood induction [36]. Here, rather than inducing a given mood, we simply recorded the participant's self-report of pre-existing mood, captured by a single item VAS measure (1-10, 10 being the happiest) [19].

To be as inclusive as possible, all participants completing ≥4 plays of each game were included in this analysis and collapsed across age and gender, giving group sizes from 3988 (Hotspot) to 4331 (React) for each of the 5 games. No strong relationship between participants' average mood and average performance was found for any of the games, with all Pearson correlation values from 0 to.15. Similarly when correlation coefficients for every participant were calculated individually for each game, no relationship was found, with the mean rho value being <.02 in all cases, and for Super Snap, Spin, and Track, not significantly different from 0. While future analysis may explore the possibility of nonmonotonic relationships between mood and performance or potential differences in subgroups of the cohort, this first analysis suggests that either a single item VAS measure is insensitive to impactful changes of mood or that mood and performance were unrelated on any task in the app.

Practice Effects and Learning Curve Analysis

Each participant's freedom to play each game uncontrolled number of times and the likelihood that this would affect an individual's performance mean that either including number of plays as a covariate or controlling this factor in analysis is the most effective way to address a gamified testing platform's individual freedom. However, visualizing at the group level, the effect of number of plays on performance is still possible.

Figure 9. Practice effects and number of participants replaying for the "React" game and the "Super Snap" game.
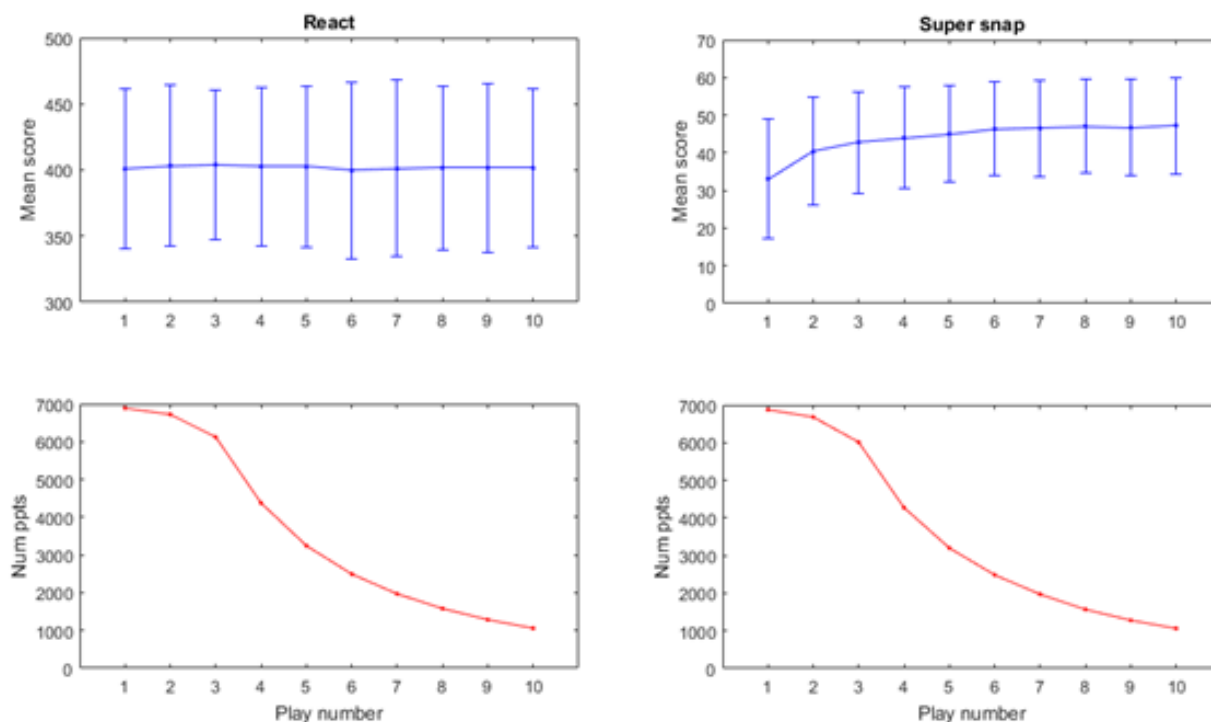
Plotting mean scores for all participants in each game, except for the React game, shows typical practice effects as participants familiarized themselves with tasks. Practice effects are very common in psychological and psychometric testing and almost certainly reflect some combination of task familiarization, development of ability tested by the task, development of a strategy to complete the task as set, and possibly, reduced anxiety about the task's mechanics [37].

While 4 of the 5 games showed typical practice effects—a stabilizing of performance following an initial rise [38]—the React game, being essentially a very basic reaction time task, seems to have been too simple to produce any practice effect-driven improvement in performance across participants' first few sessions (see Figure 9), probably because participants immediately familiarized themselves with the task on the first play, and no effective strategies can be adopted to improve performance. However, variability of the cohort as a whole—in terms of interplay interval, age, gender, and MEQ—mean that further group analysis of practice effects is unnecessary. The presence of expected stabilization of performance after a number of plays reflects the app's intention to measure variations in performance, rather than to train or improve participants' abilities. Most importantly, it means that future analysis of within-individual factors (eg, time-of-day of play) should have a stable performance level from which to contrast such changes.

Discussion

Success of App Approaches

The large cohort collected by the OU Brainwave app, and, moreover, the repeated measurement of this cohort in quick, engaging gamified versions of classic and novel psychological tests, is another demonstration of the promise of mobile app-based testing [39]. While we deliberately did not collect more detailed demographic data, we can safely say that with such a large sample, our testing cohort would have been extremely diverse compared with samples drawn from undergraduate participant pools that typify much laboratory-based research. This, along with the sheer size of the cohort tested, should mean that any reliable findings arising from this dataset are relatively robust and not hostage to cohort effects.

The usual caveats regarding the reliability of self-report data apply to our demographic and MEQ responses [40]. While this has resulted in potential concern regarding the high number of participants self-reporting their age as 18 years, the possibility remains that this is an accurate reflection. Moreover, as a full dataset, the cohort replicates a number of age-related findings, both in increased morningness in older participants and reductions in cognitive task performance. The very low proportion of participants who withheld demographic information—only 231 participants, <2% of our total cohort, withheld either their age or gender information—is very encouraging for future mobile phone-based research, which can expect a high level of engagement from participants who download the app.

OU Brainwave is not the most downloaded research-focused app, and since its release, a number of impressively large datasets have been collected and published using other app platforms [41] and Web apps [42]. However, while OU Brainwave suffered from the same participant attrition as all apps, it recruited an impressively engaged cohort who repeatedly played games (1400 participants played >10 times) even though the games did not vary or become more challenging with continued play. This suggests that some participant engagement features were successful.

