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## Contents

### Original Papers

Gamified Cognitive Control Training for Remitted Depressed Individuals: User Requirements Analysis ( <a href="#">e6</a> ) Jasmien Vervaeke, Jan Van Looy, Kristof Hoorelbeke, Chris Baeken, Ernst Koster. . . . .	2
Virtual Reality Cue Refusal Video Game for Alcohol and Cigarette Recovery Support: Summative Study ( <a href="#">e7</a> ) Mary Metcalf, Karen Rossie, Katie Stokes, Christina Tallman, Bradley Tanner. . . . .	13
Using Mobile Health Gamification to Facilitate Cognitive Behavioral Therapy Skills Practice in Child Anxiety Treatment: Open Clinical Trial ( <a href="#">e9</a> ) Gede Pramana, Bambang Parmanto, James Lomas, Oliver Lindhiem, Philip Kendall, Jennifer Silk. . . . .	24
Virtual Antenatal Encounter and Standardized Simulation Assessment (VANESSA): Pilot Study ( <a href="#">e8</a> ) Patrick Motz, Megan Gray, Taylor Sawyer, Jennifer Kett, Douglas Danforth, Kellen Maicher, Rachel Umoren. . . . .	42
Training Working Memory in Adolescents Using Serious Game Elements: Pilot Randomized Controlled Trial ( <a href="#">e10</a> ) Wouter Boendermaker, Thomas Gladwin, Margot Peeters, Pier Prins, Reinout Wiers. . . . .	51
A Mobile Game to Support Smoking Cessation: Prototype Assessment ( <a href="#">e11</a> ) Bethany Raiff, Nicholas Fortugno, Daniel Scherlis, Darion Rapoza. . . . .	64
Physical Wellness Among Gaming Adults: Cross-Sectional Study ( <a href="#">e12</a> ) James Arnaez, Georgia Frey, Donetta Cothran, Margaret Lion, Andrea Chomistek. . . . .	75

Original Paper

# Gamified Cognitive Control Training for Remitted Depressed Individuals: User Requirements Analysis

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## Abstract

**Background:** The high incidence and relapse rates of major depressive disorder demand novel treatment options. Standard treatments (psychotherapy, medication) usually do not target cognitive control impairments, although these seem to play a crucial role in achieving stable remission. The urgent need for treatment combined with poor availability of adequate psychological interventions has instigated a shift toward internet interventions. Numerous computerized programs have been developed that can be presented online and offline. However, their uptake and adherence are oftentimes low.

**Objective:** The aim of this study was to perform a user requirements analysis for an internet-based training targeting cognitive control. This training focuses on ameliorating cognitive control impairments, as these are still present during remission and can be a risk factor for relapse. To facilitate uptake of and adherence to this intervention, a qualitative user requirements analysis was conducted to map mandatory and desirable requirements.

**Methods:** We conducted a user requirements analysis through a focus group with 5 remitted depressed individuals and individual interviews with 6 mental health care professionals. All qualitative data were transcribed and examined using a thematic analytic approach.

**Results:** Results showed mandatory requirements for the remitted sample in terms of training configuration, technological and personal factors, and desirable requirements regarding knowledge and enjoyment. Furthermore, knowledge and therapeutic benefits were key requirements for therapists.

**Conclusions:** The identified requirements provide useful information to be integrated in interventions targeting cognitive control in depression.

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**KEYWORDS**

depression; cognitive dysfunction; cognitive remediation; relapse prevention; qualitative research; secondary prevention

## Introduction

### Background

In 2010, 7.4% of the total worldwide disease burden was attributed to mental and substance use disorders, of which depressive disorders accounted for the most disability-adjusted life years [1]. As such, major depression is recognized as a global leading cause of disability [2]. One of the key challenges within this context is that existing treatments frequently fail to achieve stable remission (for an overview, see [3]). Furthermore, recurrence and relapse rates are estimated to be 54% in the second year after receiving therapy [4], which increases with the number of previous depressive episodes [5,6]. As a result, preventing recurrent major depression is of paramount importance.

In this context, research suggests that impairments in cognitive control (eg, [7-9]), which refer to difficulties in executive processes such as shifting, inhibition, and updating of information in working memory [10], place one at an increased risk for recurrence of depressive episodes (eg, [11,12]). For instance, research indicates that impaired cognitive control hampers effective emotion regulation and task engagement [13,14]. Furthermore, remitted depressed (RMD) individuals are still suffering from these impairments (eg, [15,16]), where cognitive control deficits are related to the number of past episodes [17]. Interestingly, recent evidence suggests that traditional therapies leave these cognitive risk factors for depression unaffected, even when effectively reducing symptoms of depression [18]. These observations have led to the development of cognitive control training (CCT) for depression.

### Improving Cognitive Control

The idea behind CCT is that performing it activates the prefrontal cortex repetitively, which improves attention and cognitive control (for reviews, see [19,20]). In the past decade, CCT has been used in several studies regarding vulnerability for depression, and results overall seem promising (eg, [21,22]). CCT has been shown to have additional effects to treatment as usual, in terms of rumination and depressive symptomatology [19]. In a 1-year follow-up of this study, CCT also demonstrated long-term potential [23]. Other studies showed that CCT in depression is promising in combination with other treatments, for instance, with transcranial direct current stimulation [24]. Interestingly, there are some studies that have found that stand-alone CCT also has effects on rumination [21,22,25,26] and depressive symptomatology [27]. A recent meta-analysis of computerized cognitive training for depression showed that it has a small to moderate but nevertheless consistent effect on depressive symptomatology and everyday functioning [28]. Moreover, a recent randomized controlled trial (RCT) showed that CCT, compared with an active control condition, is effective in training cognitive performance and yielded significant differences in terms of rumination, depressive symptomatology, and functioning in an RMD sample [29]. Importantly, effects remained stable over time (at 3-month follow-up).

Provided the encouraging findings of well-controlled studies using CCT and the potential to reach a wider population of

at-risk individuals through Web-based administration, the CCT program needs to be suitable for Web-based administration. The CCT studies presented above used the Paced Auditory Serial Addition Task (PASAT; [30]). In this task, participants hear a stream of digits, with a certain interstimulus interval (ISI). Participants have to calculate the sum of the last 2 digits and click on the corresponding number. In an adaptive variant of the PASAT (aPASAT), the ISI decreases after a certain number of consecutive correct responses and increases after a certain number of consecutive incorrect responses. However, given that the task is not enjoyable, its user experience is problematic (eg, [31]). The task is rather monotonous and demanding, and it can be frustrating at the same time [23,26,32]. The second problem with CCT is that participants have to complete several sessions to benefit from the training (ie, they have to visit the research laboratory, hospital, or Web-based platform multiple times), which can easily lead to dropout in both research contexts and treatment settings. Indeed, dropout numbers in CCT studies can be substantial. In a selection of 10 influential CCT studies [19,24,26,27,29,33-37] in the context of depression vulnerability, mean dropout was at least 21%, ranging from 4% to 50%. If we take sample size into account, total dropout was at least 234 participants of 1697 over the 10 studies, hence 13.79%. Fortunately, enhancing treatment credibility shows potential to counter dropout [38] and improve treatment effects [39]. That is, user engagement has been identified as a crucial variable for mobile health apps [40] and CCT procedures [23], where increasing user engagement may thus be of paramount importance to increase effects of CCT interventions.

### Increasing User Engagement

One of the ways to achieve this is by means of *gamification* [41]. *Gamification* refers to the addition of game elements to nongame contexts, such as points, levels, or a narrative. By increasing engagement, users tend to do better at tasks and rate them more fun at the same time [42]. However, gamification can be implemented in various ways. There are a lot of different game features, and each can have a different effect on a different target population. It has been used in interventions for common mental disorders such as depression, but it is unclear which gamification elements act most effectively [43]. Moreover, little is known about game and gamification preferences of RMD individuals. Provided that patient preferences can influence therapy outcomes (eg, [44]), gamification elements need to be suitable and motivating for RMD individuals. Recently, a call was launched to increase adherence and decrease dropout rates in internet interventions through, among other things, increasing user engagement and adding gamification elements [45]. In addition, CCT should fit within participants' daily routine. To achieve these goals, a *user requirements analysis* was conducted.

A *user requirements analysis*' goal is to understand the needs and requirements of the intended users [46]. Conducting such an analysis can yield several benefits such as improved user satisfaction, increased productivity, and reduced costs for training and support [47]. According to the study by Robertson and Robertson [48], there are different kinds of stakeholders to consider in a user requirements analysis. In our case, the intended beneficiaries of training (operational working area)

are RMD individuals. Another group of stakeholders are those who might benefit from the training without being directly in contact with it (containing business): mental health care professionals (MHPs), who can play a key role in prescribing and monitoring CCT. This analysis will therefore regard the requirements of these 2 stakeholder groups.

### Aim of the Study

This study is a first step in developing a new intervention targeted at RMD individuals as a relapse prevention program, through CCT. To increase uptake and adherence, a user requirements analysis was considered crucial.

The aim of this study was to explore and map the needs and preferences of an RMD sample and an MHP sample. More specifically, we have 4 research questions. Questions 1 and 2 were queries for the RMD population. Questions 3 and 4 were key questions examined in the group of MHPs.

1. What are the mandatory basic requirements to start CCT?
2. How can user engagement and adherence to CCT be optimized?
3. What are mandatory basic requirements to implement CCT in treatment?
4. How can implementation of CCT in treatment be facilitated?

## Methods

### General

To receive feedback regarding the aPASAT and the broader platform, a user requirements analysis was conducted. To this end, we organized a focus group for RMD individuals, seeing that this is a cost-effective method for analyzing user requirements [49]. To best suit the busy schedules of the clinicians, we conducted individual interviews with them. All focus groups and interviews were conducted in Dutch and were semistructured, based on a topic list (see section Materials). Citations in this paper have been translated as literally as possible. Names have been changed to guarantee anonymity.

### Participants

#### Remitted Depressed Individuals

Five participants were included in this focus group. The sample consisted of 3 men and 2 women, and their ages ranged from 32 to 62 years (mean 48.4, SD 9.9). All had suffered from at least 2 depressive episodes in the past and were in remission at the time of the focus group. Three participants (1 woman) also participated in an RCT study regarding CCT in the previous year [29] and were selected as part of a follow-up from a larger sample pool. In addition, an organization for patients with depression was contacted through email and yielded the other two participants with no experience regarding CCT. All participants indicated to have a moderate to high affinity for technology as measured by the short version of the Affinity for Technology Scale (ATS) [50,51]. They were rewarded with 25 euros.

### Mental Health Care Professionals

Six MHPs agreed to be interviewed. All received a psychology degree from a Belgian university. Mean age was 36.7 years (SD 13.1) and ranged between 26 and 65 years. Of the 6 experts, 2 were females. Three participants worked as psychologists, one had recently retired but used to work as a psychologist, one was a researcher who also works as a psychologist with patients, and one was a researcher specialized in electronic and mobile apps for mental health care. The last 2 held a doctoral degree. All participants indicated to have a moderate to high affinity for technology as measured by the short version of the ATS. Participants were recruited via email. We focused on contacting therapists using a cognitive (behavioral) approach, as well as recruiting professionals from different working environments (eg, hospital, private practice, and mental health centers). Participants received an incentive of 15 euros.

### Materials

Both the focus group and the interviews were recorded on 2 audio recorders, placed at 2 different locations on the table around which everyone was seated. For the aPASAT demo, a standard Dell laptop (Dell Technologies Inc, Round Rock, Texas, USA) running Windows 7 (Microsoft Corporation, Redmond, Washington, USA) was used. The focus group and the interviews had a distinct topic list because these were conducted with different target groups. These lists were created in advance by the first author (JV), based on the research questions, and sent out to 2 coauthors (JVL and EHWK) for adaptation and approval. These lists were not changed during the focus group or interviews, but the order was flexibly adapted. However, all topics were covered.

### Procedure

#### Focus Group

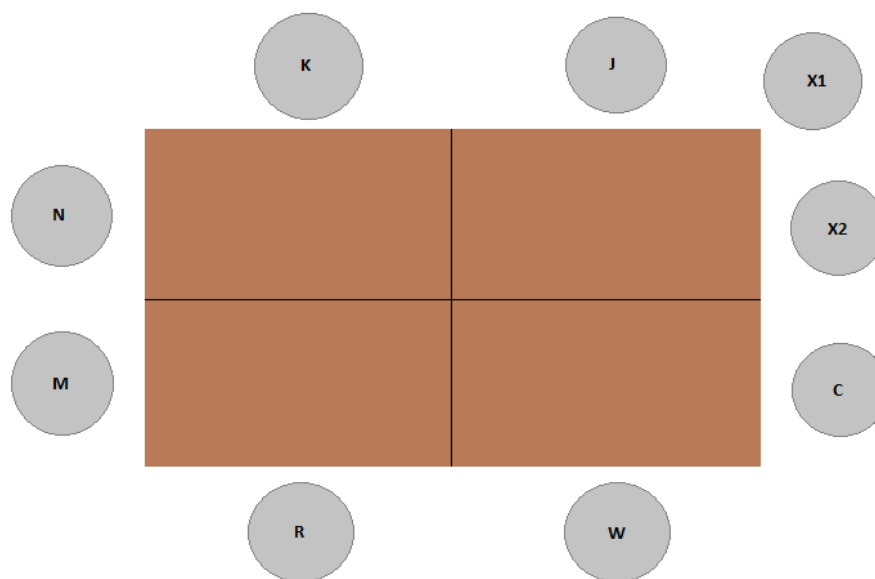
Participants completed informed consent, a demographic questionnaire, and the ATS. The seating arrangement is illustrated in Figure 1. The focus group included a demo of an aPASAT session that was used in previous studies (eg, [29]). At the end of the focus group, participants received their incentive. The whole procedure lasted about 150 minutes and took place at the Faculty of Psychology and Educational Sciences of Ghent University. The group was moderated by an investigator with extensive experience with focus groups (JVL).

#### Mental Health Care Professional Interviews

Participants completed informed consent, a demographic questionnaire, and the ATS. The interview started with broad, easy-to-answer questions as an icebreaker. After this, the aPASAT demo was presented, and the interview core questions were asked, each followed by probing questions or requests to elaborate. The interviews ended with the incentive. Duration of the interviews ranged from 45 to 90 minutes. Given the busy schedule of interested therapists, the interviews took place at a location of their choice. This resulted in 3 interviews in the work setting, 2 at the faculty, and 1 at home. The interviewer did not have previous interview experience. However, literature regarding interviews was consulted, and 2 test interviews were conducted with researchers, experienced with interviews.



**Figure 1.** Seating arrangement of the focus group. Karl (K), Jeff (J), Chris (C), Will (W), and Rachel (R) were participants. M, N, X1, and X2 were moderator, note taker, researcher from the randomized controlled trial (RCT) study, and an employee of a game developer company, respectively.



## Data Analysis

All conversations were recorded, transcribed, and analyzed using NVivo (QSR International, Melbourne, Australia), a software package for qualitative data analysis, using an inductive thematic analytic approach (as described in [52]). The coding took place in three broad stages, led by JV, in close collaboration with JVL and EHWK in the third stage. First, transcriptions were given a code as close as possible to the transcription. Here, text segments could have none, one, or multiple codes, and there was overlap between codes. Second, the codes were compared and analyzed. This was done code by code. In this stage, similar codes were merged, and codes with multiple meanings were separated so that each code had only one meaning and a clear coverage that fitted all corresponding text segments. Third, codes were grouped into categories, and different structures were imposed and discussed. Results show the final chosen structure.

## Results

### General Information

The results are organized in relation to each of the 4 research questions proposed earlier. Furthermore, each section includes a table that reflects the main findings. Finally, some pitfalls and opportunities are added at the end.

### Mandatory Requirements for Remitted Depressed Sample

Table 1 reflects the mandatory requirements for an RMD sample, which is largely self-explanatory. Patients indicated that a calm and private environment is necessary to focus on the training, but they do not want to feel isolated. Jeff (male,

52 years old, RMD individual) explained how demanding the PASAT can be:

*When I did the sessions at home, the only time I could complete them was when my children were sleeping and when I asked my girlfriend not to talk for 20 minutes.*

### Desirable Requirements for Remitted Depressed Sample

Features that might help RMD individuals to adhere to CCT are written down in Table 2. Psychoeducation is considered crucial, given that face validity is quite low, and it should emphasize that (1) the main aim of the training is to reduce depressive symptomatology and chances of relapse and (2) the importance of completing the intervention. But when doing so, it should be specific and concrete, as expressed by Rachel (female, 45 years old, RMD individual):

*I believe you need to be clear, in order to motivate people to keep doing it, to be really clear what it will yield.*

Participants further agreed that response-related feedback during training is important. This should ideally be clear, instant, and easy to process (in other words, it should not interfere with the ongoing task). Patients reported that in many contexts, feedback is important to improve task performance, whereby improvement itself can be a motivating element in the words of Karl (male, 32 years old, RMD individual):

*The first session, I was searching. The second one, I was cursing. The third one I was cursing some more, but from the fourth session on, I found it agreeable. Why? Because I noticed I was getting better. So, it is fun, to notice your own progression.*

**Table 1.** Overview of the mandatory requirements for the remitted depressed (RMD) individuals. CCT: cognitive control training. PC: personal computer. FAQ: frequently asked questions.

Category and subcategory	Requirement	Implementation
<b>Technology</b>		
Functionality	Software works, no bugs, no crashes	Develop bug-free CCT
Usability	Software should be user-friendly	Easy to use; simple text; visually appealing; available on PC and tablet
<b>Person</b>		
Skills	Some internet and technical knowledge	State clear expectations; devise good manual; write clear FAQ section
Access	Internet connection, device in possession	CCT is compatible with most browsers; both on PC and tablet
<b>Configuration</b>		
Time	Not too long and flexible planning of sessions	15 minutes per session; calendar tool to plan next session
Location	Flexible	CCT on an internet website
Setting	Calm and private, but not isolated	Including tablets enables users to complete sessions at preferred location
Pricing	For free	Available for free

**Table 2.** Overview of the desirable requirements for the remitted depressed (RMD) individuals. CCT: cognitive control training. FAQ: frequently asked questions.

Category and subcategory	Requirement	Implementation
<b>Intrinsic motivation</b>		
Psychoeducation	Knowledge about CCT mechanism and expected outcomes, preferably in an interactive manner	Provide psychoeducation that is clear, simple, and interactive
Practical or technical assistance	Practical and technical guidelines regarding CCT and protocol in case of problems	Devise FAQ section; communicate contact options
Gamification	Training should be enjoyable, engaging, and challenging, by including feedback and reinforcing messages	Include performance-dependent feedback; include performance-independent stimulating messages; individualize CCT
<b>Extrinsic motivation</b>		
Incentivization	Monetary reward after completing all sessions or monetary penalty when dropout	Will not be implemented; available for free
Motivation by therapist	Rationale, follow-up, and encouragement by the therapist when asked for or needed	Therapist will play a role in dissemination and administration, but options not clear at this point

Another gamification element that patients agreed on was simulated social reinforcement, which can be seen as a kind of reward. Social reinforcement is a form of positive reinforcement and an umbrella term for getting approval from others, by means of attention, praise, and encouragement, among others, as shown in the example of Chris (female, 50 years old, RMD individual):

*[When playing Candy Crush Saga]...there is a little figure jumping up and down and telling me "Well done!," which I enjoy hearing once in a while. Or you can hear "Sweet!," which I also enjoy hearing.*

The therapist could also play a role in adhering to the training and, more interestingly, this was also offered in the interviews with MHPs; thus, it certainly is considered possible to fulfill this role. Moreover, some MHPs even regarded motivating patients their responsibility, seeing how a therapist's opinion and presentation of a treatment can impact a patient's reception and motivation.

### **Mandatory Requirements for Mental Health Care Professionals**

Table 3 lists the mandatory requirements for a sample of MHPs. As in the previous paragraph with mandatory requirements, this is rather straight-forward.

### **Desirable Requirements for Mental Health Care Professionals**

Features that facilitate implementation of CCT are listed in Table 4. Educating therapists with regard to the training, as well as explaining how and why it works, is considered important for dissemination, especially given the low face validity of this training, as Rudy (male, 65 years old, psychologist) said:

*When I imagine my colleagues, I think there are certainly some, because they regard it as hocus-pocus, that are not willing to offer it [the training].*

**Table 3.** Overview of the mandatory requirements for the mental health care professionals (MHPs).

Category and subcategory	Requirement	Implementation
Permission	Need permission from supervisor or MHP	Get approval by showing scientific evidence; giving psychoeducation
<b>Configuration</b>		
Time	Offering training should not be time-consuming	Devise training to be minimally time-consuming for MHP
Usage	Be informed about practical information of the training	Provide clear guidelines; practical or technical assistance (eg, contact person)
Format	Available and shareable training	Freely available website (not CD-ROM or other physical carriers)

**Table 4.** Overview of the desirable requirements for mental health care professionals. CCT: cognitive control training.

Category and subcategory	Requirement	Implementation
<b>Intrinsic motivation</b>		
Psychoeducation	Knowledge about CCT mechanism and expected outcomes	Provide clear psychoeducation; tailor it to the working environment
Therapeutic benefits	CCT is beneficial in preventing or postponing a relapse; without major side effects	Test effectiveness of the CCT extensively; check for side effects
<b>Extrinsic motivation</b>		
Resource access	Having access to scientific papers or clinical tools through the university	Unfortunately not possible to implement
Training feedback	Information about execution, performance, and outcome of the patients they proposed CCT to	Unclear at this point; if possible, grant therapist restricted access to database

It might be encouraging to receive training feedback as well as outcomes with regard to depressive complaints, which would allow seeing whether training is effective for specific patients. Therapists indicated that such information could increase motivation to implement training, as Hailey (female, 26 years old, and psychologist) stated:

*If we, as caregivers, are able to check whether or not they completed a session, or that you [the researchers] would be able to send us a message, for instance “We noticed that this person is not really strict with completing the sessions,” we might be able to call that person and really motivate [him/her], like, “Really try to do it anyway” and explain again why exactly it is a good idea.*

In the example above, it is also clear that MHPs are willing to take on a motivational role, as discussed in the previous section.

### Pitfalls

RMD individuals and MHPs raised a number of additional concerns and comments that could be taken into account to prevent problems with the training. We will briefly present seven such concerns. First, the PASAT itself is based on math operations, which can be frustrating for some people, especially when time pressure is added. Second, privacy and data protection is considered important.

Third, technological skills will vary where it is important to strike a balance for being easy to operate for novice as well as skilled users. Fourth, the amount of additional work in addition to the training (such as questionnaires) needs to be limited. Fifth, having the training publically available means that nobody gets

excluded this way, but this comes with the risk of offering the training to relapsed individuals that will not be helped by the training on its own, resulting in a fail experience, further decreasing this person's mood. Sixth, the effect of the training is the strengthening of cognitive control, which is hard to measure and notice and comes only after multiple training sessions, but users might be focused on their performance which is easily measured and visible. Finally, gamification might lead to extra frustration. Having too many gamification elements within the training, so that it distracts from the task, should be avoided.

### Facilitating Factors

Facilitating factors are already existing opportunities which might support the uptake of and adherence to this training. First, depression and relapse rates are high, ensuring our training has a large potential user base. Second, in clinical practice, RMD individuals are requesting preventative programs. There are some relapse prevention programs (eg, mindfulness-based interventions), but the need for targeted interventions for cognitive vulnerability remains. However, RMD individuals sometimes take initiative themselves. Some of them will play brain training or attention games on their own. Here, it is safe to say that the step to our training would not be huge, and these individuals are motivated to prevent a relapse. Finally, some therapists still have follow-up sessions with RMD individuals, so offering the training through the therapist might be a useful strategy.

## Discussion

### Principal Findings

The aim of this study was to conduct a user requirements analysis with RMD individuals and MHPs to take into account their preferences in the next steps of development of Web-based CCT, aimed at relapse prevention in depression. For this purpose, we conducted a focus group with RMD individuals and interviewed MHPs. We performed qualitative analyses on the input provided by these participants. Finally, we identified some hindering and facilitating factors that can influence uptake of and adherence to the training.

For the RMD group, there were several mandatory requirements: the training should be functional and user-friendly and match this group's technological skill and access. Performing the training sessions should also fit within their daily routine. Furthermore, this group desired the training to be engaging. Finally, they can be motivated by knowledge of how training works (ie, psychoeducation), training progress, gamification elements in the training, external factors, and their therapist.

The MHP group postulated some key requirements as well. Offering the training should be approved by their supervisor or director when they are working in a mental health care center. When they are self-employed or need supervisor approval, scientific arguments and research showing the effectiveness of the training and explaining how the training works are needed. Psychoeducation and feedback about patients' progress can increase the chance that therapists will offer this training.

This study has 2 main strengths. First, as the endpoint of this project is creating an intervention for RMD individuals, we actually involved these end users, as well as MHPs who are in frequent contact with this population. This is in accordance with a recent call by an international collaboration, called "COMETS" (Collaboration On Maximizing the impact of E-Therapy and Serious gaming). COMETS was created to increase the uptake and adherence to internet interventions for mental health [45]. They plead for a paradigm shift that is built on 4 pillars: (1) increased focus on users, (2) increased focus on engagement, through gamification or other techniques, (3) more intersectoral collaboration, and (4) rapid testing and implementation. In this study, it should be apparent that we tried to comply with the first 2 pillars. Furthermore, we will also attempt to meet the other 2 by (1) collaborating with software developers who have more experience with good usability, design, and dissemination; (2) conducting research that tests the training's effectiveness as well as the effect of gamification; and (3) thinking about implementation of the training in the early stages of development. By taking into

account all these factors, including the results of this study, we hope to decrease dropout rates of CCT and deliver a widely available Web-based intervention.

A second strength is that our findings are in agreement with literature regarding internet-based cognitive behavior therapy, which adds to the reliability of the findings of this study. For instance, previous research has shown beneficial effects of an intuitive and interactive product [53], of reminders and motivational prompts [54], and that presented text should match the individual's reading and computer skill [55]. A study by Rozental et al [56] showed a decrease in motivation for a Web-based intervention when the amount of mandatory reading was too high, as this was too time-consuming.

### Limitations

Nevertheless, this study also has some limitations. First, both target populations were represented by a small sample. Findings can therefore not be easily generalized, but it does give us some specific insights. During the focus group with only 5 RMD individuals, opinions already diverged greatly. Although relatively few people were included, enrolling too many people in a focus group might work counterproductive [49]. Furthermore, this study counts as a first step. In subsequent research, user experience and engagement will be monitored in larger samples. The generalizability of this study might be rather low; however, the main aim here was to go into depth, which was not hindered by our final sample size. Given these limited samples, we do not assume saturation has been reached. Nevertheless, we believe that the most crucial aspects have been identified.

As a second limitation, because some of the questioned variables are a matter of personal preference, we did not go into detail about those in this study. For instance, Bartle [57] identified 4 player types, that each has their own motivation of why gamers play. Different player types are appealed to different game mechanics. Making the distinction would certainly have offered interesting viewpoints. However, as we are aiming to reach the whole RMD population, instead of specific subgroups, we chose not to include this or other distinctions.

### Future Steps

Future steps of this project will be to develop the software of the training and platform, based on the input from the RMD individuals and the MHPs, after which it will be tested in several experiments to ensure that the training is efficacious and can be disseminated. The present requirements analysis is a crucial step in ensuring that the target population will be motivated and engaged to perform the cognitive control program.

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## Conflicts of Interest

None declared.

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## Abbreviations

**aPASAT:** adaptive PASAT

**ATS:** affinity for technology scale

**CCT:** cognitive control training

**COMETS:** Collaboration On Maximizing the impact of E-Therapy and Serious gaming

**ISI:** interstimulus interval

**MHPs:** mental health care professionals

**PASAT:** paced auditory serial addition task

**RMD:** remitted depressed

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Original Paper

# Virtual Reality Cue Refusal Video Game for Alcohol and Cigarette Recovery Support: Summative Study

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## Abstract

**Background:** New technologies such as virtual reality, augmented reality, and video games hold promise to support and enhance individuals in addiction treatment and recovery. Quitting or decreasing cigarette or alcohol use can lead to significant health improvements for individuals, decreasing heart disease risk and cancer risks (for both nicotine and alcohol use), among others. However, remaining in recovery from use is a significant challenge for most individuals.

**Objective:** We developed and assessed the Take Control game, a partially immersive Kinect for Windows platform game that allows users to counter substance cues through active movements (hitting, kicking, etc).

**Methods:** Formative analysis during phase I and phase II guided development. We conducted a small wait-list control trial using a quasi-random sampling technique (systematic) with 61 participants in recovery from addiction to alcohol or tobacco. Participants used the game 3 times and reported on substance use, cravings, satisfaction with the game experience, self-efficacy related to recovery, and side effects from exposure to a virtual reality intervention and substance cues.

**Results:** Participants found the game engaging and fun and felt playing the game would support recovery efforts. On average, reported substance use decreased for participants during the intervention period. Participants in recovery for alcohol use saw more benefit than those in recovery for tobacco use, with a statistically significant increase in self-efficacy, attitude, and behavior during the intervention. Side effects from the use of a virtual reality intervention were minor and decreased over time; cravings and side effects also decreased during the study.

