Improved Risk Perception and Knowledge Following a Social Game-based Tobacco Prevention Program for Adolescents: A Pilot Randomized Comparative Trial

Georges Khalil, Erica Ramirez, Meerah Khan, Bairu Zhao, Nuno Ribeiro, Patrick Balian

Submitted to: JMIR Serious Games
on: June 15, 2024

Table of Contents

Improved Risk Perception and Knowledge Following a Social Game-based Tobacco Prevention Program for Adolescents: A Pilot Randomized Comparative Trial

Georges Khalil[1] MPH, PhD; Erica Ramirez[1] BS, RN; Meerah Khan[1] MPH; Bairu Zhao[1] BS, MS; Nuno Ribeiro[2] PhD; Patrick Balian[3] DBA

[1]Department of Health Outcomes and Biomedical Informatics University of Florida Gainesville US
[2]I3S – Instituto de Investigação e Inovação em Saúde Universidade do Porto Porto PT
[3]Warrington College of Business University of Florida Gainesville US

Corresponding Author:
Georges Khalil MPH, PhD
Department of Health Outcomes and Biomedical Informatics
University of Florida
Malachowsky Hall for Data Science and Information Technology
1889 Museum Rd, Suite 7000
Gainesville
US

Abstract

Background: Adolescence is a critical developmental phase vulnerable to tobacco initiation. Despite its clear harm to health, adolescent tobacco use remains prevalent. Games for health are a promising strategy for tobacco prevention, utilizing experiential and social learning theories to enhance engagement and improve behavior change.

Objective: This pilot study aims to (1) compare the social game-based program Storm-Heroes to a non-social program regarding adolescents' personal and social experiences, and (2) examine how these experiences predict higher tobacco knowledge and perceived risks of vaping and conventional tobacco use.

Methods: In a cluster-randomized comparative design, four after-school sites (n=74 adolescents) were recruited in person and randomized in a single-blinded format to 1 of 2 interventions: the social game Storm-Heroes (n=44) or the non-social program ASPIRE (n=35). A study team member supervised both interventions. Data were collected at baseline, immediate follow-up, and 1.5-month follow-up (60.81%, 45/74 retained). Repeated-measures mixed-effect models were conducted.

Results: A total of 45 continued until 1.5-month follow-up. Participants in the Strom-Heroes group were more likely to increase their perceived risk of vaping (B=0.40, P<0.001), perceived risk of conventional tobacco use (B=0.35, P=0.046), and tobacco knowledge (B=1.63, P<0.001) than those in the control condition. The usability level of the program was related to a higher perceived risk of vaping (B=0.16, P=0.003) and conventional tobacco use (B=0.16, P=0.025) by follow-up. Attention to the program was also related to higher perceived risk of vaping (B=0.12, P=0.002) and conventional tobacco use (B=0.14, P<0.001). Distraction was not related to either perceived risk of vaping (P=0.149) or perceived risk of conventional tobacco use (P=0.709). On the other hand, both, more attention (B=0.60, P<0.001) and less distraction (B=-0.37, P<0.001), were related to higher tobacco knowledge.

Conclusions: The increased perceived risk of vaping and conventional tobacco among Storm-Heroes participants aligns with the program's goals of improving participants' awareness of the risks associated with tobacco use and their tobacco knowledge. However, distraction weakened the effect of the program on tobacco knowledge, indicating that emphasis needs to be placed on minimizing distraction for better outcomes. With the results of this study, researchers can work to (1) advance the current version of Storm-Heroes and (2) amplify engagement in the program to improve its potential for preventing adolescents' initiation of tobacco use. Clinical Trial: This trial was registered at the Clinical Trials registry, NCT02703597.

(JMIR Preprints 15/06/2024:63296)
DOI: https://doi.org/10.2196/preprints.63296

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

Original Paper

Georges E Khalil, M.P.H., Ph.D.[1]; Erica Ramirez, Ph.D.[1]; Meerah Khan, M.P.H.[1]; Bairu Zhao, M.S.[1]; Nuno Ribeiro, Ph.D.[2]; Patrick Balian, Ph.D.[1]

[1]Department of Health Outcomes and Biomedical Informatics, The University of Florida, Gainesville, Florida, United States
[2]Department of Communication, Instituto de Investigação e Inovação em Saúde, Porto, Portugal

Corresponding Author:

Georges E. Khalil, M.P.H., Ph.D.
Department of Health Outcomes and Biomedical Informatics
The University of Florida
1889 Museum Rd, Suite 7000
Gainesville, FL 32611
E-mail: gkhalil@ufl.edu

Improved Risk Perception and Knowledge Following a Social Game-based Tobacco Prevention Program for Adolescents: A Pilot Randomized Comparative Trial

Abstract

Background: Adolescence is a critical developmental phase vulnerable to tobacco initiation. Despite its clear harm to health, adolescent tobacco use remains prevalent. Games for health are a promising strategy for tobacco prevention, utilizing experiential and social learning theories to enhance engagement and improve behavior change.