A key intention in the development of OU Brainwave was to balance the demands of behavioral experiments, in terms of data validity and operationalization of the mechanism under study, against the enjoyment and engagement of the participants. The high levels of engagement by participants who downloaded the app suggest that an in-game narrative, characters to interact with, or even an elaborate game environment may not be necessary. Studies directly manipulating the extent of gamification have reported similar lack of effect of common gamification techniques on participant attrition [43]. The games, while offering dramatically shorter sessions than one would find in laboratory testing, did not deviate far from their experimental task heritage. Except for the React game, no significant change was made from the mechanics of underlying psychological tasks, and tasks were presented without cutesy preambles, fictional scenarios, or even in-game rewards beyond simple graphing of participant performance. Withholding individual participants' performance graphs until they had completed 3 sessions likely had the effect of carrying more participants through the steepest part of the attrition and may have contributed to the app's longevity for these participants. Similarly, the embedded ability to share one's performance graph—constantly updated with continued play—encouraged both the app's spread and the individual participant's continued engagement. Future experimental psychology apps should potentially focus on these features during app design as potentially highly effective, simple tools to encourage participation. On the other hand, our older participants' tendency to contribute more data in terms of sessions played may suggest this group had greater intrinsic motivation to engage with the app, or at least suggest that participants' engagement was a function of both intrinsic motivations and app features or in-game mechanics. Future studies may find it valuable to survey users during development to isolate the most valuable engagement features.

Inclusion of the full MEQ [16] and its placement at the start of the app experience meant that morningness data collected provided possibly this early analysis's strongest finding. Our sample of over 12,500 adults revealed strong evidence for increased age correlating with morningness—with older people being more likely to be moderate or strong morning types than younger people who, in turn, are far more likely to report themselves as moderate or strong evening types. We do not replicate the finding for a similar tendency toward morningness among female respondents compared with male respondents, but as with the strong relationship found with age, this result is in line with previous studies.

Analysis of performance in the 5 cognitive tasks that make up the OU Brainwave app's games showed that the app produced valid data and is sensitive enough to detect small but significant effects of both age and gender on cognition. We found small effects of gender in 4 of the 5 tasks (React, Track, Spin, and Hotspot) and no effect in the other task (Super Snap). In each case that a difference was found, male participants scored slightly higher on average than female participants. The greatest difference was found in the Spin game, in which gender

accounted for 3.5% of variance in average score. The Spin game is a direct implementation of a mental rotation task, which has previously been found to produce large, reliable gender effects [44]. While all gender effects reported here are small, this could well be due to participants' freedom and resulting noise in the dataset. Furthermore, the unidirectional pattern of gender effects reported here mean that an alternative explanation for these effects of platform (ie, mobile phone app), rather than cognitive task cannot be ruled out.

The impact of age on game score was much more pronounced than that of gender. Here, we reported significant reduction in game scores for older participants compared with younger participants in all but the Hotspot game and comparatively large effects in the Super Snap, Spin, and React games, in which age accounted for 6.8%, 8%, and 10.2%, respectively, of variation in average score. That we found our largest effect of age related to decline in the task most heavily reliant on reaction time is of no surprise—increases in reaction time have long been associated with increasing age [45]. However, evidence we found for adverse effect of age on both mental rotation (Spin) and working memory (Super Snap), which involve more sophisticated constructs than simple reaction time, suggests that the app is indeed sensitive to fine-grained differences in specific aspects of cognitive performance.

Future Research

Future analysis will focus on the effect of time of day on performance. For example, those who report themselves as morning types can be compared with those who report themselves as evening types across each of the 5 tasks, although care must be taken to check and account for any bias induced by MEQ self-reporting before task performance. This approach will enable MEQ scores to be controlled or focused on in an analysis of task scores. Furthermore, recording both hours spent sleeping the previous night and time each participant awoke on each testing day will enable us to analyze the relative contribution of time spent awake, duration of preceding sleep, and time of day on any variation in cognitive performance.

Conclusion

The OU Brainwave app, with its cohort of ~14,000 active participants represents an exciting and rich dataset. User-focused features built into the app—extremely short testing durations, allowing participants to manage their participation, engaging them through in-app feedback on their performance, and encouraging them to become an active part of the recruitment process by sharing their own performance—were largely very successful. The variability this approach introduced into the resulting performance data presented a challenge to data analysis. However, the replication of expected results and the sensitivity of the app to group-level differences in performance reported here all suggest that research apps focusing on user engagement and enjoyment, even at the expense of rigid and rigorous experimental protocols, produce valid and valuable data. Future data-collecting research apps may benefit from a similar focus on participants as users, not just as data points.

Acknowledgments

Authors' Contributions

MT designed and developed the app, analyzed data, and wrote the manuscript. JL analyzed data and contributed to the manuscript. DL and GP designed and developed the app and contributed to the manuscript.

Conflicts of Interest

None declared.

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Abbreviations

MEQ: Morningness-Eveningness self-report questionnaire
VAS: visual analog scale

Original Paper

Patterns Among 754 Gamification Cases: Content Analysis for Gamification Development

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Abstract

Background: Gamification is one of the techniques that applies game elements, such as game mechanics and dynamics, to a nongame context (eg, management, education, marketing, and health care). A variety of methodologies have been published for developing gamification. However, some of these are only usable by people with a certain level of gamification knowledge. People who do not have such knowledge face difficulty in using game mechanics and experiencing enjoyment. To ease their difficulties, a gamification methodology should provide directions for using game mechanics.

Objective: This study aimed at collecting global gamification cases and determining patterns or differences among the collected cases.

Methods: In total, 754 cases were collected based on 4F process elements, such as play type, playful user experience (PLEX)–based fun factors, and game mechanics. In addition, the collected cases were classified into 6 categories. From the data analysis, basic statistics and correlation analyses (Pearson and Kendall) were conducted.

Results: According to the analysis results in PLEX-based fun factors, challenge and completion fun factors formed a large proportion among the 6 categories. In the results of the game mechanics analysis, point, leaderboard, and progress accounted for a large proportion among the 6 categories. The results of the correlation analysis showed no difference or specific patterns in game mechanics (Pearson $r>.8$, Kendall $\tau>.5$, $P<.05$) and PLEX-based fun factors (Pearson $r>.8$, Kendall $\tau>.7$, $P<.05$).

Conclusions: On the basis of the statistical findings, this study suggests an appropriate number of PLEX-based fun factors and game mechanics. In addition, the results of this study should be used for people who do not have gamification knowledge and face difficulty using game mechanics and PLEX-based fun factors.

Introduction

Gamification is one of the techniques that applies game elements, such as game mechanics and dynamics, to a nongame context (eg, management, education, marketing, and health care) for motivation, engagement improvement, and cooperation promotion [1,2]. Huotari and Hamari [3] defined gamification as the process of providing gameful experiences to customers and promoting customer affordance. Gamification can be applied to company operations, human resources training, marketing, and online portal to expand the loyalty, engagement, and participation of employees and customers. In 2012, Gartner Group referred to gamification as a mediator that connects technologies and humans [4]. As of 2012, gamification was

classified as being in a state of *Peak of Inflated Expectation*. Gartner Group predicted that 70% of the 3000 global enterprises actively use gamification. In the schools, gamification has facilitated motivation, self-participation, and learning-effect improvement [5]. At the enterprise level, gamification was applied to a variety of fields, such as human resource management (HRM), recruitment, and incentive provision. Gamification contributes to the encouragement of employees' sociality and significantly affects the acquisition of work-related knowledge [6].