**Conclusions:** The preliminary results suggest the intervention holds promise as an adjunct to standard treatment for those in recovery, particularly from alcohol use.

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## KEYWORDS

addiction treatment; Kinect; serious games; motion control games; virtual reality

## Introduction

### Theoretical Basis for the Game Intervention

The Take Control recovery support game uses several familiar and well-researched therapies to improve player treatment outcomes for addiction. Cue exposure therapy (CET) is a commonly used method in substance abuse treatment [1-6]. Traditionally, CET is performed with pictures of a substance, the actual substance itself, or even its scent [2]. The patient is repeatedly exposed to cues and stimuli and encouraged to ignore

the craving response or use a coping response [7-10]. In keeping with the theory that the treatment effect is due to practicing a healthier response to a cue, the player in our game is repeatedly exposed to an image of a substance, and rather than responding with use, the player is trained to substitute a more dynamic, adaptive response. They must react appropriately (destroy the substance) in order to advance in the game.

Another way to explain the effect of this game is counter-conditioning. The unwanted behavior of responding to the cue to use a substance is being replaced with a positive

action, and the new behavior is rewarded [11]. The game supports the rehearsal of the positive action of actively refusing a substance when it is presented and offers a reward to reinforce the more positive response in the form of success in the game.

The effectiveness of this game's approach to substance abuse treatment also might be partially explained by the extinction response. Extinction therapy aims to reduce a patient's conditioned response to a substance by repeated exposure without reinforcers in order to dull the craving response over time [12,13]. In our game, the patient is repeatedly exposed visually to the substance without receiving the reinforcing effect of the substance, which may produce some extinction effects. Creating new memories will overlap former memories, thus extinguishing old habits and responses [13]. Our game will allow players to use movement to form new, more adaptive associations with the substances.

Virtual reality therapy (VRT) uses virtual environments to expose patients to stimuli in a safe and controlled manner, such as with phobias or posttraumatic stress disorder [14]. In VRT for addiction treatment, the stimulus is the substance of the patient's addiction [5,7,9,10,15,16]. A VR video game has distinct advantages over other exposure methods (eg, pictures produced by a counselor). Being in a VR environment allows the player to feel more immersed in the game, resulting in greater involvement and translation into real-life actions [5]. The game also addresses the need for a safe environment to practice refusal skills, as seen in coping skills training [5,17].

Exercise, which has been shown to aid in recovery from substance use disorders [18] and reduce comorbid factors that hinder overall health and wellbeing [19,20], is another factor that may mediate the game's effect. Free movement is possible with our game because Kinect (the system) is not hindered by a controller, cords, or bulky head gear.

Cognitive behavioral therapy (CBT) has extensive research backing its effectiveness in addiction treatment [21,22]. One important interpersonal component of CBT is refusal skill practice. Patients learn how to respond rapidly, maintain eye contact, and give a clear "no" when offered drugs [23]. In our proposed game, players will practice refusal skills (such as verbally saying "no" and physically turning one's back) when offered a substance by a character.

In the specific field of technology-based interventions for substance abuse, we did not identify any similar games to Take Control. However, there was a related study conducted by Girard et al [24] showing that 4 sessions performing behaviors incompatible with smoking cigarettes (crushing virtual cigarettes) within a virtual environment were more efficacious for smoking cessation than a similar game in which patients found and crushed virtual balls. The mechanism of this treatment in the study was not well understood, but we surmised that such

virtual practice in a game environment may be uniquely helpful because it can deliver a large dose of alternative practice in a manner that people not only tolerate but enjoy. The fact that a short duration gaming experience in Girard et al [24] could improve outcomes in comparison with a placebo control suggests that games that involve the body in alternative practice may hold promise for treating addiction.

## Game Design

The Take Control recovery support game was developed for use with the Kinect motion sensor camera and device available with Xbox One and Windows operating systems.

Users hit or kick away cue images as they fly toward the user, as seen in Figure 1. If a user successfully hits the image, it explodes and the user gains in-game points. If an image hits the user or flies off the screen without being exploded, there is no negative consequence to the user's score.

Users choose a background image, like the one in Figure 2, from a menu using voice or mouse controls and then choose 1 cue item to reject per round. Users were encouraged to focus on 1 substance but could change items between rounds. Users could replay the game using different backgrounds or cues as often as desired.

The game includes photo realistic backgrounds, seen in Figure 3, but drawn substance images, seen in Figure 4. During formative studies with target audience members, it was determined that photo realistic images of cue items (cigarettes, beer bottles, etc) were not preferred since users felt that such images were too specific, and thus made the experience less relevant to them individually. There were also reports from formative testers that they believed realistic looking cues might trigger cravings, while illustrations would be less likely to do so.

## Objectives

This study considers how a lower cost, easily accessible video game could be used to support recovery treatment or individual self-efficacy, attitude, and behavior. The goal is to support users in practicing refusal skills and increase self-efficacy by denying trigger or cue items in the nonthreatening environment of the video game. Using realistic backgrounds, users can hit or kick trigger items that fly toward them. Hit items explode, and users gain points.

Primary outcome measures were an increase in reported self-efficacy, attitude, and behavior, a decrease or lack of increase in craving after having seen the trigger items, and satisfaction with the game experience. Self-reported data on continued recovery status were also assessed.

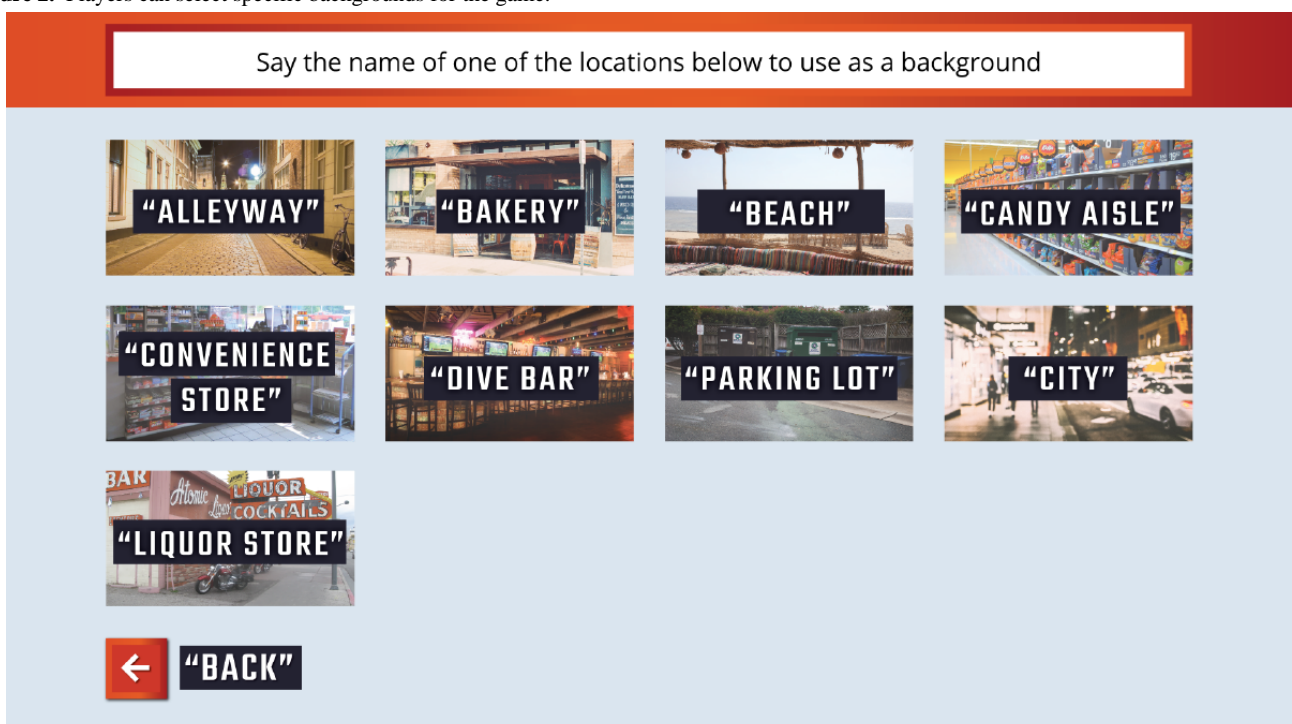
The primary goal of the study was to increase user self-efficacy, attitude, and behavior by allowing the user to practice refusing trigger items in the game context.



**Figure 1.** A staff developer swipes away a beer bottle during game play.



**Figure 2.** Players can select specific backgrounds for the game.



**Figure 3.** Game backgrounds include realistic photos.



**Figure 4.** Substance images were drawn to be less specific as preferred by the target audience.



## Methods

### Participants

The study was reviewed and approved by the Clinical Tools Inc Institutional Review Board. Participants were healthy adult volunteers who self-identified as having recently quit using cigarettes, tobacco, or alcohol. We did not collect data on coaddictions. Participants were recruited through advertisements in a local weekly news circular, on the Internet (Raleigh Craigslist), flyers placed in local public places (community centers, outside grocery stores), and via word of mouth.

Interested volunteers completed a short, open online survey that reviewed eligibility requirements (aged over 18 years, recent quitting, lack of mobility issues that would prohibit game use, fluent in English). The survey contained an informed consent section with study purpose, methods and procedures, confidentiality, benefits and inconveniences, precautions and risks, and survey submissions were limited via IP addresses.

Participants also had to be able to travel to a game setup location. For most participants, this was a small office near a local church building, on the local free bus line, with free parking available. Participants received a gift card to a national store with multiple locations in the area at each of the 4 possible sessions. Sessions typically lasted more than 15 minutes but less than 30 minutes. Participants were asked to play 8 rounds (60 seconds per round) of the game.

Use of the video game was private; research staff were available to assist with any technical difficulties or usability question outside of the testing room, but staff did observe use of the game through a window (where players could not see them) to allow users to behave naturally and not feel judged for their ability to play the game. A computer log documented use time and score, and this was associated with the participant number. The study version incorporated the Kinect for Windows software and ran on a personal computer with a large monitor to facilitate viewing of the game.



**Textbox 1.** Case and wait-list control group schedules.

## Case:

- Preassessment and Take Control game session 1
- Take Control game session 2 and assessment
- Take Control game session 3 and assessment
- One- to 2-week interval
- Follow-up assessment

## Wait-list control:

- Preassessment
- Two-week interval—no assessment
- Preassessment and Take Control game session 1
- Take Control game session 2 and assessment
- Take Control game session 3 and assessment

**Data Collection**

The study was a quasi-experimental, stratified, wait-list control trial using a convenience sample due to time limitations.

Participants in each group had the opportunity to play the game at the Clinical Tools office 3 times, with 7 to 12 days in between uses. Case group participants were asked to complete a follow-up set of measures 1 to 2 weeks after the final game use. Control group users completed a baseline set of instruments and then after at least a 2-week wait period repeated the baseline measures and then used the game 3 times.

Thus, each group had a total of 4 assessment interactions and 3 game play interactions (see [Textbox 1](#)). Assessments were mostly Likert-style questions except for the 7-Day Timeline (fill-in-the-blank), Side Effects (multiple choice), and Stages of Change (multiple choice). A random number was assigned to participants and the information kept in a locked location. Researchers used this number to log participants into the surveys associated with specific session numbers to keep the participant's multiple sessions linked.

Data collected for this study were sent to University of North Carolina at Chapel Hill, where a doctoral student in statistics analyzed the data.

**Results****Participants**

A total of 76 participants were enrolled in the summative study. A total of 7 case participants were withdrawn from the analysis: 2 case participants were withdrawn due to inconsistent data and 5 were withdrawn due to not completing the study. A total of 8 control participants were withdrawn from the study, all due to not completing the study. A total of 61 participants were included in the analysis. There were 28 females (1 Asian, 10

African American, 13 white, 1 other, 2 multiracial, 1 prefer not to answer) and 32 males (1 Asian, 14 African American, 15 white, 1 other, 1 prefer not to answer); 1 participant was unknown (chose prefer not to answer for both gender and race categories).

**Data Collection*****Quantitative Results—Substance Use***

The 7-Day Timeline instrument allowed the participant to report any substance they had used the week prior to playing the game. In [Table 1](#), percentages are reported based on a starting point of 100% for those reporting use of a substance in session 1. After playing the game twice, case participants who reported using a substance on the first 7-Day Timeline ( $n=17$ ) had an average drop to 38% of what they had been using at baseline. Of those who reported some substance use at baseline, 5 out of 17 (29%) stopped using altogether (0% use) after 2 weeks of participation. Control participants who reported using a substance on the first 7-Day Timeline had an average substance use increase from 100% to 110% during the 2-week period prior to playing the game. As shown in [Table 2](#), average substance use increased between the last game play (session 3) and 1-week follow-up (session 4) for those who completed the optional fourth session (15/17). Therefore, they went from 100% at week 1 down to 38% at week 3, and back up (average session 3) to 52% at week 4 (average session 4). Overall, there was improvement from session 1 to session 4 of about 50%.

At the follow-up point for the 7-Day Timeline, a third of those who filled out the follow-up survey had reached 0% use by the last game play session and maintained abstinence. However, 27% of participants (4/15) increased substance use after completing the study. One participant, who had reported 0% substance use at all 3 game play sessions, reported using again at follow-up.

**Table 1.** Change in substance use after 2 weeks (percentage<sup>a</sup> based on first reported use).

Characteristic	Control without game (n=11)	Case with game (n=17)
Average change in substance use compared to initial 100%, % <sup>a</sup>	110	38
Number who quit, n	0	5
Number who restarted, n	2	1

<sup>a</sup>Percentage reflects the amount of substance use increase.

**Table 2.** Substance use in case group (n=15). N/A: not applicable.

Use for participants who completed session 4 from 7-Day Timeline	Session 1	Session 3	Session 4
<b>Participants still using their substance</b>			
Used substance, %	100.00	37.74	52.37
Increased since previous session, n	N/A	2	4
Decreased since previous session, n	N/A	7	2
Use stayed the same, n	N/A	1	3
Decreased and stayed at 0% use, n		5	6
Total, n	15	15	15
<b>Participants with no substance use or those at 0%, n</b>			
Restarted	15	15	14
	N/A	N/A	1

### **Quantitative Results—Self-Efficacy, Attitude, Behavior, or Intended Behavior**

#### **Self-Efficacy Results**

In general, participants reported an increase in self-efficacy after spending 3 weeks playing the game. Table 3 displays results for each self-efficacy question and shows a growth trend for self-efficacy between sessions 1 and 3, followed by a decrease by the 1-week follow-up session 4. The difference between sessions 3 and 4 showed the most decrease in patient self-efficacy. However, on the fourth week, after not coming back and playing the game, participant average self-efficacy rating drops off. We found differences between session 3 and session 4 values in that most of the participants (21/29) had a decreased self-efficacy score or remained the same. Only 8 participants had increased self-efficacy at session 4, a week after the last time they played the game.

#### **Intended Behavior Results**

Several individual measures improved for case intended behavior from baseline (week 1) through 1-week follow-up (week 4). Case participants, on average, showed an increase from baseline to 1-week follow-up in their ratings on a 5-point Likert-type scale of their intentions to use health care (0.61 points), resources (0.24 points), and support groups (0.18 points) to assist with their substance use issues. All other intended behaviors measured showed a slight downward trend from baseline to follow-up (Table 3).

#### **Attitude Results**

Scores on attitude questions, which focused on self-responsibility to use help, started fairly low at week 1 (average 3.88), rose slightly by week 3 (average 3.99), and fell even below baseline by 1-week follow-up (average 3.67).

#### **Quantitative Results—Alcohol versus Tobacco**

Self-reported, self-efficacy, attitude, and behavior scores that were collected via Likert-style surveys at the beginning of the first game play session, and after the third, or last, session of game play for both case and control were analyzed by the substance used. Participants who had selected alcohol as their problem substance showed improvement in scores from an average of 4.19 at baseline (game play 1) to 4.31 at the third session (game play 3)—an increase of 0.11 (2-tailed *t* test, *P*=.09; see Multimedia Appendix 1). When participants who were still using alcohol at baseline were considered separately (11/26), the increase in scores over the 3 weeks was significant (going from 4.04 to 4.28, *P*=.03). In contrast, those who chose tobacco showed a slight decrease in self-efficacy scores of 0.02 points in the 2 weeks. Tobacco substance users had a decrease in mean self-efficacy score of 0.07.

The rate of participants continuing substance use after entering the study decreased for both alcohol and tobacco users (Table 4). Participants with alcohol substance use decreased their amount of substance used by 75%, whereas tobacco substance users only decreased their substance use by 4%.

**Table 3.** Case player self-assessment scores (5-point Likert-type scale; n=29).

Characteristics	Session 1 (Baseline)	Session 3	Session 1 to 3 (Difference)	Session 4 (1-week follow-up)
<b>Self-efficacy—I currently feel that:</b>				
I am happy with how far I have come in my substance use treatment and recovery	4.07	4.17	0.10	4.14
I feel good about my future regarding substance use abstinence	4.21	4.34	0.13	4.03
I am confident in my ability to overcome my substance use issue	4.07	4.38	0.31	4.07
I am confident in my ability to refuse the use of problematic substances (alcohol/drugs/tobacco)	3.93	4.07	0.14	3.79
Average self-efficacy	4.07	4.24	0.17	4.01
<b>Attitude—It is my responsibility to take control of my substance use issues by:</b>				
Using the help of support channels	4.00	4.07	0.07	3.86
Using the help of health care professionals	3.41	3.72	0.31	3.45
Using the help of friends	4.24	4.17	−0.07	3.97
Average attitude	3.88	3.99	0.10	3.67
<b>Behavior—I intend to quit using problematic substances (alcohol/drugs/tobacco)</b>				
I intend to reduce my use of problematic substances (alcohol/drugs/tobacco)	4.27	4.00	−0.27	3.93
I intend to reduce my use of problematic substances (alcohol/drugs/tobacco)	4.56	4.43	−0.13	4.15
<b>Behavior—I intend to use or continue using the help of:</b>				
Health care to assist with my substance use issues	2.96	3.57	0.61	3.41
Friends to assist with my substance use issues	4.07	4.03	−0.04	3.90
Family to assist with my substance use issues	3.43	3.61	0.18	3.34
Support groups to assist with my substance use issues	3.54	3.50	−0.04	3.61
Resources to assist with my substance use issues	3.79	4.03	0.24	3.93
<b>Behavior—I intend to seek out and participate in:</b>				
Healthy lifestyle behaviors such as eating healthily	4.31	4.48	0.17	4.10
Healthy lifestyle behaviors such as exercising	4.38	4.48	0.10	4.21
Healthy lifestyle behaviors such as socializing	4.41	4.48	0.07	4.03
Healthy lifestyle behaviors such as hobbies	4.34	4.62	0.32	4.24
Average behavior or intended behavior	4.00	4.11	0.11	3.89

**Table 4.** Average change in substance use for participants who started the study using a substance within the past week (n=24).

Substance type	Session 1 attendance, n (%)	Session 3 attendance, n (%)
Tobacco	13 (100)	12 (96)
Alcohol	11 (100)	7 (25)

### Quantitative Results—Satisfaction

The trend, on average, was that participant satisfaction with the game was positive, with scores averaging between 3.34 and 4.25 (neutral and agreement) on a 5-point Likert-type scale in response to 5 satisfaction questions (see Table 5). The average agreement decreased slightly by the end of the study, perhaps because of the decrease in novelty or instrument fatigue. Participants agreed with all satisfaction statements at the end of the study, however.

### Qualitative Results

A total of 48 participants offered additional comments in the surveys as well as in an unstructured interview after playing the

game. The positive and negative comments were divided into more general and specific comments, and the game design suggestions were recorded. Of the 76 unique comments, 50% (38/75) were positive about the game and playing the game, 9% (7/75) were negative, and 41% (31/75) were neutral or involved game design suggestions for the future (such as changes to fonts, scoring, additional backgrounds or images). Many of the positive comments (21/38) included evaluative statements like, “Fun,” “Cool,” and “Liked it.” The negative comments comprised a mixture of skepticism about the game efficacy, stress inducement, soreness, or general dislike.



**Table 5.** Game satisfaction scores (5-point Likert-type scale). N/A: not applicable.

Game satisfaction	Session 1 (n=52)	Session 2 (n=52)	Session 3 (n=52)	Session 4 (1-week follow-up; n=29)
<b>Game focus—I feel that:</b>				
The game was fun.	4.43	4.48	4.37	4.10
This game was engaging.	4.58	4.48	4.48	4.17
Based on my experience, I would recommend this game to other patients in treatment for substance use problems.	3.88	3.98	4.00	3.67
Based on my experience, this game will aid in my substance use treatment and recovery.	3.45	3.55	3.81	3.53
Overall, this game will be a useful substance use treatment and recovery tool.	3.78	3.83	4.12	3.70
<b>Game feedback—The game seems like it will help with my treatment in terms of:</b>				
Relapse prevention	3.41	3.40	3.65	N/A
Seeking help	3.22	3.10	3.38	N/A
Sticking to treatment	3.68	3.60	3.88	N/A
Better long-term outcomes	3.76	3.65	3.69	N/A
Higher quality of life	3.61	3.70	3.71	N/A

## Discussion

### Quantitative Results

There are several important results of this brief study. First, that participation in the study and use of the game seem to support abstinence from substance use based on the 7-Day Timeline reports when game users are compared to participants in the control group. The 7-Day Timeline instrument reported decreased or maintenance of no substance use at a poststudy follow up for most of the 29 participants in the game use group. That is, substance use decreased or remained the same for most users, although more for alcohol users than for tobacco users.

This suggests that participation in the study did support abstinence from substance use and that the effect might be stronger for alcohol use than tobacco use. Additional research is needed to determine if this effect is due to participation in a study or the intervention.

A second finding is that there were fewer positive results seen in substance use during the wait-list control period for those participants. In other words, there was a general increase in use, not decrease while controls waited. This suggests that being in a study and knowing that they would have to report on their substance use did not change their baseline behavior. This result strengthens the argument that it was use of the game that decreased substance use for participants, rather than participation in the study. Future research could examine this finding further.

A third finding is that scores for self-efficacy, attitude, and intended behavior went up significantly from baseline to week 3 ( $P=.03$ ) for patients still using alcohol at baseline. This, together with the greater decrease in substance use for the group that selected alcohol as the substance to work on, suggests that the game benefits may be greater with respect to alcohol use.

Finally, it is noteworthy that few participants reported an increase in use of their substance. This was a concern due to

the possibility, as seen in CET modalities, that exposing users to cues for substance use can have a triggering effect and thus have the potential to undermine recovery. This did not happen often, which is encouraging and a necessary result for further research into the use of game- or electronic-based CET adjunctive technologies.

### Participant Satisfaction, Self-Efficacy, and Behavior Key Findings

Secondary findings revolve around participant enthusiasm for the game experience and impact the potential of the game as a supportive product in the future. Participants found the game engaging and fun.

Additionally, participants felt playing the game during recovery would help with relapse prevention and related behaviors. Agreement with this was highest after session 3.

There was a slight but intriguing difference in results for those who reported recovery for alcohol use as their primary goal versus those who chose recovery from tobacco use. Specifically, self-efficacy increased for those in recovery for alcohol use, but there was a minor, not statistically significant decrease in self-efficacy for former tobacco users. Differences between these 2 groups could be an area of further research, as misuse of both substances is harmful to health in the US population. Another improvement seen from pre- to postintervention follow-up was an increased intention to use health care, resources, and support groups.

### Limitations

There are limitations worth noting in this study. The study population was small and was a convenience sample of participants who were interested in maintaining their status in recovery, and thus they may not be typical of all individuals having substance use problems. Second, time was constrained, which impacted how often participants could use the game. In an ideal setting, the game experience would be available to

participants more frequently, and a dose-response investigation could be conducted.

Kinect is a kinesthetic game and requires a minimum level of physical ability to move arms or legs, and this limits the reach of the game. A participant was able to use the game from a wheelchair in early testing, but more modifications are needed to effectively reach a mobility-limited population. Also, in terms of the physicality of the game, we believe that the possible aggressiveness of the game is balanced by the positive interactions of taking control of one's environment; however, a psychological professional would need to evaluate whether this game is appropriate for individuals with aggressive tendencies.

Given this was a short-term feasibility study, long-term studies would need to be conducted to address the complexities of rehabilitation from various addictions.

Finally, Microsoft is no longer actively developing Kinect applications; although current versions of the Xbox One continue to support use (as of August 2017). Thus, future versions of the game should explore additional platforms while maintaining the kinesthetic element of game play and explore how this impacts results.

## Conclusions

This study indicates that a serious game-based intervention has potential to be a useful part of recovery efforts for individuals seeking to maintain abstinence from alcohol or tobacco misuse or use. The use of a kinesthetic game based in a cue refusal theory framework-based intervention could prove a valuable adjunct to therapy in the future. Games have the ability to reach and engage a significant audience segment, and the use of an individually tailored game could expand potential treatment experiences.

## Acknowledgments

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## Conflicts of Interest

The authors are the employees of the small business that received the SBIR contract to develop and evaluate this game. All development and evaluation (except for the data analysis) was performed by Clinical Tools staff, including the study design, collection of data, writing of the report, and the decision to submit the report for publication. Brad Tanner is the owner of Clinical Tools Inc and may profit from any sale of the game.

## Multimedia Appendix 1

Self-efficacy, attitude, and intended behavior scores for case and control participants who completed 3 game play sessions (N=50).

[PDF File (Adobe PDF File), 18KB - [games\\_v6i2e7\\_app1.pdf](#)]

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## Abbreviations

**CBT:** cognitive behavior therapy

**CET:** cue exposure therapy

**SBIR:** Small Business Innovation Research

**VRT:** virtual reality therapy

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Original Paper

# Using Mobile Health Gamification to Facilitate Cognitive Behavioral Therapy Skills Practice in Child Anxiety Treatment: Open Clinical Trial

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## Abstract

**Background:** Cognitive behavioral therapy is an efficacious treatment for child anxiety disorders. Although efficacious, many children (40%-50%) do not show a significant reduction in symptoms or full recovery from primary anxiety diagnoses. One possibility is that they are unwilling to learn and practice cognitive behavioral therapy skills beyond therapy sessions. This can occur for a variety of reasons, including a lack of motivation, forgetfulness, and a lack of cognitive behavioral therapy skills understanding. Mobile health (mHealth) gamification provides a potential solution to improve cognitive behavioral therapy efficacy by delivering more engaging and interactive strategies to facilitate cognitive behavioral therapy skills practice in everyday lives (in vivo).

**Objective:** The goal of this project was to redesign an existing mHealth system called SmartCAT (Smartphone-enhanced Child Anxiety Treatment) so as to increase user engagement, retention, and learning facilitation by integrating gamification techniques and interactive features. Furthermore, this project assessed the effectiveness of gamification in improving user engagement and retention throughout posttreatment.

**Methods:** We redesigned and implemented the SmartCAT system consisting of a smartphone app for children and an integrated clinician portal. The gamified app contains (1) a series of interactive games and activities to reinforce skill understanding, (2) an in vivo skills coach that cues the participant to use cognitive behavioral therapy skills during real-world emotional experiences, (3) a home challenge module to encourage home-based exposure tasks, (4) a digital reward system that contains digital points and trophies, and (5) a therapist-patient messaging interface. Therapists used a secure Web-based portal connected to the app to set up required activities for each session, receive or send messages, manage participant rewards and challenges, and view data and figures summarizing the app usage. The system was implemented as an adjunctive component to brief cognitive behavioral therapy in an open clinical trial. To evaluate the effectiveness of gamification, we compared the app usage data at posttreatment with the earlier version of SmartCAT without gamification.

**Results:** Gamified SmartCAT was used frequently throughout treatment. On average, patients spent 35.59 min on the app (SD 64.18) completing 13.00 activities between each therapy session (SD 12.61). At the 0.10 significance level, the app usage of the gamified system (median 68.00) was higher than that of the earlier, nongamified SmartCAT version (median 37.00,  $U=76.00$ ,  $P<.01$ ). The amount of time spent on the gamified system (median 173.15) was significantly different from that of the earlier version (median 120.73,  $U=173.00$ ,  $P=.06$ ).



**Conclusions:** The gamified system showed good acceptability, usefulness, and engagement among anxious children receiving brief cognitive behavioral therapy treatment. Integrating an mHealth gamification platform within treatment for anxious children seems to increase involvement in shorter treatment. Further study is needed to evaluate increase in involvement in full-length treatment.

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## KEYWORDS

gamification; mobile health; ecological momentary intervention; cognitive behavioral therapy; child anxiety treatment; SmartCAT; childhood anxiety disorders

## Introduction

### Background

The results of multiple independent randomized clinical trials provide evidence that cognitive behavioral therapy (CBT) is an efficacious treatment for childhood anxiety [1-7]. CBT typically requires 10 to 20 weeks of weekly sessions with a CBT therapist [8] and emphasizes the importance of CBT skills rehearsal, exposure tasks, and practice beyond office visits (homework) [9-13]. Markedly, about 40% of anxious children receiving CBT treatment show little recovery from primary anxiety diagnoses, despite evidence suggesting CBT is an efficacious treatment [8]. One possibility is that treatment requires a willingness to learn and practice CBT skills beyond therapy sessions.