Among the collected global gamification cases, some remarkable cases are summarized as follows. The IBM (International Business Machines Co) Research Center applied gamification elements, such as point, leaderboard, and feedback, to their in-house social network service (SNS) and conducted before and after comparison studies. The study results showed that the activity in the in-house SNS increased by approximately 2.5 times after the application of gamification [7]. Team Maker (Figure 1) is a case of gamification in the form of a board game developed for leadership training based on Situational Leadership II developed by Blanchard and Zigarmi [8]. Situational Leadership II is a theory indicating that team members (followers) should be classified into 4 categories according to their sociability and job-processing ability, and appropriate leadership should be applied to each type. Team Maker consists of components such as team member cards, team leader cards, and virtual currency. Team member cards are composed of cards reflecting the characteristics of members of South Korean society. Compared with general leader cards, the legend leader cards are cards comprising existing world-famous great persons; these correspond to Situational Leadership II. Before starting the game, the players select team member cards that fit the characteristics of the members of the team to which they belong. After selecting the team member cards, the team leader cards are purchased through auction during the course of the gameplay. The player that selects the team leader card that fits the team member card wins the game. The gameplay takes approximately 60 min. Figure 2 shows the case of *The Lost City*, which promotes and helps in the understanding of the financial products. The Lost City is a case of marketing gamification developed with the support of 5 major Korean banks. Each player participating in The Lost City receives a tablet personal computer to play the game, in which virtual resources are created according to game scenarios, and the team that has accumulated the largest amount of money through trading wins the game. The Lost City was designed to enable the indirect experience of real financial products, such as mortgages and loans, in the process of using financial products provided by nonplay characters in the game.

Each player should build the facilities necessary for resource supply or demand by using borrowed virtual currency and collect the virtual currency through trade among each player. The Lost City is a game played at the financial center of Yeouido, a financial city in the Republic of Korea. Kang [9] verified that The Lost City had positive effects on the understanding of financial products, understanding of how to use financial products, and financial knowledge. Moreover, Kang proposed that to maximize the effect of experience-based learning, learner's participation promotion, and use in other educational context, gamification should be applied to learning content. With the increase in the interest in gamification, many researchers published gamification development methodology. Mora et al [10] conducted an empirical study on the gamification development methodology published from 2011 to 2015. The following are common elements of the published methodology:

- Economic (about funding and operating)
- Logic (about rule and game mechanics setting)
- Measure (about performance indication)
- Psychology (about motivating and social acting)
- Interaction (about user experience, user interface, and technology).

Bockle et al [11] published the following 4 criteria for the gamification development methodology, which allows users to develop a gamification in the order they want:

1. Purpose of adaptivity (about user's or participant's analysis)
2. Adaptivity criteria (about player type, context, goal setting, and level of contents)
3. Adaptive interventions (about user experience or user inerface and guideline for playing)
4. Adaptive game mechanics and dynamics (about game mechanics and dynamics).

There are many ways to develop gamification; however, the published methodologies are difficult to use as users with no experience face difficulty in using and applying game mechanics and fun experience. In addition, the number of these factors to be applied is a know-how factor. To solve some of these problems, this research team studied case studies to determine which game mechanics account for a large portion and what fun elements are used. For the case analysis, the 4F process, which is a gamification development methodology developed by Kim et al [12], was applied to analyze the game elements in collected cases. For the systematic study, the following 3 research questions were set, and 754 global gamification cases were collected and classified into 6 categories:

RQ 1: What is the distribution of global cases in terms of application category, play type, and published year?

RQ 2: What is the distribution of playful user experience (PLEX)–based fun factors in global cases, and is there a specific pattern noticeable in the applied factor among categories?

RQ 3: What is the distribution of game mechanics in global cases, and is there a specific pattern noticeable in the applied factor between among categories?

Figure 1. Team Maker.

Figure 2. The Lost City.

Methods

To collect global gamification cases, Google search and the gamification website *enterprise gamification* were used and related books were referred. Only cases that can be played or whose videos or screenshots could be referenced were selected. To analyze the collected data, Microsoft Excel 2010 and R studio (Psych Package) were used. The cases were collected from October 1, 2017, to January 15, 2018. The search keywords were Enterprise Gamification (Gamification examples in Enterprise) and Gamification in (of) Marketing, Recruiting, Management, Loyalty, Engagement, and Participant.

The collected cases were classified into the 6 categories to conduct a systematic study. There is an academical systematic study method for the paper such as the Preferred Reporting Items for Systematic Reviews and Meta-Analysis. However, no systematic study method has been proposed for general cases. An academic basis or criterion for general cases was not found. Most of the previous studies were classified according to a self-developed criterion. This study also approached in detail to categorize the collected cases according to self-developed criterion. This study was categorized from the perspectives of gamification value and player. The criteria for classification of the categories are shown in Figure 3 in which the terms *individual* and *group* were set on the x-axis from the gamification-player perspective and *human-oriented* and *profit-related* were set on the y-axis from the perspective of the gamification value. On the basis of these criteria, a total of 6 categories were derived:

- Commercialization (C): related to marketing, loyalty improvement, business management, and supply chain management
- Education (E): to obtain academic knowledge related to mathematics, science, and programming
- HRM (H): related to incentive, engagement improvement, and organization management
- Lifestyle (L): personal issue related to time management, money saving, and health care
- Social Issue (S): related to charity, car overspeeding problem, and hunger problem
- Training (T): to train technique required for specific jobs and tasks.

The case collection was based on the 4F process, as shown in Figure 4, and developed by Kim et al [12] for the development of gamification. The elements that constitute the 4F process were developed in consideration of 13 requirements for gamification development proposed by Morchhauser et al [13]. The 4F process is a development methodology to systematically manage the design process and improve the quality of gamification. The 4F process progresses in the order of Figure Out, Focus, Fun Design, and Finalize. In the Figure Out step, a targeting program or content is analyzed, and the personal identification (eg, age, gender, and favorite game genre), emotional state, and player type of participants are checked. To check the emotional state of participants in this step, the flow

theory [14] for the player's in-game emotion was applied. Player types were analyzed based on Bartle's 8 player types [15]: opportunists, planners, scientists, hackers, networkers, friends, griefers, and politicians. Player-type analysis for fundamental problem solving is essential because the preferred game or play types depend on the player types [16]. The next step, Focus, sets the goal of the gamified program or content to be developed, specifically about the part of content to be gamified, cooperation possibility of other field experts, play time, and play type.

The play type is set into software (mobile app and program), hardware (board game), and Big game or alternative reality game. The fun factors set up the experience of fun to be delivered. The fun types are applied based on the PLEX model (Table 1), which is a theory that organizes fun experienced by humans into 22 types [17]. The Fun Design step sets the option of gamification components, such as storytelling, main game mechanics, dynamics, and winning or losing elements ratios. The storytelling compresses the 12 steps of the characteristics of the story structure of Hero's developed by Vogler and Montez [18] into 4 steps.

The game mechanics and dynamics in the 4F process were developed by referring to the framework of Mechanics, Dynamics, and Aesthetics provided by Hunicke et al [19]. Game mechanics was applied in the same or similar sense in previous studies. Kim et al [12] summarized 25 game mechanics from previous studies through empirical research. Overall, 6 large frame types were considered: reward, reward planning, avoidance, leaderboard, identification, and quest. In this study, only 18 game mechanics that can be experienced are used. The game mechanics used are listed in Table 2. The game dynamics was not defined in the form of academic rules and should be applied appropriately to match the characteristics of the player and content. The winning or losing element ratios should be set after appropriately adjusting 3 factors: player's knowledge and skill, experience, and luck (lottery).

The Finalization step involves the completion of the prototyping of previously designed gamification and reflection through the pretester's feedback. For the prototyping, a step-by-step manager should be determined to complete and frequently check the overall process of gamification development. After the prototyping is complete, the game should be pretested by the development team, and their feedback is supplemented. These steps are repeated to improvise the prototype's quality, defined as good. This study applied the focus and fun design steps of the 4F process because of the following reasons. The 4F process is an academically proven model and has been applied to the proven gamification development methodology to ensure the reliability of the collected cases. In this study, the authors did their best to increase the reliability of the analysis results by using recently published gamification development methodologies.

The 4F process is a development methodology published in 2017 and has been compared with previous studies; it was thus used in this study.

XSL•FO

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Figure 3. The Criteria of Six Categories. HRM: human resource management.

Human-oriented

Lifestyle   Education   HRM

For individual ————————————————————————— For group

Social Issue   Training   Commercialization

Profit-Related

Figure 4. 4F Process.

Figure out	Focus	Fun design	Finalize
Step 1 Program Analysis	Step 3 Application Range Setting	Step 5 Storytelling	Step 7 Prototypes
Step 2 Player Analysis	Step 4 Funs and Experience Setting	Step 6 Mechanics and Rule	Step 8 Pretest and Feedback
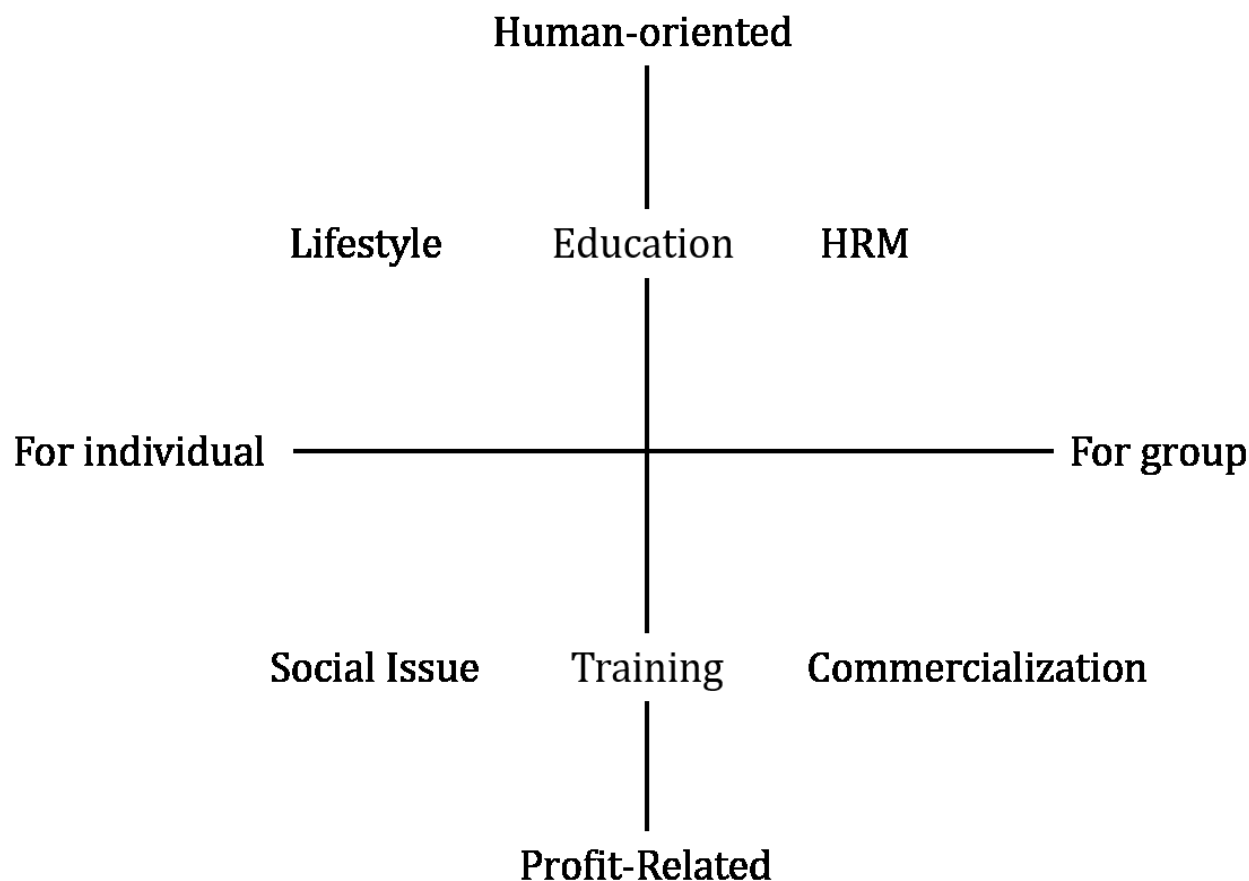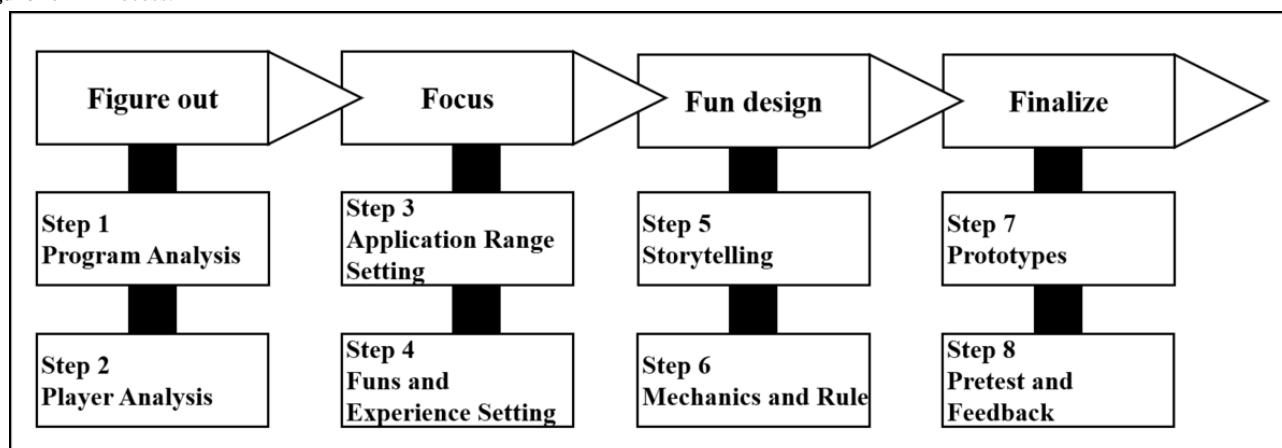
Table 1. Description of playful user experience (PLEX) fun factors.