Although homework is routinely assigned, many anxious children struggle with homework completion [14] possibly because of a lack of therapeutic commitment or motivation [15]. Unlike adults who are often self-referred, children are usually brought to therapy by their parents or caregivers. As a result, these children are not always considered to be “voluntary participants” in therapy and may view homework as unfavorable [16]. Therapists note that other noncompliance factors include forgetfulness and lack of understanding of CBT skills [14].

### Overcoming Barriers to Home-Based Skills Practice for Children

Mobile health (mHealth) technologies present potential solutions to overcoming barriers to fostering home-based skills practice for children. First, the “always-carried” and “always-on” nature of smartphones creates an opportunity to deliver CBT interventions to children in natural settings during their everyday lives, an approach referred to as “ecological momentary intervention” (EMI) [17]. EMIs can provide skills coaching to anxious children in the real world outside of sessions, when it is most needed. Anxious children can also access training materials *in situ* at their convenience throughout the day. Second, the increased processing and sensing capability of smartphones allows for more sophisticated, interactive, and engaging health intervention apps. This provides an opportunity for developers to make context-aware mHealth apps that can automatically detect when and where children require skills coaching during real-world emotional situations.

Despite this potential, the repetitive tasks (eg, self-monitoring and self-management) that characterize most mHealth apps can be exhausting and may lack intrinsic rewards [18]. An alternative to traditional mHealth apps is the use of gamification, one of many persuasive approaches that uses game design

elements to engage people in nongame contexts [19]. Among children, the use of gamification is particularly effective in addressing the problem of lack of motivation [20]. When integrated with mHealth apps, gamification can potentially make tedious activities on mHealth apps more engaging to children, thus increasing their motivation to use them.

### Goal of This Project

The purpose of this project was multifaceted. First, we redesigned our existing mHealth system, titled “Smartphone-enhanced Child Anxiety Treatment” (SmartCAT), consisting of a smartphone app (SmartCAT app), a therapist portal (SmartCAT portal), and a two-way communication connecting them [21]. This redesign included gamification techniques as well as a number of interactive skill-builder modules to increase user engagement or retention and facilitate learning. Second, we evaluated the utility of the redesigned SmartCAT as an adjunctive component to CBT treatment in an open clinical trial. User engagement data (ie, time spent on app and app use) and the app retention (app use per session) at posttreatment were used to assess the utility. Finally, the effectiveness of gamification was evaluated by comparing user engagement data with the previous version of SmartCAT without gamification.

## Methods

### User-Centered Design

A user-centered design (UCD) approach was used to gather requirements and iteratively design the system, leveraging the SmartCAT 1.0 system that had been previously pilot-tested [21]. In this version, the app notifies patients to initiate a “skills coach” module, which then cues patients to complete a series of questions about recent emotional events and to apply skills learned in therapy toward coping with that event. Throughout this study, the skills coach was scheduled from the portal by the therapist to launch automatically once per day (either at a fixed or random time depending on patients’ desire) and be completed more frequently if desired by the patient. It could also be activated at “opportune” moments when patients were experiencing acute anxiety. After completing a skills coach entry, patients were rewarded with digital points that could be “cashed in” for a prize.

Although the skills coach in SmartCAT 1.0 was actively used, averaging 5.36 times per session, children and therapists suggested several potential improvements including developing more interactive and fun ways for the children to learn and practice CBT skills in daily life and also improving rewards to

increase the rates of CBT skills practice. On the basis of this feedback, we redesigned and developed a new system using the iterative, user-centered approach described below.

The SmartCAT addresses barriers to home-based skills practice for children by (1) Providing automatic cues to children to practice skills at prescribed times and places, even when they forget to initiate skills practice on their own; (2) Motivating children to practice skills; and (3) Providing interactive ways to learn the skills and offering *in situ* learning exercises to increase understanding of skills as well as daily personalized home-based exposures. To achieve this goal, a UCD approach was used to identify key components of the system by involving CBT therapists and children in the process. Because it emphasizes user perspective or context, UCD is an appropriate method for achieving a balance between fun and function (in formal terms, between the internal goal of the system and the treatment goal of improving skills understanding) [22].

The UCD process was conducted in three steps. The initial step of this UCD process was the development of design principles based on user information captured and interpreted by therapists that deliver CBT to anxious children. The therapists served as the interface between the users (ie, anxious children) and the designer or software developer. Meetings with therapists were conducted to brainstorm and identify design ideas and criteria. Such ideas as including interactive features, treatment engagement and adherence, and educational content were addressed. These design ideas and criteria were then translated into design principles, which were in turn used to evaluate the system. The results from the design principles development step provided general guidelines for implementation by software developers for the iterative system development step. Continuous input or feedback was provided by two therapists during the system development process. A formative usability study involving the children in the study was conducted following the system development process to collect feedback and discover usability problems. Revisions were made before the system was implemented as part of the clinical trial.

The initial UCD process revealed a conceptual model for the system that includes seven key components. By implementing these components in the system, CBT treatment outcomes can hopefully be improved. The individual and specific components of the system are outlined as follows:

1. *Reminder*: home-based skills practice is often less impactful because of children forgetting to practice CBT skills beyond the clinic. According to behavioral learning theory, behavior depends on internal (thoughts) or external (environmental) stimuli or cues [23]. This means that noncompliant behaviors such as not remembering to practice CBT skills can be modified by introducing repetition of external stimuli or cues such as reminders.
2. *Game- or multimedia-based coping skills learning*: CBT for anxious children aims at reducing anxiety and preventing relapse. As CBT is a skills-based treatment, much of the work associated with treatment involves teaching children new behaviors, concrete problem-solving skills, and strategies for challenging anxious thoughts and beliefs. To improve the learning process, game-based learning can be used as an appropriate way to provide an interactive yet fun learning environment beyond the weekly in-person sessions. Ultimately, game-based learning provides a type of game play that has well-defined learning outcomes. Moreover, research suggests that games can effectively model the learning process in that games require players to be active and to provide immediate feedback as a result of players' decisions during game play [24]. To facilitate the learning of coping skills, several CBT components—such as emotion and somatic symptoms identification, cognitive restructuring, and problem solving—were translated into game formats. Audio or video recording were also used to improve such coping exercises such as deep breathing or relaxation, and problem-solving was translated into game formats such as emotion and somatic symptoms identification, cognitive rest
3. *Step-based plan for dealing with anxiety*: the “Coping Cat” program is a structured CBT program that was developed at Temple University's Child and Adolescent Anxiety Disorders Clinic [25,26]. Notably, CBT skills training is one of the two key components of the Coping Cat program. Here, anxious children learn several basic skills that are then integrated into a plan for dealing with anxiety called the FEAR plan. The FEAR plan comprises four concepts addressed in the following, easily remembered anagram: (1) *Feeling frightened?* This step aims to increase awareness of physical symptoms of anxiety; (2) *Expecting bad things to happen?* Here, the focus is on recognizing anxious self-talk; (3) *Attitudes and actions that will help*. In this step, participants develop behavior and coping talk to use when anxious; and (4) *Results and rewards*. This final step comprises a self-evaluation and administration of reward for effort.
4. *Exposure tasks*: another important component of CBT is skills practice, which involves having the children experience anxious distress in real anxiety-provoking situations. Exposure tasks tailored to the children's fears are conducted once the children demonstrate an understanding of the concept within the FEAR plan (based on the therapist's clinical judgment). To facilitate exposure task practice, a list of in vivo tasks that the children need to conduct were included. The therapist collaborates with the children to prepare the list [27].
5. *Therapist-patient interaction*: to support therapist-patient interaction beyond office visits, a Health Insurance Portability and Accountability Act–compliant messaging system is required. Using this feature, a participant can compose a message on his or her phone, and the message will be sent to a Web-based portal rather than the therapist's private phone. This protects the private space of the clinician and allows the communication to be part of the treatment record.
6. *Reinforcement through gamification*: one way to improve homework compliance is by providing positive reinforcement in the form of rewards (eg, small toys, accessories or makeup, and gift cards) for completing homework [16,28]. In many manual-based CBT treatment (eg, the Coping Cat program), therapists acknowledge or praise participants' efforts to engage in exposure challenges

(eg, talking with 5 people) by rewarding them with collectible cards (eg, baseball card), stickers, or small toys. Gamification techniques, which add gameful (rule-based and goal-oriented) experience, can provide positive reinforcement to anxious children by rewarding their efforts in completing homework.

7. *Usage monitoring*: as part of clinician-directed CBT treatment, the therapists are required to monitor a participant's adherence to treatment regimens and activities. The therapist can then use the monitoring data to determine the treatment regimen for the upcoming week.

The CBT components of the model were translated into several skill-builder modules that include an in vivo skills coach, a series of interactive games and activities to reinforce skill understanding, and a home challenge module to encourage home-based exposure (Table 1). Other skill-building activities such as viewing or practicing with a deep breathing techniques video, listening or practicing with a progressive muscle relaxation audio file, or practicing a weekly task adapted from the Coping Cat workbook were provided. The number and types of skill-builder modules can be adjusted in accordance with the children's progress during CBT treatment.

### Implementation of Gamification

Gamification aims to increase people's engagements in real life activities and encourage specific human behaviors. To some extent, the concept is already being used in manual-based CBT treatment such as the Coping Cat program [25]. During weekly sessions, eg, therapists acknowledge or praise children's efforts to engage in exposures challenges (eg, talking with 5 people) by rewarding them with collectible cards (eg, baseball card), stickers, or small toys.

Recent advances in interactive mHealth technologies allow gamification concepts to be layered on top of activities provided by mobile apps. "Swarm" app, eg, rewards its users for checking into a new place by giving digital coins, badges, stickers, and statuses. These game mechanics serve dual functions—helping users learn to use the app and making a real-world experience more engaging. Digital coins and badges give the users a sense of accomplishment, whereas status changes such as "mayorships" allow users to compete with their friends.

In this project, the system was gamified so as to drive children's engagement in completing their weekly skill-builder modules via an iterative process consisting of four steps. These steps are as follows:

1. **Identify the end goals**: identify the desired goals (ie, desired human behaviors). When defining goals, the contexts of implementation (eg, education and health) and the needs or requirements imposed by stakeholders (eg, a policy of screen time reduction for children and smartphone use in class) must be considered [29]. Ideally, the goals should be specific (clear and well-defined), measurable, attainable, and intended to support and enhance the existing context. In this project, the goal was to maintain participants' therapeutic commitment or motivation in completing between-sessions skill-builder activities.

2. **Determine interesting activities to move patients toward the end goals**: identify activities that are aligned with the goals. The activities should also capture the interest of the person. From a self-determination theory perspective, interest can be defined as an affect that occurs in the interaction between a person and an activity [30]. Interest organizes people's attention and activity. When people experience interest (being intrinsically motivated), the energy necessary for action is readily available because they are rewarded with spontaneous affective or cognitive experiences accompanying their behavior. Ryan and Deci [31] explain that intrinsic motivation can be maintained by satisfying three psychological needs:

- i. **Competence**: the need of people to gain mastery of tasks and learn different skills. When people feel that they have skill or expertise at doing something, they will be more likely to continue doing it. Opportunities to learn different skills, or be optimally challenged, can also improve a person's level of competency [32].
- ii. **Autonomy**: refers to the need to feel in control when performing activities or tasks. The core concept of autonomy is freedom. Allowing individuals freedom in choosing has been shown to improve autonomy and, consequently, their intrinsic motivation [32].
- iii. **Relatedness or connection**: refers to the need to feel connected to others. People tend to internalize and accept values and practices from those to whom they feel connected and from contexts in which they experience a sense of belonging. Providing a possibility of social connectedness that conveys security can strengthen intrinsic motivation [33].

Although interest plays a central role in intrinsic motivation, it is not central to all motivated behavior. People often engage in instrumental activities for some desired outcome not related to the activity itself (being extrinsically motivated). External rewards such as points, money, gift cards, toys, or something tangible can motivate people to complete tasks. For gamification to truly motivate people, it has to target correct and intrinsically motivated activities, as well as provide external rewards for completing the activities [34]. When working with children, extrinsic rewards have been found to be an appropriate form of motivation [35]. Table 2 shows intrinsic and extrinsic motivators that were added to the target activities.

3. **Apply game design elements to improve user experience**: key elements of gamification are applied to make activities feel more "playful." Table 3 shows the game design elements that have been implemented. Furthermore, to identify the key elements, we can view game design elements as a hierarchy that contains components, mechanics, and dynamics [36]. "Components" represent the specific forms of mechanics and dynamics. Each component is tied to one or more higher-level elements. "Mechanics" refers to a distinct set of rules or basic processes that generate user engagement and drive the action forward. "Dynamics" represents the big-picture aspects of the gamified system that are indirectly managed by the system. Initially, actions that need monitoring and rewarding are defined. Then, points, badges, and

achievements (ie, trophies and stars) are utilized to reward users when performing an action or a collection of actions. Points, levels, badges, and achievements represent the components section of the pyramidal hierarchical structure. To generate engagement, challenges and feedback representing the mechanics section are added. After completing a challenge, the user can collect rewards (ie, tangible payoffs as extrinsic motivators). Ultimately, the dynamics provided by the game element hierarchy system represents the relationship between tangible payoffs and the number of points collected (bigger prizes require one to get a higher number of points).

4. Evaluate effectiveness: depending on the goals defined in the initial step, gathering quantitative or qualitative data can assess the effectiveness of gamification. Quantitative data that includes engagement (time spent using the app, the number of digital points collected) and retention (the number of features completed between sessions) can be used to infer user behavior directly. Qualitative data such as user feedback, comments, concerns, frustrations, and

suggestions can capture perceptions and attitudes toward gamified apps.

## Participants

A total of 35 participants (aged 9-14 years; mean=11.19) met the criteria for the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) diagnosis of generalized anxiety disorder, social anxiety disorder, and/or separation anxiety disorder. These diagnoses are common in children, frequently cooccur, have a similar presentation, and respond to the same treatment approaches [37-39]. A lower age limit of 9 years and an upper limit of 14 years were chosen based on the reading level requirements for the app and the age-appropriateness of the materials, respectively.

The participants included 5 participants enrolled in a beta testing phase and 30 participants enrolled in an open trial phase who completed treatment. The participants who enrolled in the beta testing phase received similar treatment to those who enrolled in the open trial phase.

**Table 1.** Skill-builder modules.

Module	Session	Description
Skills coach	1, 2, 3, 4, 5, 6, 7	Guide the participant through developing a FEAR plan for a current or recent in vivo anxious experience.
What's the feeling? (game)	1, 2, 3, 4 <sup>a</sup> , 5 <sup>a</sup> , 6 <sup>a</sup> , 7 <sup>a</sup>	Ask the participant to identify emotional and somatic symptoms from various scenarios (including anxiety, physical pain, and hunger).
Chillax	1, 2 <sup>a</sup> , 3 <sup>a</sup> , 4 <sup>a</sup> , 5 <sup>a</sup> , 6 <sup>a</sup> , 7 <sup>a</sup>	View or practice with a video demonstrating deep breathing techniques. Listen or practice with an mp3 audio file for progressive muscle relaxation.
Thought-buster (game)	2, 3 <sup>a</sup> , 4, 5, 6, 7	Ask the participant to identify anxious vs nonanxious self-talk or coping vs noncoping self-talk.
Thought-swapper (game)	3, 4, 5, 6, 7	Ask the participant to identify coping self-talk that works best in a given situation.
Problem-solver (game)	3, 4, 5, 6, 7	Generate and evaluate potential solutions to hypothetical problems.
Challenger	4, 5, 6, 7	Therapist selects personally relevant home challenges from a menu on the portal; patient is prompted to develop a FEAR plan and complete these challenges via app.
Show that I can	1, 2, 3, 4, 5, 6, 7	Therapist selects weekly task (adapted from the Coping Cat workbook) from a menu on the portal; patient is prompted to complete the task via app.

<sup>a</sup>Optional.

**Table 2.** Intrinsic and extrinsic motivators in target activities.

Activities	Intrinsic motivators	Extrinsic motivators
Completing interactive skill-building modules ("What's the feeling?", Thought-buster, Thought-swapper, Problem-solver)	Specific modules are assigned for a particular session. As the session progresses, different modules with different challenges will be assigned (competence)  Each module can be initiated independently (autonomy)	Tangible prizes (ie, accessories and makeup, small toys and games, and gift cards for older teens)
Completing skills coach	As the session progresses, children are asked to come up with their own coping strategies instead of choosing from a provided checklist (competence and autonomy)	
Completing at-home challenges (Challenger), Chillax, and Show that I can task	At-home challenges are discussed with the therapist in face-to-face sessions. Children can choose which challenges they want to complete (competence and autonomy).	
Sending or replying to messages	Children can send messages to their therapist to ask therapeutic questions (relatedness or connection)	Attention, praise



**Table 3.** Actions, components, and mechanics.

Actions	Components	Mechanics
Initiate and complete skill-builder modules when requested to do so by app alarm	One point toward the target number of points (cumulative)	Collect a certain number of points. Therapists will assign the target points needed to redeem a selected prize. A collection of stars and a trophy will be displayed on the home screen. A progress bar and badges are displayed after the completion of actions.
Initiate and complete skill-builder modules from within the app (on one's own initiative).	Two points toward the target number of points (cumulative)	
Complete all required modules for a particular session.	One star	Collect one star for each session.
Complete all required modules for sessions 1, 2, and 3.	Silver trophy	Collect a silver trophy.
Complete all required modules for sessions 4, 5, 6, and 7.	Gold trophy	Collect a gold trophy.

## Procedures

After completing a phone screen, potential participants completed a clinical intake interview. To establish anxiety and exclusionary diagnoses, the Kiddie-Schedule for Affective Disorders and Schizophrenia for School-Aged Children-Present and Lifetime version [40] for DSM-V was used. Participants meeting study criteria were scheduled for a CBT pretest a week before the first therapy session to assess their pretreatment understanding of CBT skills. Each child and a parent or guardian attended an orientation before the first therapy session to learn how to use the smartphone app. Here, the children were provided with an Android smartphone for the duration of the study.

The children were treated using the brief Coping Cat manual and workbook [41,42], implemented over the course of 8 sessions. The treatment includes two key components: (1) CBT skills training, including emotion identification and labeling, cognitive reframing, and problem solving and (2) CBT skills practice through graded exposure to feared stimuli. It should be noted that breathing or muscle relaxation is not formally taught in the brief version. As part of the treatment, the children were asked to complete homework assignments using the app at home. These assignments consisted of specific modules delineated at the end of each session. Treatment was delivered by a master or doctoral level therapist trained in CBT for child anxiety.

As part of the treatment, the therapist was required to complete several tasks via the clinician portal, which is accessible from a computer or a tablet (see Table 4). At the beginning of each session, the therapist, in conjunction with the patient, uses the portal to review the data for the skills coach and other modules from the past week. On the basis of the subsequent discussion and level of patient improvement, the therapist selects germane modules and sets time ranges for the following week. This

information is then pushed to the app. To provide motivation and encouragement to the young patient, the therapist integrates immediate rewards (ie, points) into the treatment by managing these rewards directly from the portal. To support clinician-patient interaction, the therapist uses the portal to send or reply to messages to or from patients between sessions. If required, the therapist may also activate the location-aware feature of the app by entering the address of the anxiety-provoking location after discussing it with the patient. In this case, the address is geocoded into a latitude or longitude format by the portal and then sent to the app.

## Measures

### User Engagement

User engagement was defined as an indicator of the extent to which children interact with the app. User engagement data was reported using indications such as how much time the children spent on the app and the total number of app use during treatment.

### App Retention

App retention was defined as the extent to which children retain their willingness in completing skill-builder modules between sessions. Retention data was reported using the app use between sessions.

### Statistical Analyses

A Mann-Whitney *U* test was conducted to test whether the gamified system has a higher user engagement rate than the existing version of SmartCAT. A Cronbach alpha level of .10 was used for the test because of the exploratory nature of the study [43]. The Mann-Whitney *U* test was preferred because of an expected nonnormality of the data given the small sample size and possible extreme outliers among participants [44].

**Table 4.** Portal tasks a therapist was required to complete.

Tasks	Start of session	End of session	Between sessions
Enter custom locations and times		✓	
Select modules for upcoming week		✓	
Review skills coach or other module data from the week with child	✓		
Set target points for the following weeks	✓		
Send or receive messages			✓

## Results

### Gamified Mobile Health System (SmartCAT 2.0) for Childhood Anxiety

The app was developed using an Android software development kit (SDK). To accommodate new features (ie, low-power location monitoring and improved user interface), Android SDK version 4.2 or above was used. The minigames were developed using Unity, a cross-platform game engine developed by Unity Technologies. Unity allows the games to be run on top of Android or iPhone operating system (iOS, Apple Inc) devices.

The following key components of the system were implemented during the iterative system development process.

#### Reminder

The reminder (Figure 1, line 1) is designed to cue the anxious child toward initiating a skill-builder activity for the day. The app automatically wakes the device, shows a notification dialog, and then plays a distinct sound to get the child's attention. The dialog contains a customized message, a snooze button, and a shortcut button for initiating the module of the day. If the time is inconvenient, the child can choose to reschedule the reminder later (ie, 30 min, 1 hour, and 2 hours) up to a maximum of three times. To increase the effectiveness of the reminders, the child is also allowed to set their own preprogrammed reminders after completing a skill-builder activity.

To complement time-based reminders, we also provide location-aware reminders using geofencing. Geofencing enables automatic detection of mobile objects as they enter or exit a geofence, which is a virtual boundary for a real-world area [45]. These alert the child, as he or she enter locations that will cause him or her anxiety, to appropriately deal with the situation.

The reminders are integrated into a weekly plan for each child that is pushed to the child's app. As shown in Figure 1 (line 2), the plan represents a calendar event consisting of four parts:

- Notes: an instructional message that will be shown on the message part of the app's notification dialog
- Time: the length of the event and the 2-hour window (ie, 4-6 PM, 5-7 PM, 6-8 PM, and 7-9 PM) of the day that a notification should pop up,
- Session: each session is associated with a different set of skill-builder modules
- Optional module: an indicator to include additional skill-builder modules.

### Game- or Multimedia-Based Coping Skills Learning

The following minigames (see Figure 1, line 3) were developed to provide anxious children more interactive ways to learn important CBT skills such as emotion and somatic symptoms identification, cognitive restructuring, and problem solving.

#### “What’s the feeling?” (Emotion and Somatic Symptoms Identification Skills)

Some anxious children are insufficiently skilled in recognizing somatic cues associated with different feelings (eg, anxiety, anger, boredom, and sadness) [46]. The first thing that the children learn in therapy sessions is how to identify their individual physiological or bodily reactions to anxiety, or more specifically, their own physiological reactions toward anxiety-provoking situations. During the session, the children are shown how physical reactions provide cues associated with anxiety but are also provided with suggestions on how to help their body relax. Moreover, the children learn how to identify and classify what emotions a person is most likely experiencing based on contextual information (eg, scenarios). The “What’s the feeling?” module translates the learning process by asking the child to identify emotional and somatic symptoms from various scenarios.

#### “Thought-Buster” (Cognitive Restructuring Skills)

Clinical levels of anxiety can come from irrational or maladaptive thoughts, beliefs, or self-talk. In therapy sessions, the therapist teaches anxious children cognitive reframing techniques to modify the maladaptive nature of their self-talk. This requires the children to first recognize their self-talk. The “Thought-buster” module helps the child in classifying self-talk as either anxious or nonanxious. Self-talk in the app is presented as balloons that can be popped by tapping the screen and are randomized between screens.

#### “Thought-Swapper” (Cognitive Restructuring Skills)

Rational analysis of thoughts followed by a generation of coping thoughts marks another important task in cognitive restructuring processes. The “Thought-swapper” module guides the child in conducting rational analysis of a thought based on a hypothetical situation. For each hypothetical situation, an anxious thought presents in a thought bubble on top of the character. For each situation, the child needs to either counter the initial thought or intensify it. This way, the child can experiment and learn what coping thoughts will work best in a given situation and foster an understanding that thoughts can influence emotions.

***Problem-Solver (Problem-Solving Skills)***

Anxious children often present with problems they wish to resolve. The strategies (eg, avoidance and escape) these children have used to resolve problems in the past is often not an effective strategy for future difficulties. For example, anxious children might not leave their home to avoid panicky feelings. Although avoidance might be effective in reducing anxious distress in the short term, it is an ineffective strategy for dealing with future uncomfortable thoughts and feelings. During a face-to-face session, a CBT therapist leads the child through the steps in the problem-solving process.

The “Problem-solver” module provides an interactive way for the child to practice the four steps of problem solving: define the problem, come up with as many solutions as you can think

of, evaluate all of the options, and pick one or two best solutions. To familiarize the child with these four steps, the module imitates an SMS text message (short message service, SMS) conversation between the child and his or her virtual friend who is experiencing a hypothetical problem from his or her hypothetical life (eg, performing at the talent show after school or going to a friend’s sleepover). Here the child must help his or her virtual friend solve the problem randomly generated each time the module is initiated.

To complement the games, we have included the “Chillax” module (see [Figure 1](#), line 4) that contains a video recording of deep breathing exercises, as well as an audio recording for relaxation. These multimedia files are accessible by initiating the Chillax module—which is part of session-specific skill-builder modules—or by accessing the Media Library.

**Figure 1.** SmartCAT reminders, weekly plan, minigames, and Chillax module screen.



### ***Skills Coach: Step-Based Plan for Dealing With Anxiety***

The “skills coach” module (Figure 2, line 1) provides a series of questions that guide the child in developing a FEAR plan for a current or recent in vivo experience of anxiety. To reduce the child’s burden, checklists are provided. These checklists include common responses to items (ie, typical negative scenarios, automatic thoughts, and coping thoughts) that were generated based on the therapists’ input. As the session advances, the prepopulated responses from the checklist are replaced by text responses that encourage the child to generate his or her own response. FEAR plans are sent to the portal and stored locally on the app for later use when the patient is feeling anxious.

As illustrated in Figure 2, line 1 (right-hand screen), the therapist can review FEAR plans created using the skills coach. The FEAR plans can be ordered by importance (set by the child using the app before FEAR plan submission), session, or submission date. The FEAR plans that need to be discussed with the child have the title appearing over a yellow background.

### ***Exposure Tasks***

The therapist activates the “Challenger” module (see Figure 2, line 2) from the portal during session four or beyond. This module provides a list of in vivo exposure tasks prepared by the therapist and the child during face-to-face sessions. For each exposure task, the child must describe how each task should be conducted in the “real world situation” and/or provide a photograph showing that he or she completed this task. The child’s response will be sent to the portal for the therapist to see.