Playful user experience fun factors	Description
Captivation	Forgetting about one's surroundings and flow in it
Challenge	Testing one's ability in specific tasks
Competition	Competing himself or herself or other player (or nonplay character)
Completion	Finishing what want to do
Control	Dominating the surroundings with one's ability
Cruelty	Causing others mental or physical pain
Discovery	Finding something new information of unknown
Eroticism	Having personal feelings for others
Exploration	Investigating a new event or situation
Expression	Manifesting oneself using item or object
Fantasy	An imagined experience in the game
Fellowship	Communicating with others and to make friend in the game
Humor	Fun, joy, joke, and gags
Nurture	Taking care of oneself or to help others to be growing
Relaxation	Relaxing and healing their mental or body in the game
Sensation	Exciting by play using 5 senses
Simulation	Testing or making something that is impossible in real world
Submission	Being part of a large group of people
Subversion	Breaking social rules or laws
Suffering	Anger, loss, and frustration
Sympathy	Sharing their emotional feelings
Thrill	Exciting derived from risk and danger

Table 2. Description of game mechanics used in this study.

Game mechanics	Description
Authority	The Power to control other players, town, and item ships in the game
Avatar	Displaying the player's character visually in the game
Badge	Displaying something such as trophy and flag that player's achievement visually
Codiscovery	Completing the quest (mission) using collective ability or collaboration with others
Competition	Competing with other players' records or competing with their own shadow, nonplay characters
Countdown	A time when player must complete a specific quest (mission)
Leaderboard	Showing the player's level, point, and ranks and providing the feedback
Level	Displaying player's achievement, ability, and power to number in the game
Lottery (luck)	The gameful tool in which the winner, the course, score, and item acquisition by probability
Point	Rewarding about player's action such as quest (mission) success
Progress (bar)	Providing real-time information about the player's current play situation
Quest (mission)	A specific goal for the player's growth and providing reward when solved
Real goods	Rewarding in the real world about the achievement in the game
Scaffolding	A device that reduces difficulty when faced with difficulties
Social network	Linking player to player and displaying other's progress
Unlocking	Providing new contents and function when player clear quest (mission) or level up
Virtual goods	The item that can be purchased, acquired, and traded
Virtual money	The currency used in the game

Results

Case Features

Table 3 shows the results of basic statistics and classification applied to the elements of the Focus step of the 4F process. The table shows the analysis of the categories defined by the research team of this study, play types, and distribution of published year. According to the results of the basic statistics analysis and classification, HRM (148/754, 19.7%) had a relatively large proportion among the categories, followed by training (143/754, 19.0%), social issue (133/754, 17.7%), education (127/754, 16.9%), commercialization (108/754, 14.3%), and lifestyle (95/754, 12.6%).

In the results of play types, software relatively accounted for a large proportion of approximately 80.0% (603/754) among play types, followed by hardware (89/754, 11.8%) and Big game or Alternative Reality game (62/754, 8.2%). According to the results of distribution of published year, the most cases were collected in 2014 (291/754, 38.6%) and 2015 (208/754, 27.6%).

Result of Game Mechanics and Playful User Experience–Based Fun Factors in the Cases

Tables 4 and 5 show the distribution of PLEX-based fun factors and game mechanics for each category defined in this study. Cases were recorded in the tables in order of commercialization (C), education (E), HRM (H), lifestyle (L), social issue (S), and training (T). For example, captivation of C was used 16 times out of the 108 cases (16/108, 15.0%)

The analysis results of PLEX-based fun factors are mentioned below. The factors of challenge and completion accounted for

90% in all categories. In contrast, cruelty, submission, subversion, suffering, and thrill were not found at all or only found in a few cases. In the commercialization category, competition was relatively higher than in other fun factors, and most of the PLEX-based fun factors were similarly applied compared with other categories. With respect to the education category, discovery relatively accounted for a large proportion, followed by simulation. Apart from the first 2 PLEX-based fun factors in education, the remaining fun factors were similarly applied in other categories. In the HRM category, nurture accounted for a large proportion and a specific feature pattern was not found. In the lifestyle category, expression, fellowship, relaxation, and sensation accounted for a relatively large proportion and other fun factors were similarly applied; no specific pattern was observed. In the social issue category, a specific pattern was not determined because game mechanics in social issue were applied similar to those in other categories. In the training category, discovery and simulation accounted for a large proportion, whereas no specific pattern was determined for the other fun factors.

The analysis results of game mechanics are as follows. Point, progress, and leaderboard accounted for a high proportion in all categories. In the commercialization category, the proportion of real goods was relatively higher than that in other categories. A specific pattern of game mechanics was not found in commercialization compared with other categories. In the education category, avatar, level, unlocking, and quest (mission) accounted for a large proportion. Other game mechanics were similarly applied as in other categories. In the HRM category, badge and virtual goods accounted for a large proportion. In the lifestyle category, most of the game mechanics were similarly

applied. Thus, a specific pattern was not found. In the social issue category, the proportion of codiscovery was highest, and in the training category, authority, avatar, quest (mission), and unlocking accounted for a large proportion; this is similar to game mechanics distribution of the education.

Table 3. Case features (N=754).

Variables	n (%)
Categories	
Commercialization	108 (14.3)
Education	127 (16.9)
Human resource management	148 (19.7)
Lifestyle	95 (12.6)
Social issue	133 (17.7)
Training	143 (19.0)
Play types	
Software	603 (80.0)
Hardware	89 (11.8)
Big game or Alternative Reality Game	62 (8.2)
Distribution of published year	
Before 2010	28 (3.8)
2011	22 (3.0)
2012	34 (4.6)
2013	54 (7.1)
2014	291 (38.6)
2015	208 (27.6)
2016	86 (11.4)
2017	31 (4.1)

Table 4. Playful user experience (PLEX) fun factors distribution of each category.

Playful user experience	C[a] (108 cases), n (%)	E[b] (127 cases), n (%)	H[c] (148 cases), n (%)	L[d] (95 cases), n (%)	S[e] (133 cases), n (%)	T[f] (143 cases), n (%)
Captivation	16 (15.0)	15 (12.0)	11 (7.4)	17 (18)	16 (12.0)	19 (13.3)
Challenge	108 (100.0)	127 (100.0)	147 (99.3)	94 (99)	132 (99.2)	143 (100.0)
Competition	43 (40.0)	36 (28.3)	50 (34.0)	27 (28)	34 (26.0)	53 (37.1)
Completion	101 (94.0)	127 (100.0)	148 (100.0)	94 (99)	132 (99.2)	143 (100.0)
Control	6 (6.0)	17 (13.4)	19 (13.0)	12 (13)	16 (12.0)	27 (19.0)
Cruelty	0 (0.0)	0 (0.0)	0 (0.0)	0 (0)	0 (0.0)	1 (1.0)
Discovery	63 (58.3)	98 (77.2)	67 (45.3)	48 (51)	74 (56.0)	90 (63.0)
Eroticism	0 (0.0)	0 (0.0)	0 (0.0)	1 (1)	2 (2.0)	0 (0.0)
Exploration	38 (35.2)	35 (29.0)	13 (9.0)	18 (19)	28 (21.0)	31 (22.0)
Expression	58 (54.0)	47 (37.0)	65 (44.0)	62 (65)	69 (52.0)	74 (52.0)
Fantasy	24 (22.2)	44 (35.0)	13 (9.0)	21 (22)	20 (15.0)	33 (23.1)
Fellowship	48 (44.4)	36 (28.3)	66 (45.0)	52 (55)	64 (48.1)	52 (36.4)
Humor	11 (10.2)	3 (2.4)	7 (5.0)	11 (12)	10 (8.0)	4 (3.0)
Nurture	32 (30.0)	53 (42.0)	75 (51.0)	46 (48)	60 (45.1)	55 (38.5)
Relaxation	50 (46.3)	33 (26.0)	53 (36.0)	46 (48)	62 (47.0)	33 (23.1)
Sensation	25 (23.1)	46 (36.2)	27 (18.2)	45 (47)	31 (23.3)	53 (37.1)
Simulation	29 (27.0)	86 (68.0)	45 (30.4)	30 (32)	63 (47.4)	107 (75.0)
Submission	1 (1.0)	1 (1.0)	0 (0.0)	1 (1)	2 (2.0)	2 (1.4)
Subversion	0 (0.0)	0 (0.0)	0 (0.0)	0 (0)	0 (0.0)	0 (0.0)
Suffering	1 (1.0)	0 (0.0)	0 (0.0)	0 (0)	0 (0.0)	4 (3.0)
Sympathy	28 (26.0)	14 (11.0)	37 (25.0)	28 (29)	65 (49.0)	37 (26.0)
Thrill	3 (3.0)	1 (1.0)	0 (0.0)	4 (4)	4 (3.0)	6 (4.2)

[a]C: commercialization.

[b]E: education.

[c]H: human resource management.

[d]L: lifestyle.

[e]S: social issue.

[f]T: training.

Table 5. Game mechanics distribution of each category.

Mechanics	C[a] (108 cases), n (%)	E[b] (127 cases), n (%)	H[c] (148 cases), n (%)	L[d] (95 cases), n (%)	S[e] (133 cases), n (%)	T[f] (143 cases), n (%)
Authority	20 (19.0)	33 (26.0)	30 (20.3)	21 (22)	36 (27.0)	44 (31.0)
Avatar	41 (38.0)	76 (60.0)	65 (44.0)	38 (40)	33 (25.0)	84 (59.0)
Badge	78 (72.2)	73 (57.5)	125 (84.5)	73 (77)	84 (63.1)	79 (55.2)
Codiscovery	54 (50.0)	56 (44.1)	54 (36.5)	44 (46)	76 (57.1)	64 (45.0)
Competition	42 (39.0)	38 (30.0)	50 (34.0)	26 (27)	34 (26.0)	55 (38.5)
Countdown	29 (27.0)	49 (39.0)	27 (18.2)	32 (34)	45 (34.0)	58 (41.0)
Leaderboard	102 (94.4)	124 (98.0)	146 (99.0)	94 (99)	128 (96.2)	140 (98.0)
Level	20 (19.0)	63 (50.0)	32 (22.0)	28 (29)	19 (14.3)	46 (32.2)
Lottery (luck)	30 (28.0)	31 (24.4)	19 (13.0)	24 (25)	31 (23.3)	35 (24.5)
Point	87 (81.0)	119 (94.0)	144 (97.3)	84 (88)	112 (84.2)	132 (92.3)
Progress	105 (97.2)	126 (99.2)	146 (99.0)	94 (99)	132 (99.2)	143 (100.0)
Quest (mission)	48 (44.4)	90 (71.0)	53 (36.0)	48 (51)	61 (46.0)	82 (57.3)
Real goods	38 (35.2)	6 (5.0)	16 (11.0)	12 (13)	40 (30.1)	10 (7.0)
Social network	35 (32.4)	14 (11.0)	27 (18.2)	16 (17)	22 (17.6)	15 (10.5)
Scaffolding	20 (19.0)	46 (36.4)	20 (14.0)	16 (17)	28 (21.6)	36 (25.2)
Unlocking	21 (19.4)	45 (35.4)	24 (16.2)	22 (22)	29 (22.0)	50 (35.0)
Virtual goods	59 (55.0)	76 (60.0)	90 (61.0)	45 (45)	59 (44.4)	72 (50.3)
Virtual money	14 (13.0)	31 (24.4)	34 (23.0)	19 (19)	30 (23.0)	25 (17.5)

[a]C: commercialization.

[b]E: education.

[c]H: human resource management.

[d]L: lifestyle.

[e]S: social issue.

[f]T: training.

Correlation of Game Mechanics and Playful User Experience Fun Factors Distribution

The results of the correlation analysis are summarized in Tables 6 and 7. In this study, Pearson and Kendall correlation coefficients were used in the correlation analysis. Both parametric and nonparametric analyses should be conducted to check the statistical significance [20,21]. Pearson correlation coefficient is a type of parametric correlation analysis, and Kendall correlation analysis is a type of nonparametric correlation analysis. This study has tried to ensure the reliability of the results through 2 correlation methods.

According to Gustavo et al [22], the standard Pearson and Kendall correlation coefficients are as follows:

- small effect: $\tau=.20$ is approximately equal to $r=.30$
- medium effect: $\tau=.34$ is approximately equal to $r=.50$
- large effect: $\tau=.50$ is approximately equal to $r=.70$.