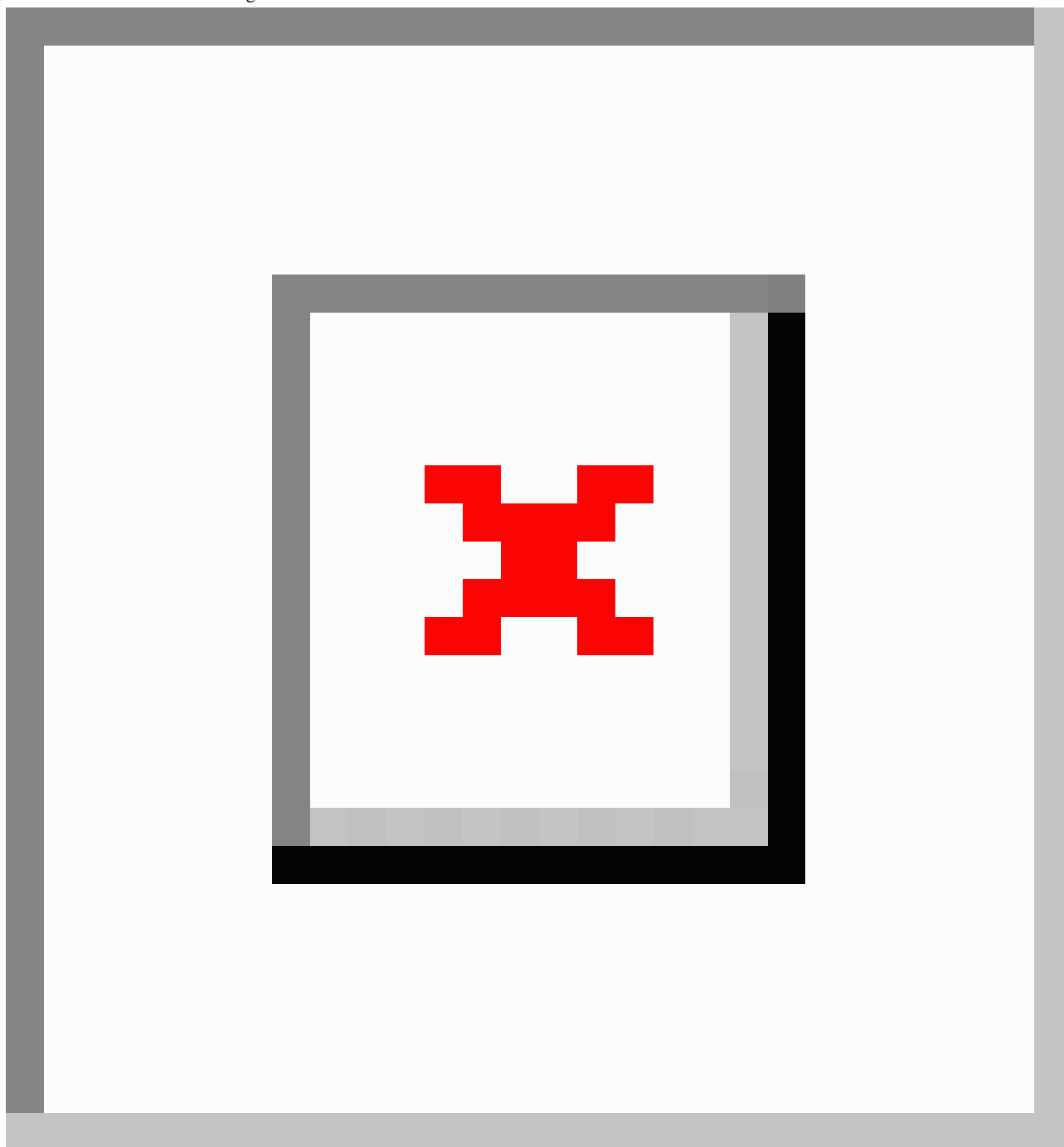
### ***Therapist-Patient Interaction***

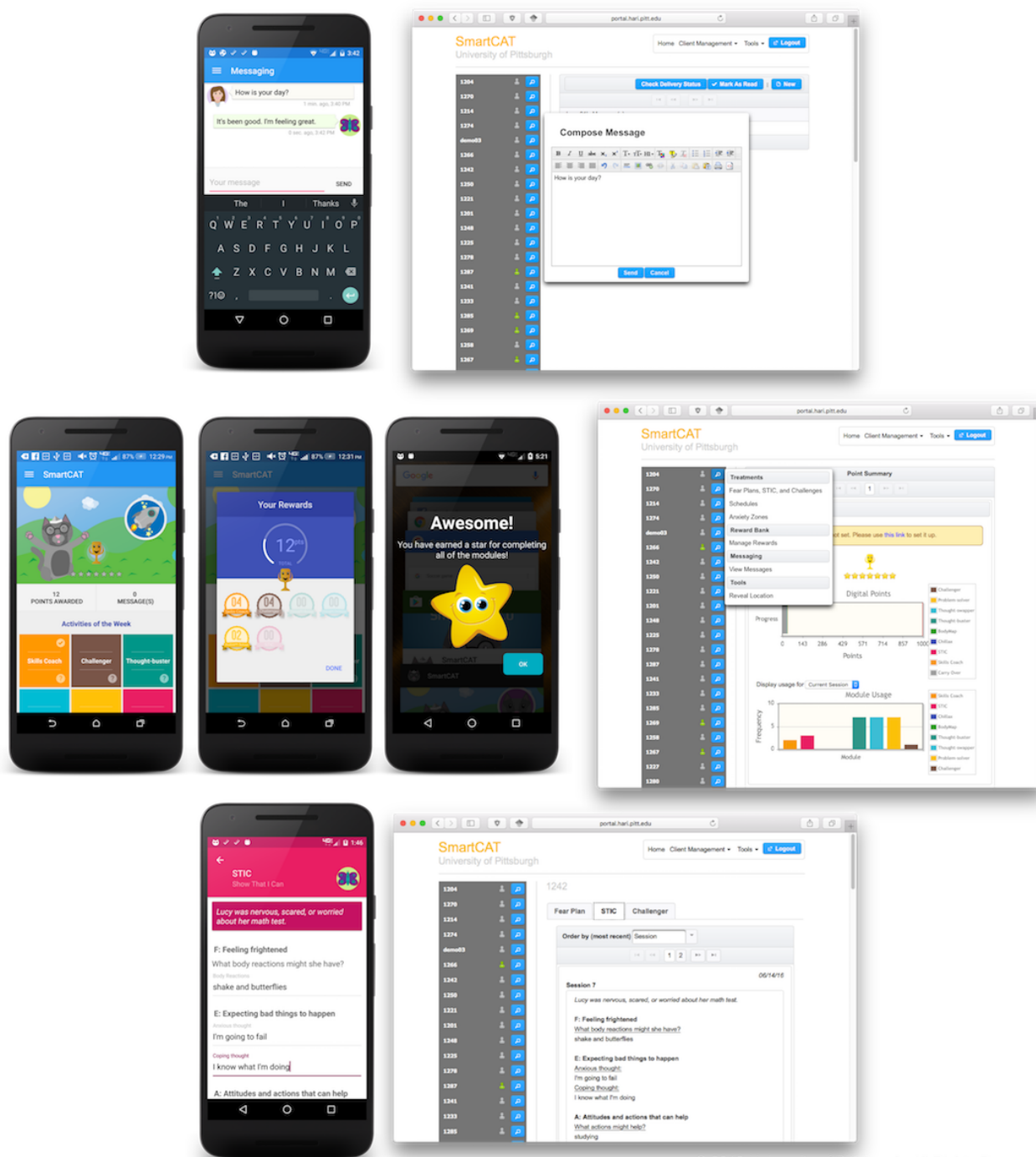
To support therapist-patient interaction, we developed a secure messaging interface (Figure 3, line 1). Using this interface, the child can compose a message on the phone, and that message will be sent to the portal rather than the therapist’s private phone. The therapist may view these messages and/or send the child a message at any time using the portal. Incoming or outgoing messages from or to the therapist were encrypted and stored in the phone’s local storage using Advanced Encryption Standard with a 256-bit key. During transmission, these messages were encrypted using Rivest-Shamir-Adleman algorithm with a 2048-bit key to prevent man-in-the-middle attacks. The portal is secure, protected by a corporate firewall.

### ***Reinforcement Through Gamification***

Skill-builder modules can be activated during instances of acute anxiety by launching the app. From the app’s home screen (Figure 3, line 2), the child can initiate the skill-builder activities that they find most useful. Each time they complete any of the skill-builder modules, digital points are awarded. The target points are associated with a prize that the child can choose and are then assigned by the therapist using the portal. Depending on the target, the points can be redeemed for the desired prize every two or three sessions. If the child acquires digital points beyond the target, however, the remaining digital points will carry over to the following session. A star will be awarded when all of the week’s skill-builder modules are completed. A maximum number of seven stars can be awarded. To maintain patient motivation during treatment, the child is challenged to get a silver trophy for collecting three stars and a gold trophy for collecting the remaining four stars.

**Figure 2.** Skills Coach and Challenger module screen.



**Figure 3.** SmartCAT secure messaging system, app and portal home screen, and Show that I can module screen.

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### Usage Monitoring

The portal allows therapists to monitor patients' progress, as well as access their skills coach, Show that I can, and Challenger entries. The home screen of the portal can be seen illustrated in Figure 3 (line 2; right-hand screen). After successful login, therapists can view a list of their patients and a summary of each patient's progress. The list provides information about each patient's smartphone connectivity—a green mark indicating that a patient's phone is currently connected and a grey mark indicating no connection. An action button, next to the connectivity status, initiates patient-related actions such as reviewing skill-builder module (skills coach, Show that I can,

and Challenger) entries, managing treatment regimens and reminders, sending or replying to secure messages, managing geofences, and digital points. A usage summary contains information on the type of trophy and the number of stars collected by each patient. Therapists can also track how far each patient is from the target points and the number and type of skill-builder modules that have been completed.

We have also included the Show that I can module (Figure 3, line 3) that contains session-specific assignments adapted from the Coping Cat workbook. This can be activated by therapists who are utilizing the Coping Cat workbook to provide additional practice with the skills learned in session that week.

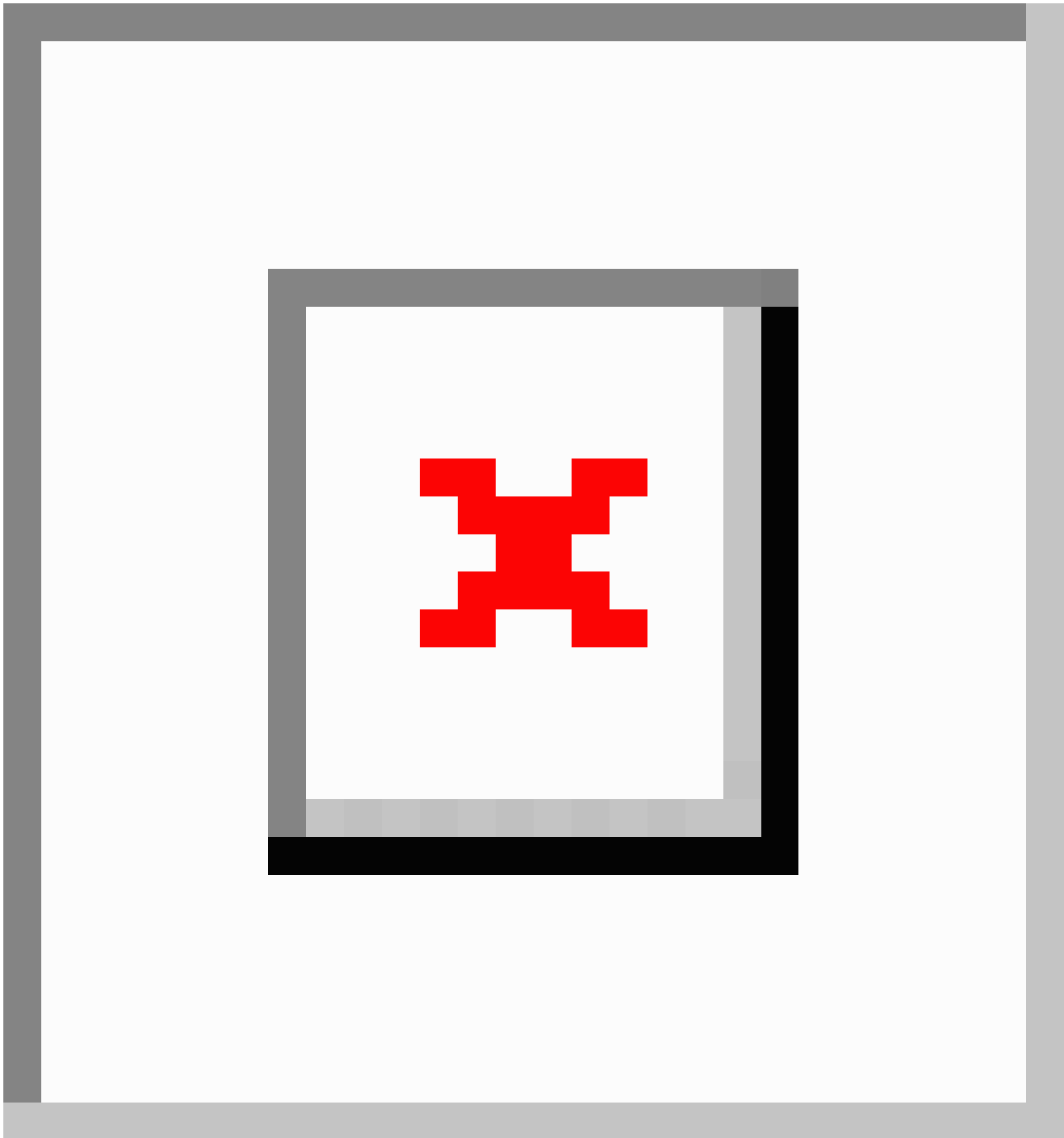
### Usage of the Gamified SmartCAT System (SmartCAT 2.0)

The child usage data revealed that the app was used frequently during treatment. On average, each child spent 35.59 min on the app (SD 64.18) completing 13.00 skill-builder modules per session (SD 12.61), suggesting high motivation during treatment. [Figure 4](#) shows the app retention of SmartCAT 1.0 compared with that of SmartCAT 2.0. The Y scale represents the app use. The average is represented by the wide horizontal line on each box plot. The median is represented by the short line. App use above 60 modules was considered an outlier and was not included. Although SmartCAT 2.0 was used more often than SmartCAT 1.0 between sessions, the pattern of use between the two systems was arguably consistent. In other words, both systems were highly utilized earlier in the session but then leveled off toward the end.

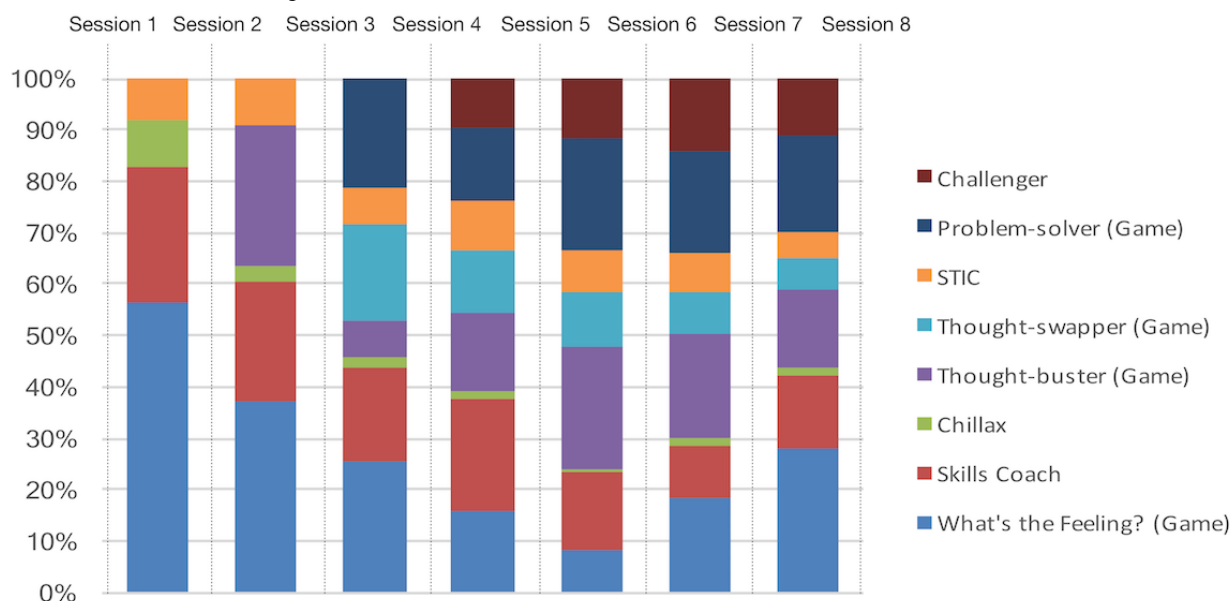
[Table 5](#) presents the summary of user engagement and retention of the existing and gamified versions, respectively. A two-tailed Mann-Whitney  $U$  test (Cronbach alpha=.10) indicated that the children were using SmartCAT 2.0 more frequently (median 68.00) than SmartCAT 1.0 (median 37.00,  $U=76.00$ ,  $P<.01$ ), with a large effect size, Cohen  $r=.56$ . The test also indicated that the children spent longer using SmartCAT 2.0 (median 173.15) than SmartCAT 1.0 (median 120.73,  $U=173.00$ ,  $P=.06$ ), with a medium effect size, Cohen  $r=.27$ .

The children were using different sets of skill-builder modules between sessions, suggesting their willingness to learn a varying set of skills. As illustrated in [Figure 5](#), the interactive skill-builder modules were completed more frequently than the other modules between sessions. This suggests that the participants were more motivated and likely to engage in learning CBT skills using an interactive and fun learning environment such as games.



**Figure 4.** SmartCAT 1.0 vs. SmartCAT 2.0 usage frequency. Usage data were collected after Session 1 and calculated at the end of Session 8.**Table 5.** User engagement and app retention by system.

System	Number of participants	Engagement (across duration of treatment)		App retention
		Time spent in minutes (SD)	App use (SD)	App use per session (SD)
SmartCAT 1.0	15	135.08 (56.48)	36.13 (13.54)	5.16 (3.03)
SmartCAT 2.0	35	248.02 (327.41)	90.40 (69.33)	13.00 (12.61)

**Figure 5.** SmartCAT 2.0 module usage between sessions.

## Discussion

### Principal Findings

Participants were satisfied with the visual appearance of the app, comfortable using the app, and making the app part of their daily routine. They stated that the app was easy to use and found it helpful when they were experiencing anxiety, as illustrated in the following quotes:

*It is amazing, it can really help you.* [Patient 1216]

*I thought the app helped me out a lot. It was like therapist on a phone.* [Patient 1240]

*Was very easy to use and learn. Keep up the good work!* [Patient 1302]

*The app was very easy to use and wasn't confusing at all.* [Patient 1309]

On average, the app was used twice a day. The therapists could track participants' weekly progress and could provide written reinforcements when required using the portal. The result of the implementation indicates that the gamified SmartCAT system has been used as expected and suggests that the inclusion of gamification can effectively increase user engagement and retention.

Although effective, the effects of gamification were not uniformly experienced by all participants. During the clinical trial, one participant did not use the app often, completing only 12 skill-builder modules throughout treatment. This participant was not motivated to use the app and was diagnosed and referred for depression treatment at posttreatment. This suggests that symptoms of depression may interfere with engagement. Six patients used the app more often—but less than an average of seven times—between sessions (<49 times across duration of treatment). This suggests that the implementation of gamification does not always lead to significant increases in user engagement and app retention. As previous studies on player motivation suggest, intrinsic and extrinsic motivators can differently influence the way people interact with game-like systems [47,48]. Thus, user experience created by gamification is likely to differ [49].

### Limitations

The project was implemented in an uncontrolled clinical trial involving a small number of patients, which must be taken into account in interpreting the results. The usage patterns observed at posttreatment may not reflect realistic usage patterns, as the patients who already have iPhones were not able to use the system on their own smartphones.

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## Conflicts of Interest

JS, BP, GP, and OL are the inventors of the SmartCAT mHealth system. JL is also the Chief Executive Officer (CEO) of Playpower Labs, Inc, which provided design and development services for SmartCAT games. He has no further ownership of the games or financial interest in the outcomes. PCK receives royalties from the sales of materials related to the treatment of anxiety in youth.

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## Abbreviations

**BCBT:** brief cognitive behavioral therapy

**CBT:** cognitive behavioral therapy

**EMI:** ecological momentary intervention

**mHealth:** mobile health

**SDK:** software development kit

**UCD:** user-centered design

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Original Paper

# Virtual Antenatal Encounter and Standardized Simulation Assessment (VANESSA): Pilot Study

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## Abstract

**Background:** Prenatal counseling at the limits of newborn viability involves sensitive interactions between neonatal providers and families. Empathetic discussions are currently learned through practice in times of high stress. Decision aids may help improve provider communication but have not been universally adopted. Virtual standardized patients are increasingly recognized as a modality for education, but prenatal counseling simulations have not been described. To be valuable as a tool, a virtual patient would need to accurately portray emotions and elicit a realistic response from the provider.

**Objective:** To determine if neonatal providers can accurately identify a standardized virtual prenatal patient's emotional states and examine the frequency of empathic responses to statements made by the patient.

**Methods:** A panel of Neonatologists, Simulation Specialists, and Ethicists developed a dialogue and identified empathic responses. Virtual Antenatal Encounter and Standardized Simulation Assessment (VANESSA), a screen-based simulation of a woman at 23 weeks gestation, was capable of displaying anger, fear, sadness, and happiness through animations. Twenty-four neonatal providers, including a subgroup with an ethics interest, were asked to identify VANESSA's emotions 28 times, respond to statements, and answer open-ended questions. The emotions were displayed in different formats: without dialogue, with text dialogue, and with audio dialogue. Participants completed a post-encounter survey describing demographics and experience. Data were reported using descriptive statistics. Qualitative data from open ended questions (eg, "What would you do?") were examined using thematic analysis.

**Results:** Half of our participants had over 10 years of clinical experience. Most participants reported using medical research (18/23, 78%) and mortality calculators (17/23, 74%). Only the ethics-interested subgroup (10/23, 43%) listed counseling literature (7/10, 70%). Of 672 attempts, participants accurately identified VANESSA's emotions 77.8% (523/672) of the time, and most (14/23, 61%) reported that they were confident in identifying these emotions. The ethics interest group was more likely to choose empathic responses ( $P=.002$ ). Participants rated VANESSA as easy to use (22/23, 96%) and reported that she had realistic dialogue (15/23, 65%).

**Conclusions:** This pilot study shows that a prenatal counseling simulation is feasible and can yield useful data on prenatal counseling communication. Our participants showed a high rate of emotion recognition and empathy in their responses.

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**KEYWORDS**

prenatal counseling; simulation; ethics

## Introduction

One out of every ten babies is born prematurely [1]. It has become standard practice for health care providers to offer expectant mothers with premature labor a prenatal consultation. This prenatal consultation addresses the complications of premature birth and gives parents a chance to engage in a dialogue about what to expect for their baby. The prenatal consultation becomes even more critical when babies are very premature and may be born at the limits of medical capacity to successfully provide life-sustaining care, otherwise known as the limits of viability [2]. Families may make life or death decisions based on the information given to them by their health care provider. Prior studies show that most parents wish to participate in decision-making in these kinds of situations [3]. However, parents often cannot recall the therapeutic options that are discussed or find that their decision-making is not impacted by physicians' predictions of survival and outcomes [3]. Rather, psychosocial influences such as religion, spirituality, and hopefulness more readily guided their decisions [2]. In some cases, up to a quarter of parents prefer to relinquish decision making autonomy, either to physicians or by leaving the situation in "God's hands" [2,4].

Despite the gravity of these conversations, there is evidence that communication during prenatal consultations could be significantly improved, and there have also been calls for a more standardized approach to perinatal counseling [4]. For example, some researchers have proposed a framework with visual aids to help parents better understand the outcomes of babies born at the limit of viability [5]. However, this approach of providing more standardized information does not always meet the needs of parents. Parents need to feel understood and supported as they advocate for their baby in a collaborative and compassionate environment [3].

Over the last two decades, the use of standardized patients (SPs) for health provider communication training has increased [4]. However, their use in prenatal counseling is limited and there is evidence that even with training, SP encounters are prone to recall bias that may lead to inconsistent feedback [6]. Virtual SPs may be a more accessible and cost-effective approach. However, in these emotionally charged conversations, the ability of the virtual patient to project a recognizable emotion is a key element to creating a valid user experience [7]. We hypothesize that a standardized virtual patient simulator called Virtual Antenatal Encounter and Standardized Simulation Assessment (VANESSA), with the capacity to express emotions, will be a feasible approach to developing health care provider communication skills in prenatal counseling.

We set out to achieve the following objectives:

1. Enhance a virtual SP simulator with animations reflecting four primary emotional states.
2. Evaluate the degree to which practicing Neonatologists and neonatal nurse practitioners (NNPs) can correctly identify the virtual SP's emotional states and the frequency of empathic responses to statements made by the patient.

3. Examine differences in participants' responses to questions posed by the virtual patient.

## Methods

This observational study was approved by the Seattle Children's Hospital Institutional Review Board. All attending Neonatologists, Neonatal-Perinatal medicine fellows, and NNPs from the University of Washington and Seattle Children's Hospital were eligible to participate, and all Neonatologists who attended a biweekly neonatal ethics interest group participated. Providers who did not routinely provide perinatal counseling were excluded.

VANESSA, a prototype virtual standardized perinatal patient of a woman pregnant at 23 weeks gestation, was adapted from a medical history-taking virtual patient simulator [8] with animated emotional responses on the Unity 3D platform [9]. The VANESSA simulator was programmed to display the emotions of anger, fear, happiness, and sadness through animations of facial expressions and body language. An SP case and potential responses were developed with input from attending Neonatologists who provided extensive perinatal counseling services (Table 1). Using the VANESSA interface with the potential patient responses programmed, the scenario was deployed to participants [10]. A structured dialogue of the scenario was programmed to include the full potential range of emotions. Potential responses to VANESSA's dialogue were developed with each set containing both empathic and nonempathic options. Demographic data and feedback on the product were collected using an online survey [11].

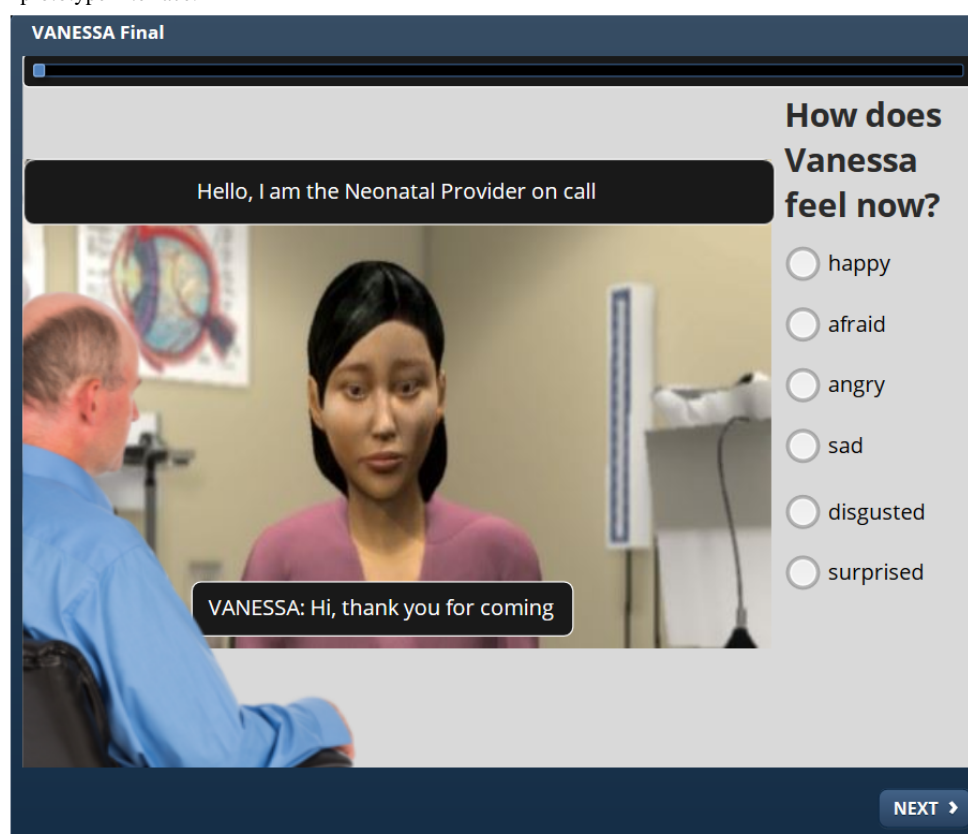
Participants were emailed a link to the online module and associated survey. First, participants were shown video clips of VANESSA displaying emotions with no dialogue (out of context) and asked to identify the emotion she was expressing. Participants were then taken through the prenatal counseling scenario with text displays of both patient and provider dialogue (in context with text) and asked to identify the emotions (Figure 1).

The online module ended with participants participating in the counseling with opportunities to choose responses to the patient's statements. The interactive counseling section provided audio from the SP and text-based responses to move the scenario forward. Participants were again asked to identify VANESSA's emotions during the case (in context with audio). The concordance between the displayed emotion and participant responses was determined for each context. At the end of the encounter, participants were asked two open-ended questions by the simulator: (1) "What would you do?" and (2) "What are my options?" Participants responded by typing into a text box. There was no limit to the length of the participant responses.

Once the scenario was finished, the participants filled out a post-encounter survey that included demographic information, years of experience, and formal training in counseling or perinatal counseling. The survey elicited participants' impressions of the usability of the simulator using a 5-point Likert scale (from 1=strongly agree to 5=strongly disagree).

**Table 1.** Excerpt of VANESSA dialogue.

Topic	Sample Dialogue	Animation
Introduction	Dr. X: Hi, I'm the neonatal provider on-call. Your obstetrician asked me to meet with you to discuss your baby with you. VANESSA: Hi, thank you for coming.	Happy
Assessing patient's comfort/ interest in talking	Dr. X: Is this an okay time to talk? VANESSA: My husband is gone for the day, but I can talk now. (Patient animation—Sad)	Sad
Assess current understanding	Dr. X: What is your understanding of what might happen in the next few days? VANESSA: It sounds like the baby is coming. I'm only six months along. (Patient animation—Afraid)	Afraid
Relationship building	Dr. X: Have you picked a name for the baby? VANESSA: I'm going to call him Robert, after my dad. Dr. X: That's a great name. (Patient animation—Happy)	Happy

**Figure 1.** VANESSA prototype interface.

## Statistical Analyses

Demographic information was analyzed with summary statistics. Multiple choice responses to statements made by VANESSA were collected and analyzed by subgroups including gender, clinical experience, job title, counseling resources used, previous perinatal counseling training, and ethics research focus. Statistical analyses included Kruskal-Wallis and Mann-Whitney tests to evaluate various study subgroups, as the data did not follow a normal distribution. A  $P$  value  $<.05$  was considered significant. Responses to the open-ended questions were analyzed using a grounded theory analysis approach. Two study team members (PM and RU) evaluated the open-ended responses. An initial list of codes was identified by analyzing

the data. Individual codes were discussed further and collapsed into major themes. The final themes were reached after thorough discussion from the two readers. A third study team member (MG) was consulted for discrepancies.