The results of the game mechanics correlation for each category are as follows. There is a statistically large correlation among each category (Tables 6 and 7). The category of commercialization and other categories are significantly correlated with education ($r=.822$, $P<.001$, $\tau=.518$, $P=.003$),

HRM ($r=.949$, $P<.001$, $\tau=.598$, $P<.001$), lifestyle ($r=.951$, $P<.001$, $\tau=.678$, $P<.001$), social issue ($r=.956$, $P<.001$, $\tau=.713$, $P<.001$), and training ($r=.877$, $P<.001$, $\tau=.607$ $P<.001$). The categories of HRM ($r=.882$, $P<.001$, $\tau=.682$, $P<.001$), lifestyle ($r=.927$, $P<.001$, $\tau=.801$, $P<.001$), social issue ($r=.846$, $P<.001$, $\tau=.507$, $P=.003$), and training ($r=.972$, $P<.001$, $\tau=.862$, $P<.001$) are significantly correlated with education. The HRM category is significantly correlated with lifestyle ($r=.969$, $P<.001$, $\tau=.742$, $P<.001$), social issue ($r=.920$, $P<.001$, $\tau=.559$, $P=.001$), and training ($r=.913$, $P<.001$, $\tau=.743$, $P<.001$). The categories of lifestyle and other categories are significantly correlated with social issue ($r=.958$, $P<.001$, $\tau=.665$, $P<.001$) and training ($r=.952$, $P<.001$, $\tau=.849$, $P<.001$). The categories of social issue and training are significantly correlated by $r=.897$ ($P<.001$), $\tau=.608$ ($P<.001$).

The results of the correlation analysis of PLEX fun factors are as follows. There is a statistically large correlation among each category (Tables 8 and 9). The category of commercialization and other categories are significantly correlated with education ($r=.898$, $P<.001$, $\tau=.735$, $P<.001$), HRM ($r=.951$, $P<.001$, $\tau=.828$, $P<.001$), lifestyle ($r=.956$, $P<.001$, $\tau=.841$, $P<.001$), social issue ($r=.953$, $P<.001$, $\tau=.841$, $P<.001$), and training ($r=.905$, $P<.001$, $\tau=.773$, $P<.001$). The categories of education

and other categories are significantly correlated with HRM (r=.893, P<.001, τ=.774, P<.001), lifestyle (r=.88, P<.001, τ=.787 P<.001), social issue (r=.9, P<.001, τ=.77, P<.001), and training (r=.975, P<.001, τ=.871, P<.001). The categories of lifestyle (r=.961, P<.001, τ=.841, P<.001), social issue (r=.97, P<.001, τ=.832, P<.001), and training (r=.921, P<.001, τ=.794, P<.001) are significantly correlated with HRM. Lifestyle is significantly correlated with social issue (r=.959, P<.001, τ=.889, P<.001) and training (r=.906, P<.001, τ=.803, P<.001). The categories of social issue and training are significantly correlated by r=.935 (P<.001), τ=.812 (P<.001).

Result of Number of Game Mechanics and Playful User Experience Fun Factors Combination

Tables 10 and 11 list the results of the number of game mechanics and PLEX fun factors used through collected cases. A total of 6 PLEX fun factors were used on average. The minimum number of fun factors was 2 and the maximum number was 18. Moreover, 4 to 8 PLEX fun factors accounted for 71% of the overall categories. The average number of game mechanics was 8. The minimum number of game mechanics was 3 and the maximum number was 18. In addition, 5 to 9 game mechanics accounted for 66% of the overall categories.

Table 6. Pearson correlation results of game mechanics.

Game mechanics	Pearson correlation				
	C[a]	E[b]	H[c]	L[d]	S[e]
E	.822[f]	—	—	—	—
H	.949[f]	.882[f]	—	—	—
L	.951[f]	.927[f]	.968[f]	—	—
S	.956[f]	.846[f]	.919[f]	.958[f]	—
T[g]	.877[f]	.972[f]	.913[f]	.952[f]	.897[f]

[a]C: commercialization.

[b]E: education.

[c]H: human resource management.

[d]L: lifestyle.

[e]S: social issue.

[f]P<.001.

[g]T: training.

Table 7. Kendall correlation results of game mechanics.

Game mechanics	Kendall correlation				
	C[b]	E[c]	H[d]	L[e]	S[f]
E	.518[f]	—	—	—	—
H	.598[g]	.682[g]	—	—	—
L	678[g]	.801[g]	.742[g]	—	—
S	.713[g]	.507[f]	.559[h]	.665[g]	—
T[g]	.607[g]	.862[g]	.743[g]	.849[g]	.608[g]

[a]C: commercialization.

[b]E: education.

[c]H: human resource management.

[d]L: lifestyle.

[e]S: social issue.

[f]P=.003.

[g]P<.001.

[h]P=.001.

[g]T: training.

Table 8. Pearson correlation results of playful user experience (PLEX) fun factors.

Game mechanics	Pearson correlation				
	C[a]	E[b]	H[c]	L[d]	S[e]
E	.898[f]	—	—	—	—
H	.951[f]	.893[f]	—	—	—
L	.956[f]	.880[f]	.961[f]	—	—
S	.953[f]	.900[f]	.970[f]	.959[f]	—
T[g]	.905[f]	.975[f]	.921[f]	.906[f]	.935[f]

[a]C: commercialization.

[b]E: education.

[c]H: human resource management.

[d]L: lifestyle.

[e]S: social issue.

[f]$P<.001$.

[g]T: training.

Table 9. Kendall correlation results of playful user experience (PLEX) fun factors.

Game mechanics	Kendall correlation				
	C[a]	E[b]	H[c]	L[d]	S[e]
E	.735[f]	—	—	—	—
H	.828[f]	.774[f]	—	—	—
L	.841[f]	.787[f]	.84[f]	—	—
S	.841[f]	.770[f]	.832[f]	.889[f]	—
T[g]	.773[f]	.871[f]	.794[f]	.803[f]	.812[f]

[a]C: commercialization.

[b]E: education.

[c]H: human resource management.

[d]L: lifestyle.

[e]S: social issue.

[f]$P<.001$.

[g]T: training.

Table 10. Average, minimum, and maximum number of applied game mechanics and playful user experience (PLEX) fun factors.

Factors and mechanics	n
Playful user experience fun factors	
Average	6
Minimum	2
Maximum	18
Game mechanics	
Average	8
Minimum	3
Maximum	18

Table 11. Number of applied Game mechanics and playful user experience (PLEX) fun factors.

Distribution	n (%)
Number of playful user experience fun factors	
2	19 (2.6)
3	59 (8.0)
4	91 (12.1)
5	145 (19.2)
6	129 (17.1)
7	88 (12.0)
8	81 (10.8)
9	46 (6.1)
10	31 (4.1)
11	31 (4.1)
12	15 (2.0)
13	9 (1.2)
14	5 (1.0)
15	1 (0.3)
16	3 (0.3)
18	1 (0.3)
Total	754 (100.0)
Number of game mechanics	
2	14 (2.0)
3	50 (7.0)
4	81 (11.0)
5	115 (15.2)
6	116 (15.4)
7	103 (14.0)
8	84 (11.1)
9	61 (8.1)
10	55 (7.3)
11	29 (4.0)
12	18 (2.4)
13	10 (1.3)
14	13 (2.0)
15	1 (0.3)
16	3 (0.3)
18	1 (0.3)
Total	754 (100.0)

Discussion

Principal Findings

The purpose of this study was to collect 754 gamification cases and derive their implication through an empirical study and a statistical data analysis. The 4F process was applied for analyzing gamification elements. Table 12 summarizes the answers to the 3 research questions. The results of this study would help people who have difficulty in developing gamification. When developing gamification, we expect that the results of this study will have a positive impact on people who have difficulty using game mechanics and experiencing fun.