## Results

### Participant Demographics

A total of 24 neonatal providers participated in the pilot study (Table 2). The group was evenly divided between those with less than 10 years of neonatal clinical experience and those with more than 10 years of experience. Most participants reported using medical research and mortality calculators as resources for their perinatal counseling (Table 2). Only the group of

Neonatologists who attended a biweekly neonatal ethics interest group listed counseling literature as a resource. Didactic lectures on perinatal counseling and perinatal counseling simulation use were infrequently utilized as resources by participants in this study. Most participants had been previously trained via clinical observation. No participants felt that VANESSA was unnecessarily complex and 96% (22/23) felt they could use VANESSA without the support of a technical person. Few respondents (3/23, 13%) disagreed with the statement that VANESSA was realistic and only one participant felt that she did not respond as other patients would.

### Emotional Identification

Of the 672 emotions presented, participants accurately identified VANESSA's emotion 78.9% (530/672) of the time. As expected, giving participants context through text and audio dialogue did improve their accuracy of emotional identification (Figure 2). When given no contextual dialogue participants were fairly accurate at 74.4% (192/258). By adding text dialogue, respondents improved to 81.7% (291/356) when the context was given. Participants' confidence in how accurate they were at identifying emotions lagged slightly behind their actual accuracy (Figure 3). When analyzed by each emotion, we found that participants were easily able to identify *happy* (89.8%, 219/244), *afraid* (78.0%, 192/246), and *angry* (80.5%, 161/200)

emotions but were less accurate at identifying the *sad* (63.8%, 134/210) emotion.

### Empathic Response to VANESSA

Participants chose empathic responses to VANESSA 75.0% (81/108) of the time. The response chosen most often was, "I can see this is upsetting." The nonempathic response most often chosen was, "I have more information to share with you, may I go on?" This response accounted for 81% (22/27) of all the nonempathic choices.

The group of Neonatologists who attended a biweekly neonatal ethics interest group were more likely to choose empathic responses ( $P=.01$ ) but were not more likely than the other groups to correctly recognize VANESSA's emotions. We also assessed differences based on gender, clinical experience, job title, counseling resources used, and counseling training. There were no statistically significant differences between these groups.

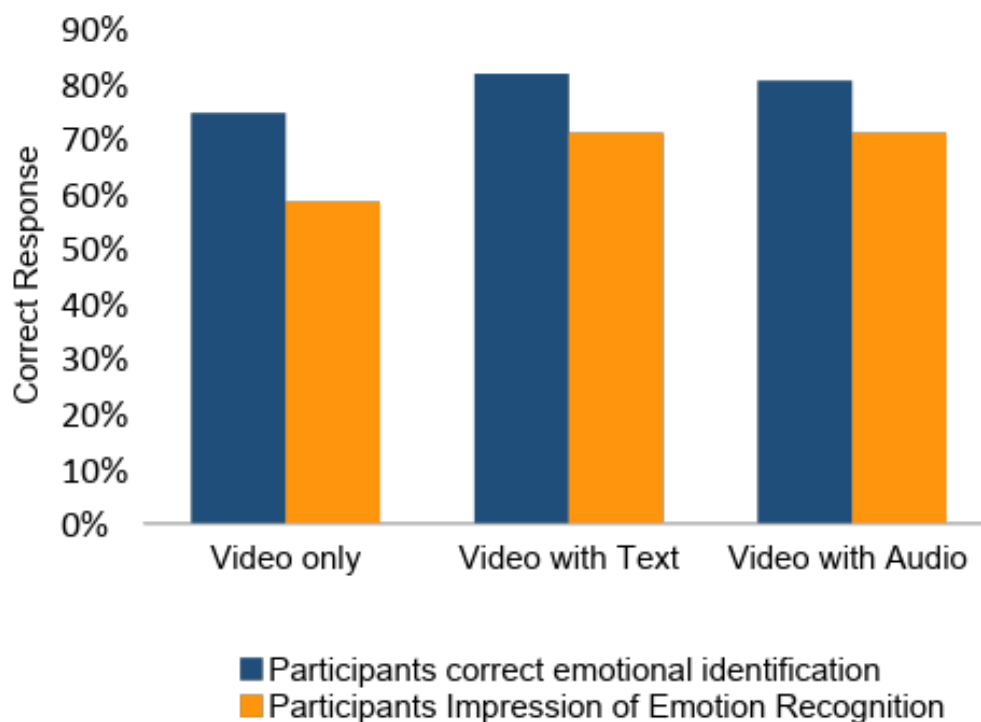
### Qualitative Analysis of Participant Responses

The qualitative analysis of the two open-ended questions of, "What would you do?" and, "What are my options?" posed by VANESSA yielded over 50 codes. The codes were distilled into four themes: *eliciting the mother's values*, *sharing the counselor's values*, *this is a difficult choice*, and *the desire to give more information* to aid the decision.

**Table 2.** Demographics of study participants.

Demographics	n (%)
<b>Gender</b>	
Male	8 (35)
Female	16 (65)
<b>Profession</b>	
Neonatal nurse practitioner	7 (29)
Physician	17 (71)
<b>Clinical experience</b>	
>10 years	12 (50)
<10 years	12 (50)
<b>Previous counseling training</b>	
Clinical observation	23 (96)
Workshop	4 (17)
Simulation	9 (38)
Communication workshop	6 (25)
<b>Resources used for perinatal counseling</b>	
Medical research	18 (78)
Counseling literature	7 (30)
Lectures	5 (22)
Simulation	3 (13)
Mortality calculator	17 (74)



**Figure 2.** Accuracy of emotion recognition versus participants' impression of accurate emotional recognition.**Figure 3.** Participants' empathic versus nonempathic responses.

Participants focused on *eliciting the mother's values*:

*Let's talk more about how you're feeling so I can help you to [the] best answer for your family.*

*There is no right or "expert" answer, but I am here to help you consider what is best for your baby given your values and unique situation.*

*Sharing the counselor's values* was demonstrated through statements such as:

*Like you, I would want the best for my baby; whatever that might be.*

*I would want to make a decision together with my partner. Is there any way for your husband to come be with you?*

Participants also acknowledged the *difficult nature of the decision* and recognized that there were different approaches:

*This decision is difficult and overwhelming. Everyone approaches these life challenges differently with different priorities.*

Few participants gave the definite answer not to resuscitate the soon-to-be-born baby when asked, "What would you do?" Some participants expressed that they didn't know what they would do if they were in that situation:

*I don't know. I've seen very loving families do different things.*

Many participants offered more information:

*I want to give you as much information as I can, so you and your family can make the decision that is the best for you.*

Others reflected the question back to VANESSA in an attempt to elicit her goals and values:

*Tell me what is important for your baby and your family.*

## Discussion

### Principal Findings

Our study findings demonstrated the feasibility and potential utility of an emotionally expressive virtual perinatal counseling simulator. The "happy," "afraid," and "angry" emotions were identified with an accuracy of 80% to 90% (192/246 to 219/244). A high level of emotion recognition by participants interacting with a female virtual SP in a simulated prenatal counseling session is encouraging and is consistent with previous studies that show that recognition of emotion is most accurate on female faces [7,12]. The "sad" emotion was identified accurately only 63.8% (134/210) of the time. This discrepancy persisted despite providing additional text or audio context through scripted conversations. It is possible that the intensity of the "sad" emotion animation was not adequate or that it may have been perceived by participants as a blend of emotions when only one forced choice response was available [13]. Previous studies

noted similar accuracy levels for *happiness*, *afraid*, *sadness*, and *angry* using photographic images of facial expressions of emotion [14].

It is important for health care providers to accurately perceive emotions to provide the appropriate support and empathy for patients who are struggling with a diagnosis or those who are coping with a loss. The responses of a subgroup of participants who attended a biweekly neonatal ethics interest group were significantly more empathic toward VANESSA. This finding is consistent with counseling literature that shows that health care providers with interest in ethics had more empathy toward their patients and demonstrates that counseling approaches employed with virtual SPs may parallel those of actual encounters [4].

Virtual prenatal counseling training may be valuable to medical and advanced practice provider training programs. A survey of neonatology program directors revealed an interest in standardizing prenatal counseling training [6]. A prenatal counseling simulator could be used for just-in-time training for residents and fellows and could serve as a way for experienced health care providers to get feedback on their prenatal counseling.

Our qualitative analysis of participant responses to VANESSA's open-ended questions yielded several themes related to the health care providers' approaches when faced with a difficult question. Most of our participants did attempt to elicit the mother's values rather than presenting their own, but fewer acknowledged that this was a difficult decision with uncertainty in the outcome. Review of the literature notes that families find these two themes to be very important in their counseling [15]. We think this issue underlines the need for further improvement in how we communicate with our patients and underscores the value of virtual SP simulators in research on prenatal counseling, which will be a focus in the next phase of VANESSA's development.

### Limitations

The limitations of our study were that it was conducted at a single academic center and it had a small sample size. Some strengths of our study are that our participants were representative of a large academic neonatology practice, our participants were evenly split between highly experienced providers and moderately experienced providers, and we had participation from both NNPs and physicians.

### Conclusions

In conclusion, this pilot study shows that a perinatal counseling simulation is feasible and can yield useful data on perinatal counseling communication. Our participants showed a high rate of emotion recognition and empathy in their responses. Further work needs to be done to develop our prototype further but demonstrating the recognition of VANESSA's emotions has laid a solid foundation for additional research to validate this approach.

## Conflicts of Interest

None declared.

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## Abbreviations

**NNP:** neonatal nurse practitioner

**SP:** standardized patient

**VANESSA:** Virtual Antenatal Encounter and Standardized Simulation Assessment

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Original Paper

# Training Working Memory in Adolescents Using Serious Game Elements: Pilot Randomized Controlled Trial

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## Abstract

**Background:** Working memory capacity has been found to be impaired in adolescents with various psychological problems, such as addictive behaviors. Training of working memory capacity can lead to significant behavioral improvements, but it is usually long and tedious, taxing participants' motivation to train.

**Objective:** This study aimed to evaluate whether adding game elements to the training could help improve adolescents' motivation to train while improving cognition.

**Methods:** A total of 84 high school students were allocated to a working memory capacity training, a gamified working memory capacity training, or a placebo condition. Working memory capacity, motivation to train, and drinking habits were assessed before and after training.

**Results:** Self-reported evaluations did not show a self-reported preference for the game, but participants in the gamified working memory capacity training condition did train significantly longer. The game successfully increased motivation to train, but this effect faded over time. Working memory capacity increased equally in all conditions but did not lead to significantly lower drinking, which may be due to low drinking levels at baseline.

**Conclusions:** We recommend that future studies attempt to prolong this motivational effect, as it appeared to fade over time.

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**KEYWORDS**

cognitive function; memory; video games; motivation

## Introduction

**Background**

Psychological problems that occur during adolescence are often associated with deficiencies in self-regulation [1-3]. For example, working memory capacity (WMC [4]) and inhibition are often impaired in adolescents with Attention-Deficit/Hyperactivity Disorder (ADHD [2,5]). During adolescence, youngsters typically start experimenting with risky behaviors [6]. For example, consumption of alcohol usually

starts in early adolescence and often at a much earlier age than is legally allowed [7]. Heavy use at this age can lead to school dropout [8] and can escalate into more severe problems later on, such as substance dependence or addiction.

Heavy drinking in youth has previously been associated with suboptimal cognitive control functions (eg, [9,10]). According to Dual Process Models of Addiction (eg, [11]), addictive behaviors emerge when an individual fails to self-regulate the impulsive reactions that develop with heavy substance use. The effects of these reactions on cognitive processing are termed cognitive biases, which can be detected using various implicit

measures [11,12]. Both inhibition [13,14] and WMC [15,16] have been found to be weaker in heavy drinking youth, thus leading to an imbalanced cognitive system [17]. As such, early intervention programs aimed at training cognitive control may play an important role in keeping these mental problems at bay. WMC, or the ability to adaptively update and monitor representations in working memory [2], has been considered the most central of cognitive control functions [18]. WMC has been the target of many training studies aiming to improve WMC, with some moderate successes in children with relatively weak WMC [19], such as children with ADHD (for review, see [20]; but see [21]). Increasing WMC has also led to reduced drinking in problem drinkers with strong automatic positive associations with alcohol [22], as well as to positive changes in symptoms of anxiety, increased inhibitory control, and reduced attention to threat in adolescents [23].

Despite its efficacy in specific adolescent groups, motivation is an important moderator of cognitive training efficacy [11,24]. As cognitive training paradigms can be very long and tedious, with as many as 25 separate sessions for WMC training (eg, [25,26]), motivation to train is likely to decline during training, which may impact the training's efficacy. Incorporating game elements into the cognitive training paradigms may help adolescents to persevere, as such elements may be better at grasping and retaining adolescents' attention and increasing their motivation to complete the training [27].

There have been several attempts to gamify cognitive training paradigms. For example, Prins et al [28] developed an elaborate game world called Braingame Brian around multiple evidence-based executive function training principles. Positive training effects with this gamified training have been found in obese children [29] and children with ADHD [26]. However, Braingame Brian is primarily aimed at primary school-aged children and may be perceived as too childish by adolescents. For this reason, we developed the City Builder game [30], which is specifically aimed at training cognitive functions and retraining substance-related cognitive biases in adolescents.

## Objectives

The City Builder game was designed as a so-called game-shell [31], where the user receives points for doing well on the training task. The training task itself was only minimally adjusted from the original evidence-based training paradigm to fit the game environment. The points collected during training could be spent during periods of play time in between the training blocks [30]. Besides the game elements, an element of alcohol-related context was also added to the training task by briefly showing a picture of alcohol during the encoding phase of the task. As this picture could be more distracting to heavier drinkers, it could potentially make the training a little more challenging for this group.

This pilot study describes the results of 10 sessions of alcohol-related WMC training using the City Builder game. We compared 3 conditions (all including the alcohol-related context): the gamified WMC training using the City Builder game (henceforth referred to as the *gamified* condition); a nongamified WMC training (the *standard* condition); and a nongamified placebo training, not expected to improve WMC

(the *placebo* condition). The primary focus of the pilot study was on how the game could help to motivate adolescents to continue training over the course of 10 sessions. Adolescents in the gamified condition were expected to show a higher motivation to train, compared with adolescents in both nongamified conditions, as measured by explicit ratings and the time spent on training. In addition, the training was expected to increase WMC, relative to placebo. As a secondary outcome, we looked at potential transfer effects of WMC training to drinking behavior, where participants were expected to drink less alcohol after the training. Furthermore, as an exploratory analysis, the potential influence of the alcohol picture on performance was analyzed, and it was expected that heavier drinkers in the sample would make more errors following the alcohol picture.

Finally, a practical problem that can occur in an experimental comparison of a training task with and without game elements is that although all participants complete the same assessments after the training, only those in the gamified condition have been rewarded during training. As these participants may have been getting used to being rewarded for their effort, the lack of rewards in the posttraining assessment could negatively affect their motivation, and in effect their performance, potentially distorting the assessment of the training effect in an unwanted way [31]. Because it is difficult to prevent this influence in an experimental research design, motivation for doing the pre- and posttraining assessments was also evaluated using self-report questions.

## Methods

### Participants

Participants were 84 adolescents from a high school in the Netherlands aged between 13 and 16 years (mean age 13.7 [SD 0.7] years; 40% [34/84] boys). Participants trained during normal school hours in 14 groups of 6 students. They were randomly assigned to 1 of the 3 training conditions stratified for age, gender, and school class. Participants in each group were allocated to the same condition (as a form of clustered randomization) to prevent them from comparing the gamified and nongamified versions among each other. There were 24 students (4 groups) in the placebo condition, 30 students (5 groups) in the standard WMC training condition, and another 30 students (5 groups) in the gamified WMC training condition. The training took place in 2 cohorts: 7 groups (2 placebos, 3 standard WMC training, and 2 gamified WMC training) finished training before Christmas break; the other 7 groups started after Christmas. The second cohort filled in an additional questionnaire assessing motivation to train after each session. Due to personal reasons, 3 students (2 from the placebo and 1 from the standard WMC training condition) dropped out during the study. The study's target sample size was between 25 and 30 participants per condition, which was based on similar studies [26,27] using a gamified working memory task. The study was approved by the Ethics Committee of the University of Amsterdam (Protocol number 2012-COP-2449).

## Design and Procedure

Before the study, parental consent was obtained for each adolescent, and at baseline, adolescents were informed about the training procedure and the reward for participation, which was a maximum of 15 euros, consisting of 5 euros for doing the baseline and posttraining assessments and an additional 1 euro for each completed training session. The training itself was not presented to the participants as an alcohol intervention; rather, it was presented as a new “computer training” that was to be tested, which could help them to gain more “mental control” over their behavior, such as (excessive) alcohol use. To keep the students motivated to continue training in all conditions, it was announced that the training money was only awarded when a minimum of 8 training sessions were completed. The training was done on university laptops in groups of 6 adolescents, whereas the assessment sessions, which were the same in all 3 conditions, were done in groups of 12 students on school personal computers. After the baseline assessment, participants performed 10 daily training sessions on school days during the next 2 weeks. When a training session was missed because of an important school activity, an extra training session was planned for a total of 10 training opportunities per participant. Finally, there was a posttraining assessment session.

## Training

### *Standard Working Memory Capacity Training*

This training was based on the Chessboard task by Dövis et al [27], but with the inclusion of several alcohol pictures. The alcohol picture was intended to slightly distract participants, with an expected greater effect on participants who drink more alcohol, as their attention can be biased toward alcohol pictures [32,33], which can affect task performance on a working memory task [34]. Participants were presented with a 4×4 grid of green and blue squares (each 120×120 pixels large, presented in a chessboard pattern) that lit up in a specific sequence of 3 or more squares. The instruction was to remember this sequence, then mentally reorder the squares to reproduce first all green squares, and then all blue squares, in the order in which they appeared. To ensure reordering was necessary in each trial, each sequence showed at least one blue square before one or more green squares. During trials, the sequence length was first announced in the center of the screen for 1500 ms. Each square then lit up for 1500 ms, with a 1000 ms interval between squares, until the current number of squares was shown. A 540×540 pixel image of a beverage containing alcohol was shown for 600 ms during one of the intersquare intervals (selected randomly). Different sets of 10 unique pictures were used for this purpose during each training session. All alcohol stimuli were taken from the Amsterdam Beverage Picture Set [35]. To prevent the use of memory strategies, the mouse cursor was invisible during the trials. After each trial, there was always feedback about whether the answer was correct, followed by a self-paced button to go to the next trial. During feedback, a progress bar also indicated how far they were during the session.

When 2 consecutive trials were answered correctly, the next sequence length was increased by one square. Similarly, when 2 consecutive trials were answered incorrectly, the next sequence length became one square shorter, with a minimum of 3 squares. Each training session lasted approximately 30 min and consisted of a minimum of 40 trials, with a first 3-min break after the first block of 20 trials and a second 3-min break after the second block of 20 trials. After the second break, participants received the option to continue with another block of training trials or wait for 5 min before going back to class collectively with the other participants in the group.

### *Placebo Working Memory Capacity Training*

This version was exactly the same as the standard WMC training, except that the sequence length was always kept at 3 to prevent a training effect while presenting a visually similar experience (cf [22]). As the overall duration of the task was shorter because of keeping the sequence length at a low level, participants in the placebo condition did a minimum of 50 trials per session (25 per training block).

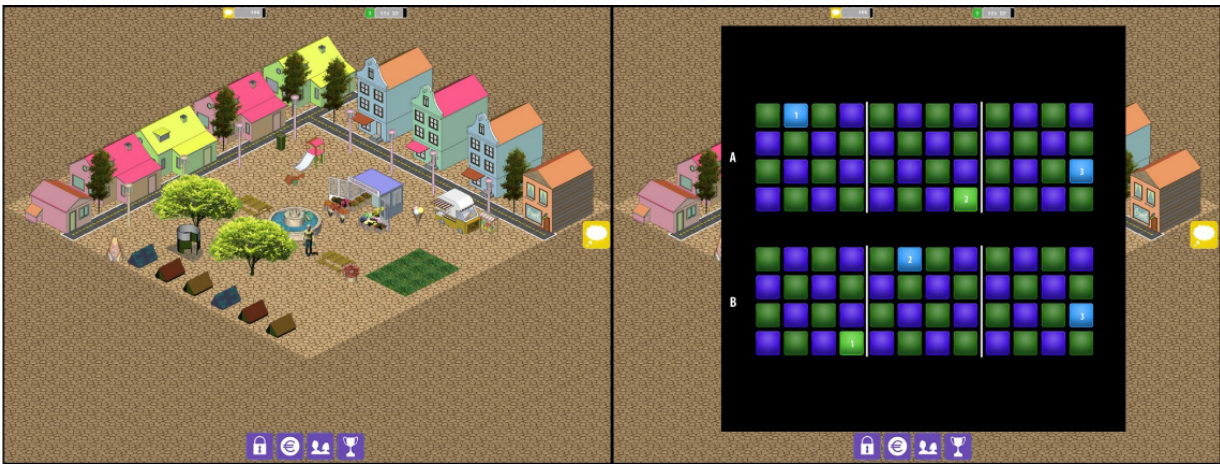
### *Gamified Working Memory Capacity Training*

This version was also similar to the standard WMC training but was embedded within a game context, the City Builder game ([30]; see Figure 1). As in the other conditions, each training session started with a block of training trials, but in the gamified WMC training condition, participants received points for correct trials. These points were saved up until the break and could then be spent as game money to buy houses, roads, trees, and other objects to build a virtual city. A social element was included in the game by letting participants view the cities built by other players, which they were also allowed to rate with a “thumbs up.” After the break (which lasted exactly 3 min), the game automatically reverted to another training block, followed by the second break. As the final training block did not include any play time, the extra collected points could only be spent during the next training session.

As shown in Table 1, the breaks between the training blocks were introduced to match the time between participants in all conditions. All conditions were given 3 optional activities during the breaks, which they could switch between however they liked: either continue training, read a book or magazine, or spend the time in silence (cf [36]), but no phones or Internet use were allowed. Only participants in the gamified WMC training condition were allowed to use this time to play the game. These alternative ways to spend the break were intended to be potentially interesting alternatives for playing the game, so that those who did chose to continue with the game indeed did so because they liked doing so, rather than being bored. Training trials done during the break did not count toward the minimum of trials during the fixed training blocks. A final block of optional bonus trials was included as an additional behavioral measure of motivation to train. The same options were provided as during the breaks, but now also those in the gamified WMC training condition were not allowed to play the game.



**Figure 1.** The City Builder game. Left pane: the game screen; Right pane: the working memory capacity (WMC) training task is presented overlaying the game screen. During instructions, the game is shown in the background (as pictured); when the trials start, the background blacks out entirely.



**Table 1.** Procedure during training sessions.

Version of working memory capacity training	Standard	Placebo	Gamified
Training block 1 (9 min)	20 trials	25 trials	20 trials
Break 1 (3 min)	Continue training, read magazine, or enjoy break in silence	Continue training, read magazine, or enjoy break in silence	Continue training, read magazine, enjoy break in silence, or <i>play the game</i> <sup>a</sup>
Training block 2 (9 min)	20 trials	25 trials	20 trials
Break 2 (3 min)	Continue training, read magazine, or enjoy break in silence	Continue training, read magazine, or enjoy break in silence	Continue training, read magazine, enjoy break in silence, or <i>play the game</i>
Optional extra training block (5 min) <sup>b</sup>	Continue training, read magazine, or enjoy break in silence	Continue training, read magazine, or enjoy break in silence	Continue training, read magazine, or enjoy break in silence

<sup>a</sup>During the first session, participants in the gamified working memory capacity training condition always started the first break with a 1-min introduction to the game.

<sup>b</sup>During the last session, the second break lasted for 8 min, and the extra training block was omitted, as there was no next session to spend the bonus points in.

Measures

Working Memory Capacity Assessment

WMC was assessed using the Self-Ordered Pointing Task (SOPT; [37]). In the SOPT, the participant is shown a set of pictures with the instruction to click on a picture they have not clicked on before. Then the pictures in the set are shuffled, and the instruction is repeated, until the number of responses equals the number of pictures presented in the set. The current version used increasingly larger sets of pictures and alternated between sets of pictures of concrete objects (eg, ball, umbrella) and sets of pictures of abstract objects (eg, lines and figures), in the following order: 4 concrete (practice), 6 concrete, 6 abstract, 8 concrete, 8 abstract, 10 concrete, 10 abstract, 12 concrete, and finally 12 abstract pictures. This was done to gradually increase the difficulty of the task to avoid a ceiling effect. The primary outcome measure of the SOPT was the total number of correct responses over all test blocks, that is, a score between 8 and 72, with a higher score indicating better WMC (for reliability and validity, see [38]).

Motivation to Train

Besides the number of bonus trials done per session (ie, during both breaks as well as in the final, optional training block) as a behavioral measure of motivation, 2 self-report questions were also added in the second cohort: “How much were you looking forward to this task?” and “How much did you like this task?,” both scored on a 10-point scale ranging from 1 (not at all) to 10 (very much). After the training, participants were asked about their previous game experience, as well as how much fun they thought the training had been, on a 5-point Likert scale from 1 (a lot of fun) to 5 (very boring); how difficult they thought the training had been, on a 5-point Likert scale from 1 (very difficult) to 5 (very easy); and how often they would continue doing the training if it would be made available at home, on a 5-point Likert scale from 1 (never) to 5 (very often).

Alcohol Use

As heavy drinking does occur at this age in the Netherlands [7], a brief personal interview version of the Alcohol Timeline Followback (TLFB) Procedure [39,40]) was used to measure alcohol consumption per day over the past 10 days. The personal interview was used to offer participants a more private and

secure environment, compared with the computer room. In addition, potential alcohol-related problems were assessed with the Alcohol Use Disorder Identification Test (AUDIT [41]), the Rutgers Alcohol Problem Index (RAPI18 [42]), and the Five-Shot Questionnaire [43]. The AUDIT includes 10 multiple-choice questions about alcohol consumption and alcohol-related problems. The overall score ranges between 0 and 40, with a score of 8 or higher indicating an increased risk of alcohol-related problems. The RAPI18 is an 18-item questionnaire for assessing problem drinking, specifically among adolescents. Each item concerns a statement about the frequency of an alcohol-related problem occurring during the past year, with scores on a 4-point Likert scale ranging from 0 (never) to 3 (more than 5 times). The Five-Shot Questionnaire contains 5 multiple-choice items about alcohol use. The maximum score is 7, with a score over 2.5 indicating alcohol misuse or alcohol dependence.

### Additional Baseline Measures

To check for baseline differences in intelligence quotient (IQ), a subselection of 30 items from Raven Standard Progressive Matrices (RPM [44]) was assessed. Baseline differences in reward sensitivity were checked using the Dickman Impulsivity Inventory [45], which contains 23 true or false questions divided over 2 subscales, and the Behavior Inhibition System/Behavior Approach System scale [46,47], which consists of 20 Likert scale items over 4 subscales. Finally, basic family structure, family drinking habits, and parental social economic status were also assessed.

### Statistical Analyses

Before running the analyses, all dependent variables were screened for univariate outliers (scores removed more than 3 SDs from the group mean), which resulted in the exclusion of 2 outliers on the AUDIT, 1 on the Five-Shots Questionnaire, 4 on the TLFB, 1 on the SOPT sum score, 2 on the RAPI18, 1 on the SOPT, 1 on the BAS Fun seeking, and 2 on the BAS Reward responsiveness subscales. Due to technical problems, the data of 4 participants at baseline, TLFB data for 3 participants, and RPM data for 1 participant were lost. All analyses were thus performed on the remaining number of participants.

The hypothesized effects of training condition over time were ascertained through the use of factorial repeated measures analyses of variance, using condition as a between-subjects factor (with 3 levels: standard, placebo, and gamified), and time as a within-subjects factor (with 2 levels: before and after the training). Motivation was compared on several measures using regular analyses of variance (or nonparametric variants thereof, in those cases where one or more statistical testing assumptions were violated), as well as a growth model analysis on the number of bonus trials done during each session. Finally, an exploratory analysis of variance was performed using the percentages on specific squares following the alcohol picture.

## Results

### Baseline and Missing Data

Due to various reasons (eg, illness), some participants missed one or more sessions but were allowed to continue training.

Five participants, however, did not complete the full assessments and were therefore excluded from the relevant prepost analyses. In total, 29 participants completed the full training in the gamified WMC training condition; 27 in the standard WMC training condition and 20 in the placebo condition. Levels of drinking were very low at baseline. The average sum score on the AUDIT was 1.2 (SD 2.3), with 52 participants having a sum score of 0, and 0.4 (SD 1.1) on the RAPI18. Therefore, it was decided to include these 2 long-term measures again after training to make sure this finding was stable. This was the case. There were no baseline differences in age, gender, IQ, impulsivity, or WMC between conditions (all  $P$  values  $>.05$ ).