Table 12. Summary of results.

Research question and question keywords	Result
1	
Categories	Category classification: 6 categories
Play types	Play types: software (80%), hardware (12%), and Big game or ARG[a] (8%)
Published year	High proportion of published year: 2014 and 2015
2	
PLEX[b] fun factors distribution	High proportion of PLEX fun factors: challenge and completion; low proportion of PLEX fun factors: cruelty, submission, subversion, suffering, and thrill
Correlation each category	Correlation analysis: distribution of PLEX fun factors was similar in each category (a positive correlation for each category)
3	
Game mechanics distribution	High proportion of game mechanics: point, progress, and leaderboard; proportion of game mechanics was similarly distributed and used
Correlation each category	Correlation analysis: distribution of game mechanics was similar in each category (a positive correlation for each category)

[a]ARG: alternative reality game.

[b]PLEX: playful user experience.

Discussion of Research Question 1

Among the 3 types of gameplay, software accounted for 80% of overall cases. It is related to recent advances in information technology such as smartphones, smartpads, and improvement of internet environment. As technology advances, because access to software type of gamification has been strengthened, the player is possible to play the variety of type of gamification contents without time and space constraints. Furthermore, software type of gamification is used to secure marketing and potential customer and their loyalty, and it is possible to solve the inconvenience of accessing services such as online banking system and stock trading system.

Baptista and Oliveira [23] applied gamification to a software type of mobile banking system to improve its usability and accessibility to customers. For validating the results of their study, a structural equation was used. According to the results of their study, a software type of gamification was possible to improve customers' engagement, accessibility, and usability. Baptista and Oliveira [23] suggested using gamification for changing customers' behavior through gaming experience.

According to the results of this study, the largest number of gamification cases are published in 2014 and 2015. It is assumed that the collected cases are maintained through continuous updating. However, this does not imply that new cases have not been published. Global gamification cases have increased steadily since gamification was activated, with a significant increase observed in 2014 and 2015, and these cases are being kept. Dicheva et al [24] conducted an empirical research of an advanced study on gamification in education. The number of education gamification cases began increasing from 2013, and the distribution of overall cases was similar to that obtained in this study. Additional studies should be conducted to infer clear conclusions about the year of distribution for published cases.

Discussion of Research Question 2

In the analysis results of PLEX fun factors from among the 6 categories defined in this study, challenge, completion, and competition constituted a large proportion of overall categories. The distribution of PLEX fun factors in this study resembles that of Kim's study [25]. The reason why the fun factors of challenge and completion accounted for a large proportion is assumed to be related to the winning condition. The structure of gamification is also designed to be similar to that of the game. Players must challenge and solve problems to win the game. Gamification also provides a resolvable problem such as a game for players. In the process of problem solving, the fun factors of challenge and completion are added. For this reason, both these fun factors accounted for a large proportion among the fun factors. The fun factor of competition was used assuming that it will allow more players to participate. On the other hand, the fun factors of cruelty, submission, subversion, suffering, and thrill were either found in a few cases or not found in the collected cases. These 5 fun factors were found to be very difficult to implement and apply within game-based content.

The correlation analysis results of PLEX fun factors showed similar patterns among the 6 categories. This means that there is no particularly preferred pattern according to the application field of the PLEX fun factors. Having no particularly preferred pattern among the PLEX fun factors implies that there was no difference among the fun factors. The correlation analysis results can be shown as the grounds for the use of suitable PLEX fun factors regardless of the applied target. However, reckless use of fun factors is harmful to the quality of gamification. Depending on the results of this study, it is recommended to use 4 to 8 PLEX fun factors.

Discussion of Research Question 3

In the analysis results of game mechanics among the 6 categories defined in this study, points, progress, and leaderboard constituted a large proportion of the overall categories. The

distribution of game mechanics in this study resembles that of Dicheva et al's study [24]. In most cases, points have been shown to be used as concept of reward. Progress and leaderboard have been using similar concepts in most cases. However, both these game mechanics are of a different nature and should be analyzed separately. On the other hand, badge, a Point, Badge, and Level system [26], found its utilization to be lower than points and leaderboard. It is assumed to have been caused by regional or cultural differences. In North America, many people are found collecting badges from local universities. In Asia, badge collection is quite strange. Due to these regional or cultural differences, it is assumed that the use of badge is relatively low. Specially, among the 6 categories of social issues, the game mechanics of codiscovery was found to be relatively higher than that in other categories. It is important to address social issues, but it can be thought of as using collective intelligence.

In the correlation analysis results of game mechanics, the correlation among the 6 categories was significant. This indicates that most categories are based on similar game mechanics. However, reckless use, such as of PLEX fun factors, can harm players. This study recommends using 5 to 9 game mechanics when exploring game mechanics. A designer or developer would like to use these many game mechanics during the gamification development process.

Limitations and Future Direction

The limitations of this study are as follows:

- Criteria for case classification without Mutually Exclusive and Completely Exhaustive (MECE)
- Absence of a differentiated method of data analysis
- Validity and reliability problems caused by applying a single gamification development methodology

- Limits of the restricted search range centered on the Google search engine and *enterprise gamification* websites.

Before conducting this study, criteria were set to classify the cases. However, the category could not fully classify the cases because MECE was not applied. Using MECE and a proven taxonomy to analyze the cases based on academic grounds, more relevant study results must be obtained.

Recent developments in big data have begun to refine data analytics. This study only performed basic statistical analyses on the correlation between PLEX fun factors and game mechanics. However, further studies should be conducted considering not only the number used in the data analysis techniques but also the relevant factors such as player type. For this, data should be collected more systematically, and analysis techniques should be applied accordingly to conduct further studies.

This study only used the 4F process to analyze the collected cases. Therefore, analytical factors from different perspectives should be obtained. Researchers in related fields are constantly developing methodologies to develop systematic gamification such as 6D process [27] and the 13 requirements for gamification development [13]. In addition, player-type classification procedures should be added through data analysis. Examples of representative player type classifications include Bartle's 8 player types [15], BrainHex [28], and Octalysis [29].

The cases used in this study were collected only through Google search and *enterprise gamification* Web page. However, future study should be conducted on a wider range of cases, including cases analyzed in previous papers. Future study should be conducted through diverse case collection for verifying the reliability and feasibility of study results.

Acknowledgments

Conflicts of Interest

None declared.

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Abbreviations

HRM: human resource management
MECE: Mutually Exclusive and Completely Exhaustive

XSL•FO
RenderX

PLEX: playful user experience
SNS: social network service

XSL·FO

RenderX

XSL•FO

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