### Effects of Training

There was a main effect of time on WMC as measured with the SOPT sum score,  $F_{1,72}=6.033$ ,  $P=.02$ ,  $\eta_p^2=0.077$ , but no effect of training condition,  $F_{2,72}=0.052$ ,  $P=.95$ ,  $\eta_p^2=0.001$  (see Table 2). When an inclusion threshold of participants who had completed at least 8 out of 10 training sessions (cf 20 of 25 sessions in [22]) was used as a cut off for the effects analyses, resulting in the exclusion of 2 participants in the gamified WMC training condition, 3 in the standard WMC training condition, and 2 in the placebo condition, these effects did not change. There was no training effect on alcohol consumption as measured with the TLFB over time,  $F_{1,62}=1.410$ ,  $P=.24$ ,  $\eta_p^2=0.022$ .

### Motivation

Table 3 features several measures of motivations by group. There was a slight trend that suggests more participants preferred to have the game at home compared with the nongamified versions. The standard WMC training was rated as less fun to do, Kruskal-Wallis  $H_2=10.093$ ,  $P=.006$ , compared with both the gamified (Mann-Whitney's  $U=233.0$ ,  $z=3.145$ ,  $P=.002$ ,  $r=-.413$ ) and the placebo version ( $U=410.5$ ,  $z=2.128$ ,  $P=.03$ ,  $r=.301$ ). Motivation to do the SOPT assessment increased over time in the nongamified conditions, but it decreased in the gamified WMC training condition, a difference that was significant,  $F_{2,28}=7.363$ ,  $P=.003$ ,  $\eta_p^2=0.345$ . Post hoc comparisons using the Tukey HSD test indicated that the mean score for the gamified WMC training condition ( $-0.6$  [SD 1.2]) was significantly lower than both the standard WMC training ( $1.3$  [SD 1.8]) and the placebo condition ( $1.0$  [SD 0.8]). A similar pattern of results was observed for the change in the level of fun on the SOPT, but these did not reach significance. Finally, there was a difference in the average number of training sessions completed between conditions, where adolescents in the gamified WMC training condition completed significantly albeit slightly more sessions on average than participants in the 2 nongamified conditions.

As another measure of motivation to train, we looked at the total number of bonus trials done during each session (ie, during both breaks as well as in the final, optional training block), where we numbered the sessions per participant (see Figure 2 and Table 4). For this analysis, we used a multiple-step approach. As the count variable (number of bonus trials) had a



skewed distribution, but not all sessions had many zeros, a Poisson distribution was used rather than zero inflation (cf [14]).

Robust Maximum Likelihood was used as an estimator to account for the nonnormality. The first step taken was a confirmatory factor analysis (CFA) on the total number of bonus trials during each session (cf [48]). As session 1 showed much higher numbers of bonus trials in all conditions, compared with the following sessions, the CFA did not converge when session 1 was included, and it was therefore excluded from the analysis. The resulting CFA on sessions 2 through 10 showed that all factor loadings were significant. Due to the nature of the Poisson model, using numerical integration, no standardized factor loadings are available. The second step involved looking at the overall effect of condition on the latent session factor, which was significant:  $B=-.444$ ,  $SE=0.088$ ,  $P<.001$ , indicating more bonus trials were done in the gamified WMC training condition compared with the other conditions.

In the final step, we looked at change over time using a growth model of sessions 2 through 10, again with the bonus trials count variables as latent growth indicators. Several models were

compared, first constraining groups to be equal or not (ie, assuming there were or there were no group differences), and subsequently constraining only the slopes to be equal or not (ie, assuming there were or there were no differences in the decrease of bonus trial counts), and the intercepts to be equal or not (ie, assuming there were or there were no baseline differences in bonus trial counts). The best model fit in terms of Akaike Information Criterion (AIC [49]), as well as the Bayesian Information Criterion (BIC [50]), was found for the model with free (decreasing) slopes, but with constrained (equal) intercepts for the standard and gamified WMC training conditions,  $AIC=2758$ ;  $BIC=2782$ . In this model, the placebo training's intercept is at 0.667, whereas both the standard and gamified WMC training's intercepts are at 1.219; slope coefficients are  $-2.855$  for the placebo,  $-1.782$  for the standard, and  $-0.859$  for gamified WMC training. Note that due to the nature of the count model used here, these coefficients do not represent the actual number of bonus trials but should rather be interpreted relative to each other, for example, the decrease is much steeper in the placebo condition compared with the gamified WMC training condition.

**Table 2.** Training outcomes by group.

Measure	Standard	Placebo	Gamified	Total
SOPT <sup>a</sup> sum score pretraining, mean (SD)	55.4 (4.5)	55.1 (4.8)	56.2 (4.5)	55.6 (4.6)
SOPT sum score posttraining, mean (SD)	57.4 (5.3)	57.3 (4.3)	55.9 (4.8)	56.8 (4.9)
TLFB <sup>b</sup> sum score pretraining, mean (SD)	0.3 (0.6)	0.2 (0.5)	0.1 (0.2)	0.2 (0.5)
TLFB sum score posttraining, mean (SD)	0.3 (0.7)	0.1 (0.2)	0.0 (0.2)	0.1 (0.4)

<sup>a</sup>SOPT: Self-Ordered Pointing Task.

<sup>b</sup>TLFB: Timeline Followback; shows the number of standardized drinks during the week before the assessment.

**Table 3.** Motivations by group.

Measure	Standard	Placebo	Gamified	Total	P value
<b>Questions assessing motivation</b>					
How much fun was the training? (mean [SD]) <sup>a</sup>	3.7 (0.7)	3.2 (0.9)	3.1 (0.7)	3.3 (0.8)	.006 <sup>b,c</sup>
Would you like to have the training at home? (yes; absolute [%])	2 (7)	0 (0)	5 (17)	7 (9)	.10
How often would you train at home? (mean [SD]) <sup>d</sup>	1.4 (0.7)	1.3 (0.5)	1.7 (0.8)	1.5 (0.7)	.13 <sup>b</sup>
How much were you looking forward to this task (the SOPT)? (mean [SD]) <sup>e,f</sup>	1.3 (1.8)	1.0 (0.8)	-0.6 (1.2)	0.4 (1.6)	.003 <sup>c</sup>
How much did you like this task (the SOPT)? (mean [SD]) <sup>e,f</sup>	1.1 (1.8)	0.5 (1.1)	-0.1 (1.8)	0.4 (1.7)	.21
Number of training sessions completed (mean [SD])	8.8 (1.1)	8.4 (1.1)	9.1 (0.8)	8.8 (1.0)	.04 <sup>g</sup>

<sup>a</sup>5-point Likert scale from 1 (a lot of fun) to 5 (very boring).

<sup>b</sup>Nonparametric Kruskal-Wallis test was applied due to violation of normality.

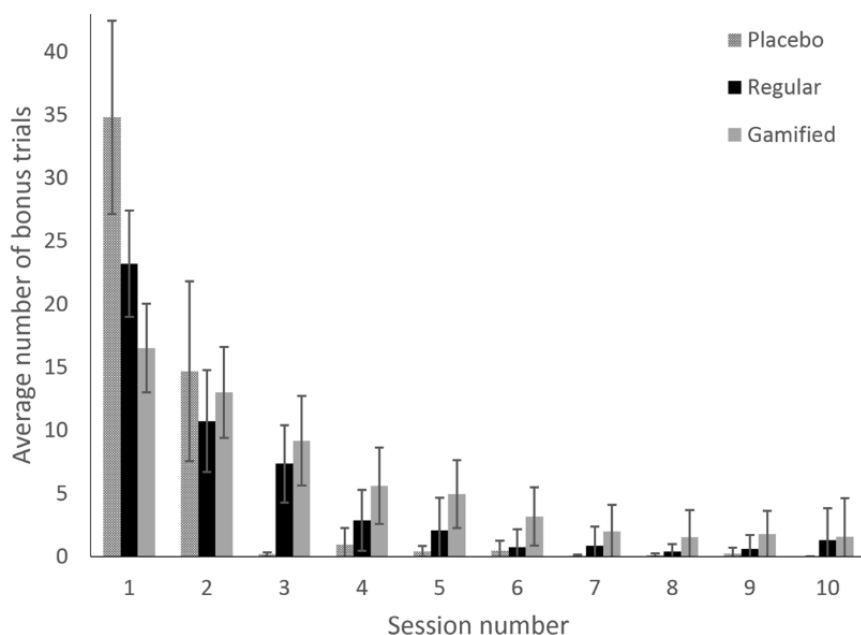
<sup>c</sup> $P<.01$ .

<sup>d</sup>5-point Likert scale from 1 (never) to 5 (very often).

<sup>e</sup>Mean (SD) of change score. Change score is defined as the difference between the pre- and posttraining assessment scores.

<sup>f</sup>10-point grade from 1 (low) to 10 (high).

<sup>g</sup> $P<.05$ .

**Figure 2.** Average number of bonus trials per session. Error bars indicate 95% CI.**Table 4.** Average number of bonus trials per session.

Session	1	2	3	4	5	6	7	8	9	10
Placebo, mean (SD)	34.8 (19.2)	14.7 (17.8)	0.2 (0.4)	1.0 (3.2)	0.4 (1.1)	0.5 (1.9)	0.1 (0.2)	0.1 (0.3)	0.2 (0.8)	0.0 (0.0)
Standard, mean (SD)	23.2 (11.8)	10.7 (11.1)	7.3 (8.4)	2.9 (6.6)	2.0 (7.0)	0.8 (3.8)	0.9 (3.9)	0.4 (1.4)	0.6 (2.5)	1.3 (3.4)
Gamified, mean (SD)	16.5 (9.8)	13.0 (10.0)	9.2 (9.9)	5.6 (8.5)	4.9 (7.5)	3.2 (6.5)	2.0 (5.8)	1.5 (5.7)	1.8 (4.7)	1.6 (4.7)

**Table 5.** Error percentages on specific squares.

Measure	Standard	Placebo	Gamified	Total	P value
<b>Including placebo condition (N=84), mean (SD)</b>					
Error percentage on squares directly following the alcohol picture	24.2 (5.8)	5.8 (3.8)	24.7 (4.8)	19.1 (9.8)	<.001 <sup>a,b</sup>
Error percentage on squares not directly following the alcohol picture	24.3 (5.9)	6.8 (4.3)	24.2 (5.2)	19.3 (9.5)	<.001 <sup>a,b</sup>
Ratio of errors directly following the alcohol picture over those that do not	1.00 (0.08)	0.85 (0.13)	1.03 (0.09)	0.97 (0.12)	<.001 <sup>a,b</sup>
<b>Without placebo condition (N=60), mean (SD)</b>					
Error percentage on squares directly following the alcohol picture	24.2 (5.8)		24.7 (4.8)	24.5 (5.2)	.33 <sup>a</sup>
Error percentage on squares not directly following the alcohol picture	24.3 (5.9)		24.2 (5.2)	24.2 (5.5)	.66 <sup>a</sup>
Ratio of errors directly following the alcohol picture over those that do not	100.3 (8.2)		103.0 (8.7)	101.6 (8.5)	.22
Average sequence length <sup>c</sup>	5.5 (0.8)		5.6 (0.7)	5.5 (0.7)	.41

<sup>a</sup>Nonparametric Kruskal-Wallis test, which was applied due to violation of normality.

<sup>b</sup> $P < .001$ .

<sup>c</sup>The average number of squares shown per trial.

To determine the influence of the alcohol picture during the encoding phase of the training trials, we looked at the percentage of errors made specifically on squares that directly followed the alcohol picture versus the error percentage on squares that did not directly follow the alcohol picture. Overall, error percentages were different between the training conditions, but this was mainly because in the placebo condition, all sequences had

exactly 3 squares, and thus fewer errors were made. When this condition was excluded, the standard and gamified WMC training conditions did not differ (see Table 5). The average sequence length also did not differ between the standard and gamified WMC training conditions (the placebo condition was not included as all sequences had exactly 3 squares). As the level of drinking was very low in this sample, no relationships

between error percentage and alcohol consumption were found (all  $P$  values  $>.05$ ).

## Discussion

### Principal Findings

In this pilot study, we investigated the beneficial effects of a serious game environment on adolescents' motivation to do cognitive training. Although no relevant differences were found in the primary outcome measure (WMC), several interesting findings were obtained regarding motivation to train. First, the self-reported motivation questions posed after the training was completed showed mixed results, with participants only having a slight preference against the standard WMC training. This may indicate that participants did not like the game more than they liked the placebo WMC training, but it can also mean that they merely lost interest over time. Other than the nongamified training versions, the gamified WMC training, being presented as a game, likely increased participants' expectations of its entertainment value. If the game then did not fully satisfy these expectations over the 10 sessions of training, this may have influenced the motivation assessment after the training. As such, it is advisable to assess motivation to train at multiple points in time to see if there might be an initial effect that fades over time. This can be achieved with a behavioral measure of motivation, such as the number of training trials done beyond the minimum amount required. This number was found to be higher in the gamified WMC training condition than in the nongamified conditions, but it also declined over time in all conditions.

Regarding the bonus trial analysis, the fact that the first session showed a much higher numbers of bonus trials in all conditions, compared with the following sessions, may actually make sense from a theoretical standpoint. Given that during the first session, all versions of the training were new to the participants, when the option to do extra trials was first presented, it may have been curiosity rather than motivation that drove participants to do some bonus trials. From the second session forward, though, this option was no longer novel, suggesting that actual motivation to train would have taken over.

It should be noted that the wish to spend the points collected through training by playing the game during the breaks may have limited the time available for doing bonus trials. This may have inadvertently led to an underestimation of the motivation to train. Relatedly, the number of bonus trials may have been skewed a little due to the fact that, on average, bonus trials in the placebo condition were shorter than those in the active training conditions. This might explain the initial peak in the placebo condition in session 1, while also underscoring the fact that the decline in sessions 2 and 3, which is attributed to motivation, is also most notable in this condition. As we unfortunately did not record the time spent on doing bonus trials or playing the game, the number of bonus trials was the only behavioral measure of motivation we were able to analyze. Future studies should therefore consider also looking at the time spent on bonus trials and playing the game as additional behavioral measures of motivation.

A theoretical explanation for the declining motivational effect found, in terms of fewer bonus trials done per session over time, could be that the points awarded during training may be acting primarily as extrinsic motivators [51]. Although the points have value in that they can almost immediately be turned into game assets, they are arguably less fun to collect on their own. This means that although playing the game in between the training blocks may tap into some intrinsic motivation for the participant, the training itself remains limited to extrinsic motivators. As extrinsic motivators are known to suffer from diminishing returns [52], it is likely that they provide less motivation to train over time, which can explain the decline in bonus trials [31]. Future research could focus on determining the specific intrinsic or extrinsic motivational value of each game element by comparing them separately. Although the design used in this pilot study is not suited for such a comparison, as each condition either included all or none of the game elements, identifying those game elements that specifically tap into participants' intrinsic motivation may help to make motivation to train last longer.

### Strengths and Limitations

In line with previous motivational results [36,53-55], the gamified WMC training version was found to motivate adolescents to train more intensively over the course of the 10 training sessions, compared with the nongamified versions. Finding ways to motivate adolescents to sustain a high training performance is very important as long as these training paradigms remain long and tedious. Interestingly, the beneficial effects found by Dövis et al [55] were the combined result of a gamified WMC training and additional systematic external reinforcement by training coaches. Although this pilot study did not use coaches, it could be argued that a combination of motivational game elements and external reinforcement might give better motivational results.

The second motivational finding concerns participants' motivation to perform well on the study's main cognitive outcome measure: the pre- and posttraining WMC assessments (SOPT). Although WMC was found to increase over time in all training conditions, which could indicate a practice effect, where participants' performance increased due to having done the task before, motivation to complete the task had increased after the training in the nongamified conditions but had decreased in the gamified WMC training condition. This finding is in line with our hypothesis that the rewarding nature of the gamified WMC training condition may negatively affect motivation to complete assessment tasks afterward. Although it is unclear if, and to what degree, this motivational effect may have influenced the assessment of the actual training gain, it does have important implications for future research aiming to validate serious games, compared with their nonrewarding, original counterparts. Incorporating the assessment task in the game and having a mini-assessment at the start of every training session (cf [56]) is one option to prevent decline in motivation for the postassessment in the gamified WMC training condition. However, this may also intensify the entire training program by prolonging its overall duration.

The results presented in this paper do have to be interpreted with some caution because of several limitations. First, no training effects were found on drinking behavior; however, alcohol use was very low at baseline in this sample. As it obviously could not get much lower through training, no inferences on the effects of (gamified) cognitive training on drinking behavior should be made based on this study. It would be interesting for future intervention research to include adolescents with cognitive deficits and at risk for problematic alcohol use [57]. Second, when comparing the active training conditions, there were no discernable effects of the alcohol pictures presented during training trials on the percentage of errors made during these trials, nor did they affect the average sequence length. When the active training conditions were compared with the placebo condition, the latter showed a notably lower percentage of errors on squares directly following the alcohol picture. This could be due to the easiness of trials in the placebo condition, so that presentation of a distractor resulted in a more optimal level of arousal, but further research is necessary to disentangle this effect. Although the alcohol pictures may have inadvertently introduced a priming effect, which was not assessed separately, they were presented in the same manner in all conditions, and no effects on drinking were found. Nevertheless, future studies that incorporate alcohol pictures in their WMC training should consider assessing, for example, attentional bias toward alcohol before and after exposure, especially if a future training study is done in heavier drinkers. Third, despite the fact that we did find an increase in WMC over time, this did not go beyond the level found in the placebo group. Several studies report optimal cognitive and behavioral training results (eg, reduced alcohol intake [22]) with around 15 to 25 sessions of training [20,58], rather than the 10 sessions presented here (but see the study by de Voogd et al [59], who found significant training results using an emotional WMC training over 8 sessions). The fact that the game's benefit

to participants' motivation to train had already faded over 10 sessions underscores the need for a solution for the motivational aspect of the training. Future studies are thus encouraged to design motivating game elements aimed at adolescents that keep the training fun for at least that many sessions. Finally, although each group of 6 participants was randomized into the same condition, some school classes still included groups of students allocated to different conditions. Therefore, it cannot be ruled out that conversations between students about the differences between the conditions may have had an influence on motivation. To prevent this, future studies should include a larger sample which allows for cluster randomization using full classes or, preferably, full schools.

## Conclusions

Despite these limitations, to the best of our knowledge, this study is the first to demonstrate that WMC training in adolescents can benefit from the use of game elements by increasing motivation to train. It follows that the challenge for future research will be in trying to prolong this effect, for example, by making bigger, more immersive games that last longer (although this is quite a challenge, even in commercial gaming). By closely monitoring the levels of motivation throughout the study, as well as by managing participants' expectations about the entertainment value of the training, which may still be an important factor in determining the training outcome, more insight may be acquired into the specific effectiveness of the use of game elements in cognitive training. Finally, future research could also apply gamified WMC training in specific at-risk groups, such as adolescents who have specific difficulties with traditional training approaches due to attention- or motivation-related problems. Moderation analyses can then be used to reveal individual differences in the effectiveness of the gamified training, identifying those who could benefit the most from these motivational features.

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## Conflicts of Interest

None declared.

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**Editorial notice:** This randomized study was not registered, which is explained by the authors as being due to the data coming from an older study that was not registered. The authors reiterate that this study should be considered a pilot study. The editor granted an exception of ICMJE rules for prospective registration of randomized trials because the risk of bias appears low and the study was considered formative. However, readers are advised to carefully assess the validity of any potential explicit or implicit claims related to primary outcomes or effectiveness.

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## Abbreviations

**ADHD:** attention-deficit/hyperactivity disorder  
**AIC:** Akaike information criterion  
**AUDIT:** Alcohol Use Disorder Identification Test  
**BIC:** Bayesian information criterion  
**CFA:** confirmatory factor analysis  
**IQ:** intelligence quotient  
**RAPI18:** Rutgers alcohol problem index  
**RPM:** Raven standard progressive matrices  
**SOPT:** self-ordered pointing task  
**TLFB:** Alcohol Timeline Followback  
**WMC:** working memory capacity

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Original Paper

# A Mobile Game to Support Smoking Cessation: Prototype Assessment

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## Abstract

**Background:** Cigarette smoking results in an estimated seven million deaths annually. Almost half of all smokers attempt to quit each year, yet only approximately 6% are successful. Although there are multiple effective interventions that can increase these odds, substantial room remains for improvement. One effective approach to helping smokers quit is contingency management, where quitting is incentivized with the delivery of monetary rewards in exchange for objective evidence (eg, exhaled carbon monoxide levels) of abstinence.

**Objective:** We assessed the feasibility and promise of *Inspired*, a contingency management mobile app for smoking cessation that uses game-based rewards to incentivize abstinence from smoking instead of the monetary (or material) rewards typically used. We sought participant feedback and limited objective data on: the features and design of *Inspired*, interest in using *Inspired* when it becomes available, the likelihood of *Inspired* being an effective cessation aid, and the rank order preference of *Inspired* relative to other familiar smoking cessation aids.

**Methods:** Twenty-eight treatment-seeking smokers participated in this study. Participants attended a single one-hour session in which they received an overview of the goals of the *Inspired* mobile game, practiced submitting breath carbon monoxide (CO) samples, and played representative levels of the game. Participants were then told that they could play an extra level, or they could stop, complete an outcome survey, receive payment, and be dismissed. A sign-up sheet requesting personal contact information was available for those who wished to be notified when the full version of *Inspired* becomes available.

**Results:** Using binary criteria for endorsement, participants indicated that, assuming it was currently available and fully developed, they would be more likely to use *Inspired* than: any other smoking cessation aid (21/28, 75%), the nicotine patch (23/28, 82%), a drug designed to reduce smoking cravings (23/28, 82%), or a program involving attendance in training sessions or support group meetings (27/28, 96%). In the questionnaire, participants indicated that both the *Inspired* program (26/28, 93%) and the *Inspired* game would be “Fun” (28/28, 100%), and 71% (20/28) reported that the program would help them personally quit smoking. Fifty-eight percent of participants (15/26) chose to continue playing the game rather than immediately collecting payment for participation and leaving. Eighty-two percent of participants (23/28) signed up to be notified when the full version of *Inspired* becomes available.

**Conclusions:** This was the first study to evaluate a game-based contingency management app that uses game-based virtual goods as rewards for smoking abstinence. The outcomes suggest that the completed app has potential to be an effective smoking cessation aid that would be widely adopted by smokers wishing to quit.

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## KEYWORDS

smoking; smoking cessation; contingency management; mobile apps; virtual rewards; health games; video games; digital games; carbon monoxide; incentives

## Introduction

Worldwide, cigarette-smoking-related death and illness are leading public health concerns, resulting in an estimated seven million deaths each year [1]. There are almost one billion smokers worldwide [1]. Thus, smoking cessation is a critical, worldwide public health concern [2].

Many efficacious smoking cessation interventions have been developed, yet ample room remains for improvement. Each year, one-third to one-half of all smokers attempt to quit at least once [3], but the annual incidence of successful quitting is less than 5% [4]. Media campaigns and cessation programs can increase quit attempts and successful cessation rates, respectively, by a margin of nearly 50% [3,5]. Smoking cessation rates that are better than those obtained with a placebo are achieved with: physician advice; counseling by health professionals; a variety of cognitive-behavioral, social-influence, and motivation-enhancement cessation programs; and drug treatments, including nicotine replacement therapies (gum, patch, spray, lozenge, and inhaler), selected antidepressant therapies (eg, bupropion), and nicotinic receptor agonist therapy (varenicline) [5,6]. Nevertheless, nearly 80% of smokers who attempt to quit do so without the assistance of any of these approaches [7]. Half or more consider counseling and cessation programs ineffective, and over a third consider pharmacotherapy ineffective [8]. Most young smokers report they would never use any of these methods, other than the nicotine patch (which only 50% would use) [9]. Thus, three major weaknesses of current approaches to smoking cessation are: underutilization, lack of appeal to smokers who wish to quit, and in general, modest efficacy in supporting smoking cessation. Clearly, more appealing and more efficacious smoking cessation interventions are needed.

Contingency management (CM) is one of the most efficacious aids for initiating smoking abstinence [10-12]. Contingency management for smoking cessation consists of delivering rewards (typically financial) contingent on objective evidence of smoking abstinence (eg, low levels of the combustion product carbon monoxide (CO) in the exhaled breath). Unfortunately, the effectiveness of CM on a population level has been limited by several constraints leading to low adoption rates and shorter than optimal treatment durations. These factors include the cost of providing the cash or cash-equivalent rewards [13-16], the distances that must be traveled, and the time required for participation in supervised monitoring procedures at a clinic [13,15]. Monetary rewards for smoking cessation can range from \$100-\$500 per person for approximately two 12-week interventions [11,17,18]. The cost of these payments limits the feasibility of widespread CM adoption. Furthermore, the ongoing nature of these costs limits the acceptability of longer-term treatment or booster sessions that could otherwise extend program effects (by reducing relapse).

CM procedures require biochemical verification of abstinence because participants are much more likely to falsify self-reports when rewards are delivered contingent on abstinence [19]. Carbon monoxide (CO) is one method to biochemically verify abstinence; however, the half-life of CO is short (approximately 3-6 hours), requiring at least twice-daily check-ins to verify abstinence [20]. To address this barrier, Dallery and colleagues developed an efficacious CM intervention that is delivered over the internet [11,17,21,22], in which participants are provided with a breath CO monitor, and remotely record and submit video clips of themselves providing their breath CO samples. More recently, *mobile* CM for smoking cessation (where participants use the camera on their smartphone to record and submit the video clips) has been shown to be feasible, acceptable, and efficacious in supporting smoking abstinence [23-25]. However, even these internet and mobile CM interventions rely on monetary incentives to support abstinence; thus, cost remains a barrier to widespread dissemination.

To directly address the remaining barriers for widely disseminating CM (ie, cost and sustainability), we proposed to develop a mobile game-based CM intervention for smoking cessation. As with existing mobile CM for smoking cessation, participants would be provided with a breath CO monitor and required to remotely record and submit video clips of themselves providing their breath CO samples twice daily. In our proposed mobile app, the *monetary rewards* typically used to incentivize bio-verified abstinence will be replaced with in-game virtual-good rewards that can immediately be used to help players meet game objectives. Virtual goods can be provided by software at essentially no cost, yet they can have significant economic and monetary value (as evidenced by the multi-billion-dollar market for game-based virtual items) [26,27]. This suggests that rewards in the form of in-game content may readily substitute for monetary rewards in a CM procedure, drastically reducing cost while maintaining efficacy. The game will have the benefit of maximizing reward potency by minimizing delays to the receipt of rewards for abstinence once they are earned, as participants can immediately “consume” the rewards in the game. The proposed game design operationally encourages social support for smoking abstinence by imposing group contingencies [28], such as assembling players into teams and providing a reward that is only obtainable if all, or a majority of members reach a specified smoking cessation milestone (eg, no smoking for 24 hours). Operationally this design leverages self-interest (in obtaining access to the team reward) to incentivize social support (through interteam messaging) for others’ smoking cessation. The app will also enable standard, nonincentivized social support (eg, “click here to send congratulations to player C for <meeting a cessation milestone>”).

We previously published the results of an online survey of smokers to assess the social validity of a mobile game-based CM intervention for smoking cessation which uses virtual goods, instead of money, as rewards [29]. From a sample of 235



smokers recruited through Craigslist (ranging in age from 18-64 years), 75% reported playing video games. Among most smokers, 78% reported playing social games (ie, played casual games online). This rate is slightly higher than the population at large. Approximately 73% of all smokers and 70% of all video game players reported that contingent access to virtual rewards in the place of money would motivate smokers to abstain. Additionally, 75% of those surveyed would recommend or use a treatment such as this if they knew someone who wanted to quit, or if they were trying to quit themselves [29].

With the support of these promising outcomes, we developed and evaluated a prototype of *Inspired* (working title), a mobile game-based CM intervention to promote smoking cessation. The goal of the current project is to assess the feasibility and promise of *Inspired* by having treatment-seeking smokers play several levels of a prototype of the game and then ask them for qualitative feedback through a survey. We also indirectly observed feasibility and promise by recording users' decisions to play an optional, extra level of the prototype.

## Methods

### Participants

Participants were recruited online through Craigslist, a free classified advertisement service, and Facebook, a social networking website. One hundred and eight individuals responded to our advertisements, reporting that they were smokers and indicating when they would be available to come in for a one-hour prototype testing session. All participants met the prescreening qualification criteria; therefore, no one who expressed an interest was excluded for any reason other than

failure to respond to emails (N=28; see Table 1 for participant characteristics).

The advertisement specified that Rowan University researchers were seeking cigarette smokers to test a prototype of a game to help people quit smoking, and that they would be compensated \$40 for their participation. Participants were eligible if they reported smoking cigarettes, expressed a desire to quit smoking, and were available during the testing session times. All study procedures were approved by the Rowan University Institutional Review Board. All participants provided informed consent before beginning the session.

### Materials and Procedure

#### Prototype/Demo

Because this was a prospective assessment of a planned intervention, a complete product was not yet available for evaluation in this study. Instead, led by one of the project investigators, subjects participated in a guided "walk-thru" of the proposed intervention in which they had hands-on experience utilizing the key components of the intervention that had been developed to date ("demo"), and were presented with mock-ups of planned features and when and where they would otherwise appear in the normal sequence of events in a fully developed version of the product.

Specifically, participants experienced recording and submitting breath CO readings, using a piCO+ breath carbon monoxide monitor (Bedfont, United Kingdom). In addition to submitting an initial breath CO sample, participants were also asked to imagine scenarios in which they had passed or failed various breath tests for a period and were told what rewards they would or would not have received given each scenario.

**Table 1.** Participant demographics (N=28).

Variable	Value
<b>Gender, n (%)</b>	
Female	10 (36)
<b>Race, n (%)</b>	
White	10 (36)
Black	11 (39)
Asian	1 (4)
Unknown	6 (21)
<b>Ethnicity, n (%)</b>	
Hispanic	5 (18)
Not Hispanic	19 (68)
Unknown	4 (14)
<b>Cigarettes per day, n (%)</b>	
10 or less	16 (57)
11-20	10 (36)
21-30	2 (7)
<b>Fagerstrom Test for Nicotine Dependence, mean (SD)</b>	3.39 (2.6)

The demo version of the game that participants played illustrated the “core game experience.” The abstract objective of the game was “growth.” The core game experience was set in a lush vegetative environment, and the activity involved holding the tablet with both hands in landscape view and swiping different colored pollen-gems from a rotating queue center-screen into specific locations on lotus flowers to the left or right of the screen (see Figure 1). The challenge in this activity was to match color patterns under the pressure of time where the lotus flowers would eventually expire. The colored pollen-gems would also only remain in the queue for a limited time before being replaced. Better performance led to more lotus flowers being available within a level. At the end of the level, participants could see a hypothetical number of resources earned for completing that level (see Figure 2), which were awarded for completing sets, according to the difficulty of making the set (the least to most points were awarded as follows: no pattern < all same color < 4/4 matched the color template on the lotus flower). The levels became increasingly difficult because of the speed of the falling pollen and the difficulty with making four

out of four matching sets. Each level was designed for casual gameplay, lasting approximately five minutes.

Features that were mocked-up or only verbally described included: push-notifications on the platform device (eg, “It’s time to take a breath test”); player-to-player messaging; gifting and social support for smoking cessation (players could “send” gifts on the gift screen, but receipt of the gifts by another player was not implemented, Figures 3 and 4); group contingencies; specific rewards for not-smoking (eg, a side-cache of various pollen-gems that persisted until used, or resources to build structures); and a requirement to submit a breath sample (pass or fail) to unlock access to the next game level. Players were also shown that there would be growth of structures displayed on the home page as they progressed through the game over time (in step with ever increasing abstinence through the course of the intervention; Figure 5 versus Figure 6), but they were instructed that in the full version of the game the structures would produce different virtual resources that the player could then utilize in core game play, to advance their progress in the game, to make and exchange gifts with other players, and more.

**Figure 1.** Screenshot of core game activity.



**Figure 2.** Screenshot of virtual rewards.





Figure 3. Screenshot of receiving a social reward.



Figure 4. Screenshot showing how to give a social reward.

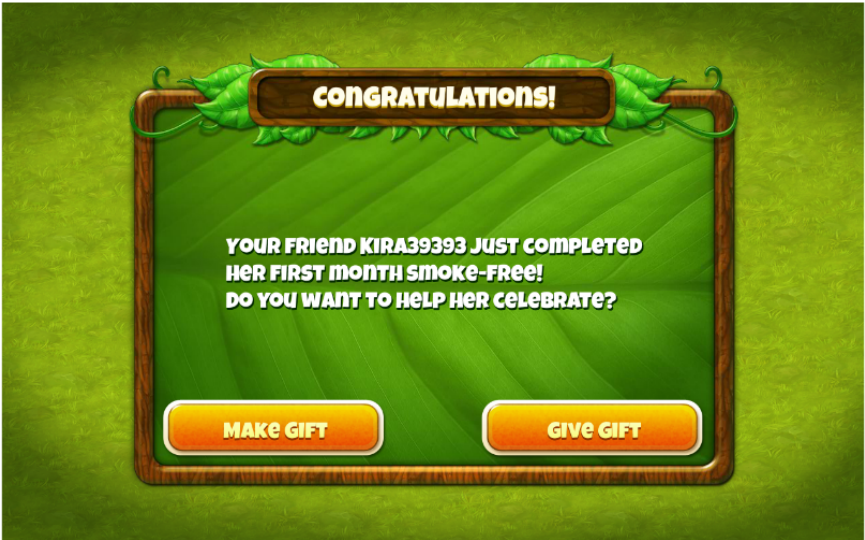
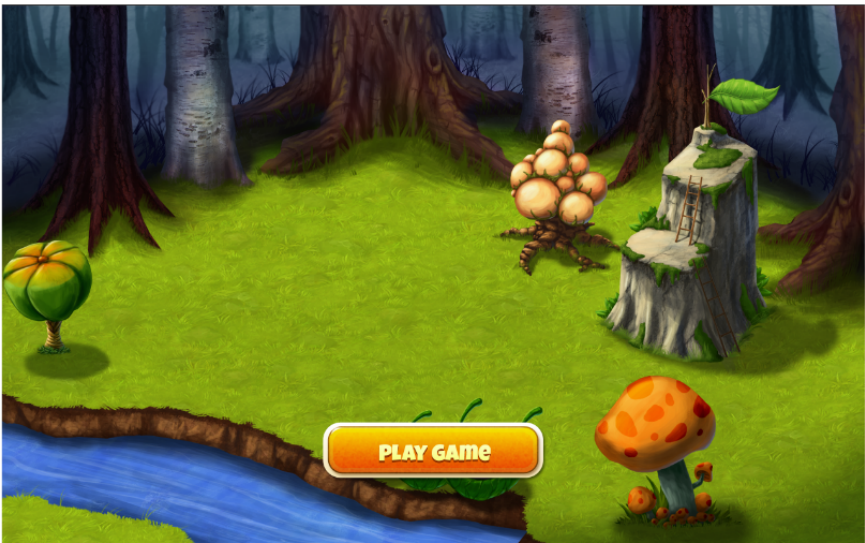


Figure 5. Screenshot of home screen early in game.



**Figure 6.** Screenshot of home screen later in game.

### Study Participation Sessions

Seven groups ( $n=3-7$  participants per group) of treatment-seeking smokers participated in the prototype evaluation sessions. Each group participated in one session, lasting approximately one hour. Sessions began with the consent process. Participants were then told how smoking releases carbon monoxide (CO) into the lungs as a by-product of combustion, and how our intervention could reliably detect if they had been smoking by measuring CO in the exhaled breath. A brief presentation described how the app would be designed to integrate breath monitoring with gameplay and in-game rewards to function as a smoking cessation aid. Each participant was loaned an Android tablet (Nexus 7 2013; Google, Asus) and a piCO+ CO meter (Bedfont; Kent, United Kingdom) and were asked to submit a video sample of their CO using the camera on the tablet. The video samples showed them exhaling into the CO meter and showing their CO value to the camera. All prototype game evaluation sessions were video recorded using a Samsung HMX-F90 camcorder.

One of the authors and game developers (NF) provided an overview of the game objectives to players, after which they were asked to begin playing the game on the Android tablet. Participants could ask questions about the game at any time. When subjects completed all the levels scheduled for use in the demonstration, they were told that there was one extra level that they had the option to play. They could either end the game at that point and finish the last few steps of the study (ie, complete an exit survey and receive payment), or they could stay a few minutes longer and play one extra level before completing the final steps. It was made clear that the choice was entirely theirs and that there would be no penalty for skipping the extra level.

At the end of the prototype evaluation session, participants completed a brief prototype evaluation survey, which consisted of four parts. The first part asked participants to classify how well they agreed with each item using a 100-mm visual analog scale (VAS; anchors, 0 mm= "Definitely Not," 50 mm="Maybe," and 100 mm="Yes, Absolutely"). The second part consisted of multiple-choice and free-response questions

(eg, how much they would be willing to pay to use the program, what did they like most and least about the game, and more). The third part of the survey consisted of multiple-choice demographic questions to collect information about race, ethnicity, and gender. The fourth and final part of the survey was comprised of the six-item Fagerstrom Test for Nicotine Dependence [30].

Before leaving, participants were told that a sign-up sheet was available on which they could provide their contact information if they were interested in being contacted when the full version of the game was released.

### Data Analysis

The median and interquartile range (0-100 mm) for each item on the outcome evaluation were calculated. Additionally, the percentage of participants who "endorsed" each statement was defined in the following two ways: (1) ratings of 51 or higher on the VAS translate as an endorsement on a binary scale (eg, anchors "Disagree, Agree"), whereas (2) ratings of 67 or higher translate as an endorsement on a three-choice scale (eg, using the anchors "Definitely Not," "Maybe," and "Yes, Absolutely").

## Results

Twenty-eight individuals participated in the prototype evaluation study (see Table 1 for demographic information). To analyze the VAS scores, prototype evaluations and their median (interquartile range, IQR) scores are presented in Table 2.

When an endorsement was defined by a ranking of 51 or higher (binary), at least 71% of participants endorsed statements that they would use *Inspired* (Q1), recommend *Inspired* to a friend (Q2), expect *Inspired* would help themselves (Q3) and others (Q4) quit smoking, consider both the game (Q6) and the intervention as a whole (Q5) to be "fun," and that they would be more likely to use *Inspired* than any other smoking cessation aid they were familiar with (Q10a-e), including the nicotine patch (Q10b, range 71%-100% ,  $n=20-28$ , depending on the item; see Table 2).

**Table 2.** Prototype evaluation median (interquartile range, IQR) of visual analog scale (VAS) ratings and percent of endorsements at rankings of  $\geq 51$  (binary) and  $\geq 67$  (trinary; all % out of 28 total participants).

Item #	Median (IQR) VAS	Endorsed, % ( $\geq 51$ )	Endorsed, % ( $\geq 67$ )	Item
Q1	84 (67-98)	86	75	Would you use the proposed full version of <i>Inspired</i> to help you quit smoking and stay smoke-free?
Q2	95 (79-99)	93	89	Would you recommend <i>Inspired</i> to a friend that wants to quit smoking?
Q3	63 (50-94)	71	46	Do you think using the <i>Inspired</i> program would help you to quit smoking?
Q4	93 (69-98)	93	79	Do you think the <i>Inspired</i> program could help some smokers quit smoking?
Q5	86 (65-98)	93	71	Do you think using the <i>Inspired</i> program as a whole (including breath monitoring, playing the game, and giving and receiving rewards for not smoking) will be FUN?
Q6	86 (72-98)	100	79	Do you think the <i>Inspired</i> game will be FUN to play?
Q7	62 (51-68)	79	29	In terms of FUN, where do you think you would rank the <i>Inspired</i> game compared to all other games you have ever played on a smart-phone (including games you played only once)?
Q8	70 (51-98)	75	50	Do you think incorporating information about the health benefits of not smoking directly into the game would make the <i>Inspired</i> program more effective in helping people quit smoking?
Q9	76 (69-99)	100	79	Do you think incorporating tips about how to quit smoking such as ways to deal with cravings directly into the game would make the <i>Inspired</i> program more effective in helping people quit smoking?
<b>Q10</b>				If the full version of <i>Inspired</i> were currently available, and you were selecting a smoking cessation aid to use in your next attempt to quit smoking, do you think you would be more likely to use <i>Inspired</i> than...
Q10a	72 (51-97)	75	54	...any other smoking aid?
Q10b	92 (59-98)	82	71	...the nicotine patch?
Q10c	98 (59-100)	82	68	...a drug designed to help reduce your cravings?
Q10d	92 (74-99)	96	86	...a program that involves you attending multiple training sessions or support group meetings?
Q10e	87 (59-100)	93	68	...hypnosis?

The items with the lowest percentages of endorsement were Q3 (would help me), Q8 (add health benefit tips), and 10a (1st choice, 21/28, at least 75%), and the highest percentages of endorsement were Q6 (fun), and Q9 (add tips about cravings: 28/28, 100%). Alternatively, if endorsement was defined as a ranking of 67 or higher (trinary), at least 29% of participants (8/28) endorsed every item, at least 50% (14/28) endorsed all but two items (Q3 and Q7), and at least 75% (21/28) endorsed all but six items (Q3, Q7, Q8, Q10a, Q10c, and Q10e), with a range of at least 29%-89% (n=8-25) across all the items. The item that received the lowest percentage of endorsements was Q7 (fun relative to other games: 8/28, 29%), whereas the item that received the highest percentage of endorsements was Q2 (would recommend to a friend: 25/28, 89%). Additionally, when asked a multiple-choice question whether the game was fun, 63% (17/27) said "Yes," 22% (6/27) said "Maybe, it has the potential to be fun," and 15% (4/27) said, "No." When asked the question, "If the *Inspired* program had been demonstrated to be just as effective as other smoking cessation aids (such as

the nicotine patch), and included ongoing access to the game, the monitoring program, and a CO monitor that was yours to keep, how much would you be willing to pay for the program?", the mean (SD) responses were \$14.40 per month (SD \$16.20) or \$133 for a one-time purchase (SD \$186).

In the free-response portion of the survey, when participants were asked what they liked best about the *Inspired* game, the most frequent response was that they liked the game itself, either because it was fun, creative, challenging, or because they liked the puzzle style of the game (12/28, 43%). Participants also reported that they liked the rewards delivered for abstinence (8/28, 29%), the community and social support aspects of the game (7/28, 24%), the simple instructions (5/28, 19%), the graphics (4/28, 14%), and the ability of the game to serve as a distraction from smoking (4/28, 14%). A couple of participants also mentioned that they liked the CO monitor (3/28, 10%). When asked what they liked least, the most frequent response was that they thought the game lacked variety (8/28, 29%). Participants also noted that glitches with the game needed to



be resolved (eg, swiping gems to the correct location, screen loading, and more; 4/28, 14%), the graphics could be improved (4/28, 14%), and that the game was too easy (3/28, 10%). Other comments included: the CO meter was too bulky, there were too many screens, the game was too challenging, they did not like the idea of social support, and that the game felt disconnected from the rewards. Two participants did not indicate any weaknesses with the proposed intervention (2/28, 7%). Participants were also asked to give suggestions about how to move forward with the game, and the only response that appeared more than once was to improve variety in the game (9/28, 33%). Other suggestions were to provide real rewards for abstinence, resolve glitches, improve graphics, and to explore having insurance companies cover the cost of the game.

Fifty-eight percent of participants (15/26) given the option to play an extra level of the game chose to do so, and 86% (23/28) signed up to be notified when the full version of the game was released.

## Discussion

This was the first evaluation of a mobile game-based CM intervention for smoking cessation. The prototype of *Inspired* was endorsed on multiple dimensions by a group of treatment-seeking smokers. Most participants reported that they felt the game would help them, or a friend, quit smoking. For *Inspired* to be effective at motivating smokers to quit using game-based rewards as incentives for abstinence, it is critically important that the game be fun. If the game is not fun, the virtual rewards will not be effective at reinforcing abstinence. In the current study, the extent to which the prototype of *Inspired* was fun was evaluated in multiple ways. To begin, VAS responses in the prototype evaluation survey (see Table 2), addressed whether participants thought the *Inspired* intervention program was fun (Q5), and 71%-93% (n=20-26) of participants agreed, depending on how an "endorsement" was defined. Additionally, 82% (23/28) of participants reported that the game was either already fun or had the potential to become fun with further development. Finally, probably one of the strongest indicators that the game has potential to be both fun and effective at supporting smoking cessation was the behavior of participants when they were given the option to play an extra level. More than half of participants (16/28, 58%) decided to play the extra, optional level, which meant they may have delayed smoking their next cigarette (following about one hour of abstinence; ie, the duration of the study), as well as getting paid, by at least five additional minutes. The goal of the game is to decrease smoking, and the fact that the prototype for *Inspired* may have been capable of displacing smoking for even a brief period is encouraging. Between 57%-76% of participants (n=16-21) said they were more likely to use *Inspired* than any other smoking cessation aid, including evidence-based pharmacological interventions such as varenicline and the nicotine patch, which are endorsed in the Clinical Practice Guidelines for smoking cessation [6]. This finding supports previous research suggesting that the use of pharmacological or other evidence-based interventions may be not be preferred among individuals attempting to quit [8,9]. It should also be noted that mobile game-based smoking cessation is not incompatible with these

other interventions but could instead serve as a fun, alternative, and yet evidence-based complement to these existing interventions.

Item Q7 on the prototype evaluation survey was included to help inform the game design team of how they were doing, at this early stage of development. Participants were asked to rank the intervention game relative to every other game they had ever played on their smartphone. Because participants were asked to compare this prototype of the game, which was less than 10% developed at the time of testing, to existing and fully developed mobile games, a median VAS of 64 was a promising outcome. Furthermore, the question asking how much participants would be willing to pay for the intervention suggests that there may be commercial viability of the proposed game, with answers ranging from \$1.99-\$60 per month, or \$9.99-\$700 as a one-time fee. Finally, 85% (23/27) of study participants signed up to be notified when *Inspired* becomes available so they can use it if they have not yet successfully quit smoking by that time, further supporting the potential commercial viability of the game.

Participants provided useful feedback for moving forward with game development, probably the most consistent of which involved adding variation to the game to keep it interesting and engaging. Overall, feedback about the type of game, the game graphics, as well as the social elements and CO monitoring in the game, were viewed favorably. Smaller, portable versions of the CO monitor have come to market since this prototype evaluation was conducted, thereby addressing concerns about the meter being bulky (eg, CO by Bedfont).

It should be noted that *Inspired* was designed to address smoking cessation specifically; therefore, multiple game design decisions were made to address the unique needs of individuals trying to quit. First, the core game mechanic, which required players to hold the device with both hands in landscape view and swipe pollen-gems into locations on various lotus flowers (see Figure 1), was chosen to make it difficult to simultaneously smoke while playing the game. Second, each level of the game was designed for casual gameplay, lasting approximately five-minutes, to reflect how long it might normally take to smoke a cigarette [31]. Third, visual elements of the game motif were associated with wellbeing and growth. The design intentionally avoided anything that might serve as a cue for smoking (eg, smoke, certain words, and more). This was done to avoid having the game elicit cue-induced cravings and subsequent smoking, and to enhance the ability of the game to displace smoking. Although not asked to comment on this directly, participants were asked to indirectly address this decision with Q8 and Q9 on the survey (see Table 2), where they reported the mobile game would be stronger if it incorporated messages about the health benefits of smoking cessation and tips about avoiding cravings. High endorsements on these two items suggested that future iterations of the game should explore incorporating this information in to the game, but in a way that does not also elicit cravings or trigger smoking.

The current study has a few limitations worth noting. First, because of the small sample size it was not possible to determine whether there were differences in endorsements, or other

measures, between high and low nicotine dependent participants. Some items seemed to suggest differences, but it was not possible to evaluate the potential differences using inferential statistics. Second, information about the participants' individual histories with playing games, particularly mobile games, was not collected. Anecdotally, it was made clear that there was a range of past experiences. However, because the game is being designed as a smoking cessation aid, a level of heterogeneity of past experiences with video games is expected among the target population of treatment-seeking smokers as well. A third limitation is the possibility that participants rated the game favorably to avoid offending the experimenters and game designers (ie, demand characteristics). To mitigate this concern, we made it clear to participants at the beginning of the group sessions that they were being asked to give an honest evaluation of a very early version of the game, and that their feedback could help shape the future development of the game. Although it is impossible to rule out potential bias, participants felt comfortable giving the game a low rank-order relative to other,

commercially available games (Q7 received the lowest scores), as well as other available smoking cessation aids. In the free response section participants provided useful feedback for improving the program. Finally, the fact that over half of the participants voluntarily played an extra, unrequired level of the game alleviates some concerns about bias; however, it cannot be ruled out.

Although there are other digital games that have been evaluated for smoking cessation, none are based on the empirically supported procedures and theoretical foundations of contingency management and behavior analysis [32-34]. This study is the first to show that a mobile game-based CM intervention has potential to be both helpful and fun to smokers who wish to quit. The prototype evaluation suggests that the proposed game would not only reduce the cost of delivering CM for smoking cessation and enable extended program reach and duration, it might also be preferred over currently extant smoking cessation aids and interventions.

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## Conflicts of Interest

BRR does not have any conflicts of interest. DR, DRS, and NF are in conflict because they have the potential to benefit from sales of the final *Inspired* game.

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## Abbreviations

**CM:** contingency management

**CO:** carbon monoxide

**IQR:** interquartile range

**VAS:** visual analog scale

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Original Paper

# Physical Wellness Among Gaming Adults: Cross-Sectional Study

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## Abstract

**Background:** Video and hobby gaming are immensely popular among adults; however, associations between gaming and health have primarily been investigated in children and adolescents. Furthermore, most research has focused on electronic gaming, despite traditional hobby gaming gaining prominence.

**Objective:** To determine whether the number of platforms used, platform preference, and gaming time are associated with obesity, physical activity, sedentary behavior, and cardiovascular risk factors in an adult gaming population.

**Methods:** We conducted a cross-sectional analysis using data obtained from 292 participants who attended a large Midwestern gaming convention. We collected data using a computer-based questionnaire that comprised questions on gaming behavior, demographics, physical activity (using the International Physical Activity Questionnaire), and health characteristics. In addition, we used multivariable-adjusted linear and logistic regression to model health outcomes as a function of the number of platforms used, platform preference, and weekday and weekend gaming time quartile.

**Results:** After adjusting for covariates, we observed a significant linear trend for increasing odds of being obese and higher weekend sitting time by the number of platforms used ( $P=.03$  for both). The platform preference and weekend gaming time quartile exhibited significant associations with odds of meeting physical activity recommendations ( $P=.047$  and  $P=.03$ , respectively). In addition, we observed higher odds of being obese among those reporting that they sat most or all of the time while gaming [odds ratio (OR) 2.69 (95% CI 1.14-6.31) and OR 2.71 (95% CI 1.06-6.93), respectively].

**Conclusions:** In adult gamers, the number of platforms used, which platforms they prefer to play on, and the amount of time spent gaming on weekends could have significant implications for their odds of being obese and meeting physical activity recommendations.

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**KEYWORDS**

video games; electronic gaming; traditional gaming; obesity; physical activity; sedentary behavior

## Introduction

Although electronic gaming is a popular leisure activity among young adults, little is known about the impact of gaming participation on health in this age group [1]. Most research investigating the relationship between gaming and healthy lifestyle behaviors or health outcomes has focused on children.

Prior studies have established an association between video game use and obesity in children, independent of the time spent watching television and physical activity [2,3]. Additionally, health-oriented gaming interventions have been primarily conducted in children [4,5]. Although research on gaming has focused on children, a systematic review of health gaming research by Kharrazi et al [6] reported that 65 of 108 studies



enrolled participants no older than 20 years. Furthermore, after adjusting for the study sample size, the mean age of participants in studies on gaming was 13 years, which is not reflective of the current gaming population. Furthermore, some studies on adults have found that gaming is typically associated with a higher body mass index (BMI), particularly among males [7-9].

In 2017, the Electronic Software Association reported that 67% of American households own at least one gaming console and 65% of Americans play games at least 3 hours/week, resulting in U.S. \$ 30.4 billion spent on games and game-related equipment [10]. In addition, hobby games (eg, tabletop board games, collectible card games, and role-playing games) have also witnessed an upsurge in sales in recent years [11]. While electronic and hobby gaming are typically viewed as sedentary activities, energy expenditure could differ between different types of gaming (eg, live action role-play vs tabletop role-play), especially with the rise of “exergames” that incorporate physical movement and activity as a part of the core game mechanics [12-14].

Sedentary behavior, defined as “any waking behavior characterized by an energy expenditure  $\leq 1.5$  metabolic equivalents of task, while in a sitting, reclining, or lying posture,” has been associated with several adverse health outcomes, including obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease [15-19]. Studies on sedentary behavior have primarily focused on television watching, total screen time, or overall sitting time, while few have attempted to investigate differential associations for specific types of sedentary behavior, including video or hobby gaming.

This study aims to add to the current literature on gaming and health by addressing two consistent issues. First, most research concerning the relationship between gaming and health has focused on children and adolescents. Although adult gamers constitute the largest portion of the gaming audience, limited research has been conducted on this population. Second, the assessment of gaming in several studies has been limited in scope. In past research, gaming is often examined as either time spent gaming or whether participants gamed at all. Most studies focus solely on electronic gaming; however, when tabletop gaming is considered, both types are considered one gaming group. Thus, the relationship between health and the type of gaming people prefer as well as the different forms of gaming people use remains unclear. Hence, this study aims to address these limitations by focusing on an adult gaming population and using multiple measures of gaming behavior to elucidate how gaming correlates with health in this population.

## Methods

### Participants

In this study, participants were recruited among attendees of a large Midwestern tabletop gaming convention held in summer 2014. They completed an online questionnaire that assessed gaming habits, physical activity, sedentary time, and other health characteristics, either at the convention center or off-site at a later time. A total of 332 individuals completed the online

questionnaire. Of these, we excluded 8 participants who reported they did not play games on any platform, 14 who reported  $>35$  hours of recreational physical activity per week, and 18 who had missing data on physical activity, platform preference, sitting time, or BMI. Hence, we enrolled 292 participants in this study.

### Measurement of Video and Hobby Game Playing

The first section of the questionnaire gathered information on gaming platform preferences, time spent gaming, and amount of sitting while gaming. We asked participants to identify the two gaming platforms that they used most often among the following: computer, console, handheld, tabletop, live action role-play (LARP), phone, and tablet platforms. In addition, participants identified other platforms that they used besides the two most used platforms. Furthermore, we asked participants about the proportion of time they spent sitting while gaming, whether they took breaks during gaming and how frequent, and whether they felt that they had worked out after a gaming session was over.

### Measurement of Physical Activity and Sedentary Behaviors

We used the International Physical Activity Questionnaire (IPAQ) to determine the usual level of physical activity [20]. Specifically, we used the IPAQ to gather information on leisure time walking, moderate-to-vigorous physical activity (MVPA), and typical methods of transportation in the 7 days before arriving at the convention. In addition, we used the Sedentary Behavior Questionnaire to evaluate time spent in the following 8 different sedentary activities on an average weekday or weekend: gaming, watching television, talking on the phone, doing office work, listening to music, reading, playing an instrument, or doing artwork or crafts [21]. Furthermore, 9 categories were provided for response, ranging from no time on an activity to  $\geq 6$  hours/day.

### Measurement of Health and Demographic Characteristics

In addition to collecting data on physical activity and sedentary time, we assessed other health characteristics, including height, weight, smoking status, and number of cigarettes smoked per day. In addition, participants completed questions on their medical history, including the diagnosis of high blood pressure, nongestational diabetes, elevated cholesterol, myocardial infarction, stroke, and cancer, as well as whether they had a disability that limited their physical activity. We also asked participants how many servings of fruit and vegetables they ate per day. Finally, we asked participants to provide demographic information, including ethnicity, race, gender, marital status, age, income, country of residence, education level, and employment status.

### Statistical Analysis

In this study, all statistical analyses were performed using SAS statistical software, version 9.4 (SAS Institute Inc, Cary, North Carolina, United States). The exposures of interest were the preferred gaming platform, number of platforms used, and time spent gaming. The outcomes of interest were BMI, obesity status

(BMI<30 vs BMI≥30), physical activity, sedentary time, and presence of a cardiovascular risk factor (diagnosis of ≥1 of diabetes, hypertension, and high cholesterol).

We assessed the baseline characteristics of the study population by calculating means (SD) for continuous variables and frequencies (%) for categorical variables. In addition, we assessed means (SD) and frequencies (%) of health characteristics based on the number of platforms used and platform preference. In this and all analyses for platform preference, gaming on a handheld console, phone, or tablet was grouped into the “other electronic” category due to small sample sizes in each of these categories. Furthermore, we used the Kruskal–Wallis test and Fisher’s tests with Monte Carlo approximation to test for the significance of the association between platform preference and each variable.

We then assessed the association between the number of gaming platforms used and BMI, obesity, physical activity, sedentary time, and cardiovascular risk factors. As these were not normally distributed, BMI was log-transformed, and the sitting time was square root-transformed. For physical activity, we categorized participants depending on whether they fulfilled the physical activity 2008 Physical Activity Guidelines for Americans of 2.5 hours of MVPA per week [22]. While linear regression was used for analyzing continuous outcomes of BMI and sitting time, logistic regression was used to analyze the categorical outcomes of obesity, meeting physical activity guidelines, and the presence of cardiovascular risk factors. Furthermore, we conducted a test for linear trend by treating the number of platforms used as a continuous variable.

Similar analyses were performed to examine the association between platform preference, as well as time spent gaming, and each of the health outcomes. For platform preference, participants who preferred tabletop gaming were assigned to the reference group, and analysis of covariance was used for the continuous outcomes (BMI and sedentary time) to test the significance of platform preference overall. In addition, we used fractional logistic regression to test the significance of platform preference for dichotomous outcomes. Then, weekday and weekend gaming time was examined in quartiles to investigate associations between gaming time and each outcome. Besides, the median of the gaming time quartiles was modeled as a continuous variable to test for linear trend. Furthermore, we used logistic regression to investigate the association between the proportion of time spent sitting while gaming and the odds of being obese.

For all analyses of gaming and health outcomes, we used age-adjusted and multivariable-adjusted models. All multivariable-adjusted models included age, race, gender, employment, income (income >75,000/year vs income ≤75,000/year), servings of fruit per day, and servings of vegetables per day. Based on the exposure and outcome, other covariates included in multivariable-adjusted models were fulfilling physical activity guidelines, the presence of a disability, the number of platforms used, and weekday and weekend gaming time. The specific variables included in each model are listed in the footnotes of each table in this study.

## Results

### Characteristics of Study Population

The study population was predominantly white (259 of 290, 89.3%) and male (197 of 290, 68.6%), with a mean age of 34.2 (SD 10.6) years (Multimedia Appendix 1). Most participants were either overweight (77 of 292, 26.4%) or obese (154 of 292, 47.3%), with a mean BMI of 31.2 (SD 8.8) kg/m<sup>2</sup>. The mean hours per week of MVPA was 5.2 (SD 5.9), with 166 of 292 (56.9%) participants reporting that they fulfilled the physical activity guidelines of at least 2.5 hours of MVPA per week. Nearly one-quarter (66 of 290, 22.8%) of the participants responded that they had a disability or health condition that restricted their ability to be physically active. In fact, 67 of 290 (23.1%) participants reported that they had a cardiovascular risk factor. The most preferred gaming platforms were tabletop gaming (116 of 292, 39.7%) and computer gaming (103 of 292, 35.3%). Most participants (196 of 292, 67.1%) used at least three different platforms.

### Characteristics of Study Population by Platform Preference

We assessed the baseline characteristics according to the type of platform that was most preferred (Table 1). We observed significant differences by the platform preference in age, weekend sitting time, weekday and weekend gaming time, proportion of time spent sitting, and servings of vegetables per day ( $P=.002$ ,  $P=.002$ ,  $P<.001$ ,  $P<.001$ ,  $P=.001$ , and  $P=.02$ , respectively). While participants who preferred tabletop games were the oldest, with a mean age of 36.4 (SD 9.8) years, those who preferred console games were the youngest, with a mean age of 30.6 (SD 10.9) years. Weekend sitting time was the highest among participants who preferred LARP [9.9 (SD 3.5) hours/day] and the lowest among those who preferred tabletop games [7.0 (SD 3.6) hours/day]. Although participants who preferred computer games reported the highest time spent gaming on both weekdays and weekends [2.5 (SD 1.7) and 3.0 (SD 1.8) hours/day, respectively], they also constituted the highest proportion of participants who fulfilled physical activity recommendations (65 of 103, 63.1%).

### Characteristics of Study Population by Number of Platforms Played

Next, we assessed the baseline characteristics by the number of platforms used (Multimedia Appendix 2). We observed significant differences by the number of platforms used in age and time spent gaming on weekdays and weekends ( $P=.01$ ,  $P=.02$ , and  $P=.002$ , respectively). In addition, participants who reported playing ≥4 platforms were the youngest, with a mean age of 31.3 (SD 9.1) years, whereas those who only played 1-2 platforms were older, with mean ages of 37.4 (SD 13.4) and 37.1 (SD 11.6) years, respectively. Not surprisingly, the mean time spent gaming on weekdays and weekends increased as the number of platforms used increased. Furthermore, those who played ≥4 platforms reported 2.0 (SD 1.6) hours/day of gaming on a typical weekday and 2.6 (SD 1.7) hours/day of gaming on a typical weekend day.

**Table 1.** Means (SD) and frequency (%) of characteristics by gaming platforms most preferred.

Characteristic	Tabletop (n=116)	Computer (n=103)	Console (n=41)	Other Electronic (n=25)	LARP <sup>a</sup> (n=7)	P value
Age, years, mean (SD)	36.4 (9.8)	33.0 (11.4)	30.6 (10.9)	35.0 (9.3)	31.9 (8.0)	.002
BMI <sup>b</sup> , kg/m <sup>2</sup> , mean (SD)	32.1 (8.5)	30.4 (8.4)	30.6 (8.6)	30.2 (10.6)	34.6 (13.3)	.41
Obese, n (%)	58 (50)	45 (43.7)	23 (56.1)	8 (32)	4 (57.1)	.32
MVPA <sup>c</sup> , hours/week, mean (SD)	4.5 (4.6)	5.2 (5.7)	6.7 (8.0)	5.0 (7.5)	7.3 (8.8)	.94
≥2.5 MVPA, hours/week, n (%)	63 (54.3)	65 (63.1)	23 (56.1)	11 (44)	4 (57.1)	.47
<b>Sitting time, hours/day, mean (SD)</b>						
Weekday	8.7 (4.9)	9.4 (4.1)	9.0 (4.0)	9.6 (5.4)	11.3 (4.8)	.35
Weekend	7.0 (3.6)	8.6 (3.6)	8.6 (4.4)	8.0 (5.5)	9.9 (3.5)	.002
<b>Time spent gaming, hours/day, mean (SD)</b>						
Weekday	1.0 (1.2)	2.5 (1.7)	2.0 (1.7)	1.1 (0.9)	0.9 (1.0)	<.001
Weekend	1.3 (1.4)	3.0 (1.8)	2.5 (1.7)	1.4 (1.2)	1.4 (1.3)	<.001
<b>Cardiovascular risk factors, n (%)</b>						
Yes	24 (20.9)	25 (24.5)	8 (19.5)	9 (36.0)	1 (14.3)	.51
No	91 (79.1)	77 (75.5)	33 (80.5)	16 (64.0)	6 (85.7)	
<b>Proportion of time spent sitting while gaming, n (%)</b>						
Half or less	17 (14.9)	12 (11.9)	4 (9.8)	7 (28)	5 (71.4)	.001
Most or All	97 (85.1)	89 (88.1)	37 (90.2)	18 (72)	2 (28.6)	
<b>Take breaks while gaming, n (%)</b>						
Yes	96 (85.7)	78 (80.4)	30 (76.9)	17 (80.9)	6 (100)	.53
No	16 (14.3)	19 (19.6)	9 (23.1)	4 (19.1)	0	
<b>Frequency of breaks, n (%)</b>						
Every ≤55 minute	63 (65.6)	48 (61.5)	21 (70.0)	6 (35.3)	4 (66.7)	.76
1 hour +	33 (34.4)	30 (38.5)	9 (30.0)	11 (64.7)	2 (33.3)	
Servings of fruit per day, mean (SD)	1.0 (0.9)	1.0 (0.9)	1.2 (1.1)	1.1 (1.2)	0.5 (0.7)	.38
Servings of vegetables per day, mean (SD)	2.0 (1.2)	1.9 (1.2)	1.6 (1.2)	1.5 (1.1)	0.9 (0.8)	.02

<sup>a</sup>LARP: live action role-play.<sup>b</sup>BMI: body mass index.<sup>c</sup>MVPA: moderate to vigorous physical activity.

## Association of Number of Platforms Played and Physical Wellness

Table 2 presents the associations of obesity, physical activity, sedentary time, and cardiovascular risk factors with the number of platforms used. We observed that a higher number of platforms used was significantly associated with a higher BMI in the age-adjusted model but was only marginally significant in the multivariable-adjusted model ( $P=.045$  and  $P=.07$ , respectively). Compared with participants who reported using 3 platforms, those who reported using ≥4 platforms exhibited a multivariable-adjusted odds ratio (OR) of 1.55 (95% CI 0.78-3.09) for obesity, whereas those who reported using 1 platform exhibited an OR of 0.48 (95% CI 0.14-1.58;  $P_{\text{trend}}=.03$ ). In addition, we observed a significant positive linear trend for

weekend sitting time and number of platforms used ( $P_{\text{trend}}=.03$ ;  $\beta=.11$ ); however, no significant associations existed between the number of platforms used and physical activity or the presence of cardiovascular risk factors.

## Association of Platform Preference With Physical Wellness

Table 3 presents the results of the regression analysis for the platform preference with the same outcomes as the previous analysis. In multivariable-adjusted models, a significant association was observed between the preferred gaming platform and fulfilling physical activity guidelines ( $P=.04$ ). Compared with participants who preferred tabletop games, those who preferred computer games had higher odds of performing 2.5 hours of MVPA per week (OR 2.70, 95% CI 1.28-5.69).

**Table 2.** Associations between the number of gaming platforms used and health outcomes.

Characteristic	Gaming platforms				<i>P</i> value
	1	2	3	4+	
<b>BMI<sup>a,b</sup></b>					
Age-adjusted	−0.11	−0.02	Reference	0.03	.045
Multivariable-adjusted <sup>c</sup>	−0.07	−0.02	Reference	0.04	.07
<b>Obese, OR<sup>d</sup> (95% CI)</b>					
Age-adjusted	0.58 (0.22-1.50)	0.76 (0.42-1.38)	1.00	1.41 (0.78-2.54)	.03
Multivariable-adjusted <sup>c</sup>	0.48 (0.14-1.58)	0.78 (0.39-1.54)	1.00	1.55 (0.78-3.09)	.03
<b>≥2.5 MVPA<sup>e</sup>, hours/week, OR (95% CI)</b>					
Age-adjusted	1.18 (0.46-3.05)	0.77 (0.43-1.39)	1.00	0.68 (0.38-1.23)	.46
Multivariable-adjusted <sup>f</sup>	1.06 (0.34-3.30)	0.73 (0.38-1.42)	1.00	0.61 (0.32-1.18)	.50
<b>Weekday Total Sitting, hours/day<sup>g</sup></b>					
Age-adjusted	0.004	−0.01	Reference	0.03	.79
Multivariable-adjusted <sup>c</sup>	−0.10	−0.02	Reference	0.11	.26
<b>Weekend Total Sitting, hours/day<sup>g</sup></b>					
Age-adjusted	−0.16	−0.18	Reference	0.08	.03
Multivariable-adjusted <sup>c</sup>	−0.22	−0.19	Reference	0.05	.03
<b>Cardiovascular Risk Factors, OR (95% CI)</b>					
Age-adjusted	0.46 (0.12-1.78)	1.02 (0.48-2.17)	1.00	1.49 (0.69-3.21)	.14
Multivariable-adjusted <sup>h</sup>	0.45 (0.10-2.03)	1.12 (0.49-2.56)	1.00	1.61 (0.68-3.79)	.19

<sup>a</sup>BMI: body mass index.<sup>b</sup>Log-transformed variable; beta estimate.<sup>c</sup>Adjusted for age, race, gender, education, employment, income >75,000/year, meeting physical activity recommendation, disability, servings of fruit per day, and servings of vegetables per day.<sup>d</sup>OR: odds ratio.<sup>e</sup>MVPA: moderate to vigorous physical activity.<sup>f</sup>Adjusted for age, race, gender, education, employment, income >75,000/year, disability, servings of fruit per day, and servings of vegetables per day.<sup>g</sup>Square root-transformed variable; beta estimate.<sup>h</sup>Adjusted for age, race, gender, education, employment, income >75,000/year, meeting physical activity recommendation, servings of fruit per day, and servings of vegetables per day.

In addition, in the age-adjusted model, a significant association existed between the preferred gaming platform and weekend sitting time ( $P=.02$ ). Participants who preferred tabletop games reported spending the least amount of time sitting on weekends, whereas participants who preferred LARP reported spending the most time sitting on weekends. However, the association between the gaming platform and weekend sitting was attenuated in multivariable-adjusted models ( $P=.11$ ). Furthermore, we observed no significant associations between the preferred gaming platform and BMI or the presence of cardiovascular risk factors.

### Association of Weekday and Weekend Gaming Time With Physical Wellness

Next, we assessed the association of weekday and weekend gaming time with obesity, physical activity, and cardiovascular

risk factors. [Multimedia Appendix 3](#) presents the regression results for the weekday gaming time quartile. Participants who gamed 1-3 hours on weekdays tended to report cardiovascular risk factors with an OR of 3.23 (95% CI 1.10-9.53). However, we observed no significant linear trends for the weekday gaming time overall. We observed a significant association between weekend gaming time and fulfilling physical activity guidelines after adjusting for covariates ( $P=.03$  and  $P=.02$ , respectively; [Table 4](#)). Furthermore, participants who gamed >3 hours/day on a typical weekend had 0.40 (95% CI 0.19-0.85) times the odds of performing 2.5 hours/week of MVPA.

### Association of Time Spent Sitting While Gaming and Obesity

Furthermore, we examined the odds of being obese by the proportion of time spent sitting while gaming ([Figure 1](#)).

**Table 3.** Associations among gaming platform most preferred, body mass index, physical activity, and sitting time.

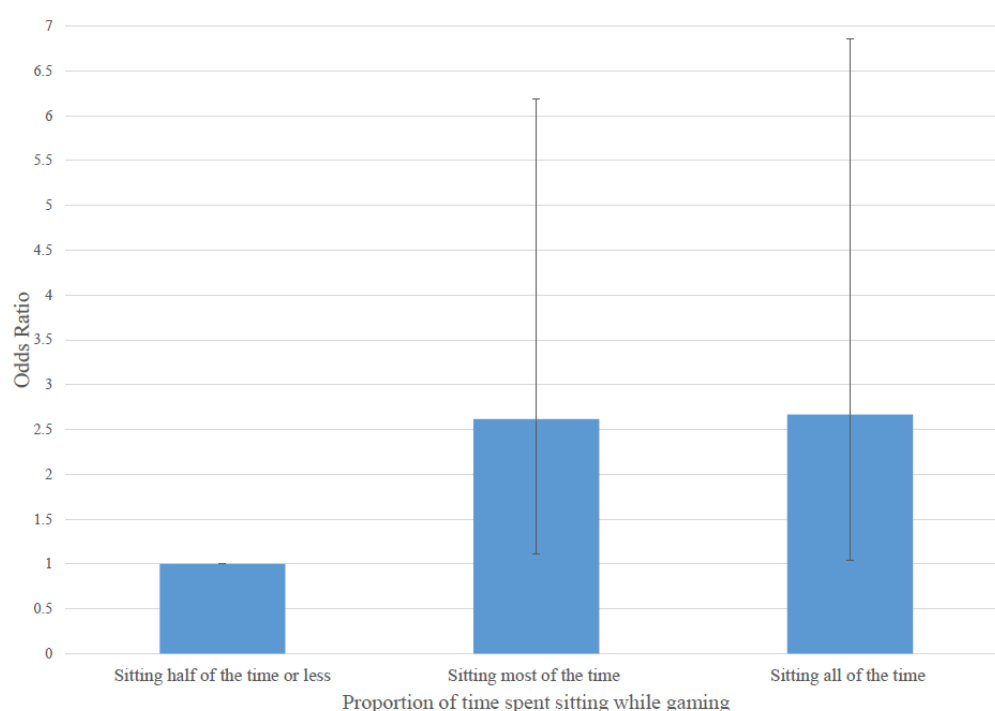
Characteristic	Tabletop	Computer	Console	Other Electronic	LARP <sup>a</sup>	P value
<b>BMI<sup>b,c</sup></b>						
Age-adjusted	Reference	−0.04	−0.03	−0.07	0.06	.60
Multivariable-adjusted <sup>d</sup>	Reference	−0.02	−0.004	−0.02	0.05	.96
<b>Obese, OR<sup>e</sup> (95% CI)</b>						
Age-adjusted	1.00	0.84 (0.49-1.44)	1.47 (0.70-3.06)	0.48 (0.19-1.21)	1.48 (0.32-6.98)	.28
Multivariable-adjusted <sup>d</sup>	1.00	0.91 (0.43-1.93)	1.99 (0.73-5.39)	0.35 (0.11-1.13)	0.84 (0.10-7.13)	.20
<b>≥2.5 MVPA<sup>f</sup>, hours/week, OR (95% CI)</b>						
Age-adjusted	1.00	1.43 (0.83-2.47)	1.06 (0.51-2.20)	0.66 (0.28-1.57)	1.11 (0.24-5.20)	.48
Multivariable-adjusted <sup>g</sup>	1.00	2.70 (1.28-5.69)	1.07 (0.43-2.65)	0.65 (0.24-1.78)	0.66 (0.10-4.47)	.04
<b>Weekday Total Sitting, hours/day<sup>h</sup></b>						
Age-adjusted	Reference	0.17	0.08	0.14	0.44	.38
Multivariable-adjusted <sup>i</sup>	Reference	0.15	−0.04	0.07	0.80	.19
<b>Weekend Total Sitting, hours/day<sup>h</sup></b>						
Age-adjusted	Reference	0.31	0.25	0.16	0.53	.02
Multivariable-adjusted <sup>i</sup>	Reference	0.20	0.001	0.06	0.59	.11
<b>Cardiovascular Risk Factors, OR (95% CI)</b>						
Age-adjusted	1.00	1.71 (0.84-3.48)	1.55 (0.56-4.28)	2.83 (1.02-7.86)	1.04 (0.11-9.72)	.31
Multivariable-adjusted <sup>j</sup>	1.00	1.98 (0.77-5.08)	1.46 (0.41-5.20)	2.40 (0.72-7.96)	0.85 (0.07-10.59)	.51

<sup>a</sup>LARP: live action role-play.<sup>b</sup>BMI: body mass index.<sup>c</sup>Log-transformed variable; beta estimate.<sup>d</sup>Adjusted for age, race, gender, education, employment, income >75,000/year, meeting physical activity recommendation, weekday gaming quartile, weekend gaming quartile, number of platforms used, disability, servings of fruit per day, and servings of vegetables per day.<sup>e</sup>OR: odds ratio.<sup>f</sup>MVPA: moderate to vigorous physical activity.<sup>g</sup>Adjusted for age, race, gender, education, employment, income >75,000/year, weekday gaming quartile, weekend gaming quartile, number of platforms used, disability, servings of fruit per day, and servings of vegetables per day.<sup>h</sup>Square root-transformed variable; beta estimate.<sup>i</sup>Adjusted for age, race, gender, education, employment, income >75,000/year, meeting physical activity recommendation, number of platforms used, disability, servings of fruit per day, and servings of vegetables per day.<sup>j</sup>Adjusted for age, race, gender, education, employment, income >75,000/year, meeting physical activity recommendation, weekday gaming quartile, weekend gaming quartile, number of platforms used, servings of fruit per day, and servings of vegetables per day.



**Table 4.** Associations among weekend gaming time, body mass index, and physical activity (N=292).

Characteristics	Weekend gaming time, hours/day				P value
	Quartile 1 ( $\leq 0.5$ )	Quartile 2 ( $>0.5$ - $<2$ )	Quartile 3 (2-3)	Quartile 4 ( $>3$ )	
<b>n (%)</b>	78 (26.6)	51 (17.5)	103 (35.3)	60 (20.1)	
<b>BMI<sup>a,b</sup></b>					
Age-adjusted	Reference	-0.01	0.001	0.04	.33
Multivariable-adjusted <sup>c</sup>	Reference	0.03	-0.002	0.06	.21
<b>Obese, OR<sup>d</sup> (95% CI)</b>					
Age-adjusted	1.00	0.77 (0.37-1.57)	1.14 (0.63-2.07)	1.09 (0.55-2.18)	.63
Multivariable-adjusted <sup>c</sup>	1.00	0.87 (0.41-1.88)	1.11 (0.58-2.12)	1.06 (0.49-2.26)	.81
<b><math>\geq 2.5</math> MVPA<sup>e</sup>, hours/week, OR (95% CI)</b>					
Age-adjusted	1.00	0.60 (0.29-1.23)	0.76 (0.41-1.40)	0.38 (0.19-0.77)	.01
Multivariable-adjusted <sup>f</sup>	1.00	0.59 (0.28-1.25)	0.84 (0.44-1.61)	0.40 (0.19-0.85)	.03
<b>Cardiovascular Risk Factors, OR (95% CI)</b>					
Age-adjusted	1.00	0.82 (0.33-2.02)	1.03 (0.48-2.21)	1.33 (0.53-3.30)	.45
Multivariable-adjusted <sup>g</sup>	1.00	0.84 (0.33-2.13)	1.00 (0.45-2.13)	1.03(0.39-2.72)	.88

<sup>a</sup>BMI: body mass index.<sup>b</sup>Log-transformed variable; beta estimate.<sup>c</sup>Adjusted for age, race, gender, education, income  $>75,000$ /year, employment, meeting physical activity recommendations, disability, servings of fruit per day, and servings of vegetables per day.<sup>d</sup>OR: odds ratio.<sup>e</sup>MVPA: moderate to vigorous physical activity.<sup>f</sup>Adjusted for age, race, gender, education, income  $>75,000$ /year, employment, disability, servings of fruit per day, and servings of vegetables per day.<sup>g</sup>Adjusted for age, race, gender, education, income  $>75,000$ /year, employment, meeting physical activity recommendations, servings of fruit per day, and servings of vegetables per day.**Figure 1.** Multivariable-adjusted odd ratios for being obese according to proportion of time spent sitting while gaming. Adjusted for age, race, gender, education, income over 75k/yr, employment, meeting PA recommendations, disability, weekday and weekend gaming time quartile, number of platforms played, servings of fruit per day, and servings of vegetables per day. Error bar denotes 95% confidence interval.

Compared with those who spent half of the time or less sitting while they gamed, gamers who sat most of the time or all of the time while they gamed had 2.62 (95% CI 1.11-6.19) and 2.67 (95% CI 1.04-6.86) times the odds of being obese, respectively.

## Discussion

### Principal Findings

This cross-sectional study among attendees of a large gaming convention highlighted some critical associations between gaming and physical wellness. The total number of gaming platforms used exhibited a substantial, positive association with both obesity and weekend sitting time. In addition, the specific platform preferred for gaming was significantly associated with fulfilling physical activity guidelines, where individuals who preferred computer games were more likely to fulfill physical activity guidelines than those who preferred tabletop games. Not surprisingly, more time spent gaming on weekends was associated with decreased odds of fulfilling physical activity recommendations. Furthermore, this study established that the proportion of time spent sitting while gaming was associated with higher odds of being obese.

### Gaming and Obesity

Previously, three cross-sectional studies established an association between game playing and BMI. Ballard et al [7] reported that the length of video gaming sessions positively associated with BMI ( $r=.27$ ;  $P<.01$ ) in a study comprising 116 male participants. In a study including 562 participants, Weaver et al [9] reported that persons who gamed exhibited a significantly higher mean BMI than nongamers among males, but not females. Dunton et al [8] reported a significant interaction between gaming and physical activity that impacted the relationship between gaming and BMI in a study comprising 10,984 adults. For those with <60 minutes of MVPA per day, the predicted marginal mean BMI was significantly higher ( $P<.001$ ) in those who gamed at all than in those who did not game. No significant differences were observed in the predicted marginal mean BMI between gamers and nongamers among those who had at least 60 minutes of MVPA. In contrast, this study did not establish a significant association between weekday or weekend gaming time and BMI or the odds of being obese.

The differences in findings can be explained by several potential reasons. First, differences exist among studies in the classification of gaming. The Ballard et al [7] study included individuals with a substantial variation in gaming habits, ranging from individuals who gamed very infrequently (never to a few times per month) to individuals who gamed almost every day of the week. The Dunton et al [8] and Weaver et al [9] studies only compared gamers with nongamers. In contrast, this study was conducted among attendees of a large tabletop gaming convention; therefore, it comprised few nongamers in the analysis and participants were mostly gamers, averaging 12.6 hours/week of gaming time. In addition, the Ballard et al [7] study only enrolled males; however, we enrolled both males and females. The Weaver et al [9] study was stratified by gender and found significant associations in males only. In this study, we examined interactions between our exposures of interest and

gender; however, none of the interactions were statistically significant. Thus, we did not stratify by gender in our final models. In the Dunton et al [8] study, the association between any gaming and higher BMI was only noted in individuals who had <60 minutes of physical activity a day; results among active people were similar to the findings of our study.

### Gaming and Physical Activity

Nonetheless, findings from this study were similar to those from the study by Ballard et al [7] with regard to the association between gaming time and physical activity. We found that as weekend gaming time increased, the odds of fulfilling physical activity recommendations decreased. In the Ballard et al [7] study, the frequency of game play was significantly negatively correlated with the duration of exercising ( $r=-.21$ ;  $P<.05$ ). Moreover, the duration of video game play was significantly negatively correlated with the frequency of exercising ( $r=-.21$ ;  $P<.05$ ) and days of walking ( $r=-.22$ ;  $P<.05$ ).

The most surprising finding was that individuals who preferred computer gaming were more likely to report engaging in 2.5 hours of MVPA per week compared with other groups, despite reporting the highest amount of time spent gaming on weekends; this association could partially be due to the age distribution. A higher proportion of individuals were in the 18-25 age range who preferred computer gaming, and this age range comprised a higher proportion of individuals who fulfilled physical activity recommendations. Additionally, the proportion of individuals who were obese was also lower for participants who preferred computer gaming (45/103, 43.7%) than it was for those who preferred tabletop gaming (58/116, 50%). We reanalyzed after additionally adjusting for obesity. Those who preferred computer gaming continued to exhibit significantly higher odds of fulfilling physical activity recommendations than those who preferred tabletop gaming.

### Time Spent Sitting While Gaming and Obesity

This study reported that participants who sat for most or all of their time spent gaming had higher odds of being obese. On average, participants spent 1.69 and 2.07 hours on gaming during the week and weekends, respectively, rendering gaming a substantial source of sedentary activity. Recent research has indicated that breaking up sedentary time can exert health benefits associated with obesity. Using isotemporal substitution, Healy et al [23] established that decreasing the mean prolonged sedentary time (sedentary bout  $\geq 30$  minutes) by 30 minutes and increasing the nonprolonged sedentary time (sedentary bout <30 minutes) by 30 minutes is associated with a 0.35 kg/m<sup>2</sup> reduction in BMI. Using isotemporal substitution, Gupta et al [24] reported that replacing long sedentary bouts (sedentary bout >30 minutes) with brief bouts of sedentary behavior (sedentary bout  $\leq 5$  minutes) is associated with a 0.87 kg/m<sup>2</sup> reduction in BMI. These findings could be a major factor explaining the association between proportions of time spent sitting while gaming and obesity. In this study, most participants (64.8%) took breaks from gaming every  $\leq 55$  minutes; however, a much smaller portion (17.6%) took breaks every  $\leq 25$  minutes. As a result, those gaming for longer bouts are unlikely to break

them up into smaller bouts of time that are more beneficial to body composition.

### Strengths & Limitations

This study has several strengths. First, we assessed and examined gaming in multiple ways: the number of platforms used, platform preference, and weekday and weekend gaming time quartile. Past research has not distinguished gaming by either the type of platform that was preferred or the number of platforms an individual used but has typically categorized individuals as gamers or nongamers [8,9]. In fact, previous research has also focused primarily on electronic gaming, whereas this study considered hobby gaming as well. Second, prior studies have focused on total gaming time without attempting to parse out associations for weekday and weekend gaming time separately. It is imperative to examine weekday and weekend gaming separately as the amount of leisure time is much more limited on weekdays compared with weekends. Finally, this study focused on adults who game, an underrepresented demographic in gaming research, despite being the largest demographic of gamers [6,10].

This study also has several limitations. First, our study cohort comprised gamers who were adequately enthusiastic about the hobby and healthy to attend a gaming convention and might not be representative of adult gamers in general. Second, we were only able to enroll a very small number of nongamers (n=8). Thus, our analysis only included game-playing adults, and we could not assess how these associations compare with a nongaming adult population. In addition, the assessment of

gaming had limitations as we did not obtain information on whether participants used exergames and only asked about specific games rather than game types. Third, the small sample size hindered the statistical power of the analysis. Reviews on gaming health literature by LeBlanc et al [25] and Kharrazi et al [6] have identified low sample size as a consistent issue that arises in this field of research. Comparable studies by Ballard et al [7] and Weaver et al [9] also had a limited sample size, with 116 and 562 participants, respectively. Fourth, we used a self-reported measure of physical activity, and such measures have had issues with overestimation of physical activity in prior studies [26,27]. As with all observational studies, we cannot eliminate the possibility of residual or unmeasured confounding. Finally, as this was a cross-sectional study, we cannot make any inference as to the direction of the relationships observed.

### Conclusion

In summary, we found that the number of gaming platforms used associates with higher odds of being obese, while platform preference and weekend gaming time associates with the odds of fulfilling physical activity recommendations. Further research on gaming and health in adults would benefit from extensive, longitudinal studies to facilitate the examination of prospective associations between gaming characteristics and clinical outcomes, as well as using objective measurements of physical activity using accelerometers. Given the popularity of gaming among both adults and children, there is a need to better understand the relationship between gaming and health outcomes so as to determine strategies to potentially use gaming to help improve physical wellness.

### Acknowledgments

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### Conflicts of Interest

None declared.

### Multimedia Appendix 1

Baseline characteristics of the study population (n=292).

[PDF File (Adobe PDF File), 79KB - [games\\_v6i2e12\\_app1.pdf](#)]

### Multimedia Appendix 2

Means (SD) and N (%) of characteristics by the number of platforms played.

[PDF File (Adobe PDF File), 66KB - [games\\_v6i2e12\\_app2.pdf](#)]

### Multimedia Appendix 3

Associations of weekday gaming time with obesity, physical activity, and cardiovascular risk factors.

[PDF File (Adobe PDF File), 38KB - [games\\_v6i2e12\\_app3.pdf](#)]

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## Abbreviations

**BMI:** body mass index

**IPAQ:** International Physical Activity Questionnaire

**LARP:** live action role-play

**MVPA:** moderate-to-vigorous physical activity

**OR:** odds ratio

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