Objective: This pilot study aims to (1) compare the social game-based program Storm-Heroes to a non-social program regarding adolescents' personal and social experiences, and (2) examine how these experiences predict higher tobacco knowledge and perceived risks of vaping and conventional tobacco use.

Methods: In a cluster-randomized comparative design, four after-school sites (n=74 adolescents) were recruited in person and randomized in a single-blinded format to 1 of 2 interventions: the social game Storm-Heroes (n=44) or the non-social program ASPIRE (n=35). A study team member supervised both interventions. Data were collected at baseline, immediate follow-up, and 1.5-month follow-up (60.81%, 45/74 retained). Repeated-measures mixed-effect models were conducted.

Results: A total of 45 continued until 1.5-month follow-up. Participants in the Strom-Heroes group were more likely to increase their perceived risk of vaping (B=0.40, P<0.001), perceived risk of conventional tobacco use (B=0.35, P=0.046), and tobacco knowledge (B=1.63, P<0.001) than those in the control condition. The usability level of the program was related to a higher perceived risk of vaping (B=0.16, P=0.003) and conventional tobacco use (B=0.16, P=0.025) by follow-up. Attention to the program was also related to higher perceived risk of vaping (B=0.12, P=0.002) and conventional tobacco use (B=0.14, P<0.001). Distraction was not related to either perceived risk of vaping (P=0.149) or perceived risk of conventional tobacco use (P=0.709). On the other hand, both, more attention (B=0.60, P<0.001) and less distraction (B=-0.37, P<0.001), were related to higher tobacco knowledge.

Conclusions: The increased perceived risk of vaping and conventional tobacco among Storm-Heroes participants aligns with the program's goals of improving participants' awareness of the risks associated with tobacco use and their tobacco knowledge. However, distraction weakened the effect of the program on tobacco knowledge, indicating that emphasis needs to be placed on minimizing distraction for better outcomes. With the results of this study, researchers can work to (1) advance the current version of Storm-Heroes and (2) amplify engagement in the program to improve its potential for preventing adolescents' initiation of tobacco use.

Trial Registration: This trial was registered at the Clinical Trials registry, NCT02703597.

Keywords: tobacco prevention; vaping; combustible tobacco; risk perception; adolescent; games; social interaction

Introduction

Adolescence forms a critical developmental phase that is particularly vulnerable to tobacco initiation [1-3]. Research indicates that exposure to nicotine during this period is associated with clear impairments in brain growth, psychological harm, and long-term physical health outcomes [4,5]. Despite the well-known risks associated with adolescent tobacco use, the rates of use among this age group remain a concern. In 2023, approximately 28% of high school students and 14.7% of middle school students reported ever using a tobacco product [6,7]. Of the youth who reported ever using tobacco products, approximately 50% of them are current tobacco users [6,7]. As a result, the need for tobacco prevention is clear.

One particularly promising strategy for tobacco prevention is the application of games for health. Gameplay can include an amalgam of entertainment and education strategies to drive health behavior change [8]. Based on the experiential learning theory and the social learning theory, the immersive nature of gameplay facilitates a successful learning process through a playful and entertaining environment [9,10]. Game-based interventions can increase motivation, engagement, and overall sustainability of health behaviors [11]. In addition to our work, researchers have shown the success of games for health through randomized controlled trials [12-15].

Engaging gameplay has proven to be a promising avenue for tobacco prevention [16]. Based on a systematic review [17], most games for combustible tobacco prevention and cessation, have leveraged the use of rewards and interactive activities to drive behavior change. Of these interventions, success was mainly found for smoking cessation games, not prevention [17,18]. On the other hand, games meant for vaping or electronic cigarette (e-cigarette) prevention have recently shown success. One example is a game called “Invite Only VR”, which showed improvement in e-cigarette knowledge, nicotine addiction knowledge, perceived addictiveness of e-cigarettes, and perceptions of harm [19]. Also, one comprehensive game covering vaping and combustible tobacco, smokeSCREEN, improved anti-tobacco beliefs and tobacco knowledge [20]. These results highlight the potential success of game-based interventions.

By including various gaming elements (eg, competition, collaboration, reward, goal setting, and storytelling), games can provide flexibility in addressing different issues pertaining to tobacco use. One qualitative study for the design of tobacco prevention games examined adolescents' gaming preferences and showcased the elements of cooperation, storytelling, and physical performance, as key experiential learning elements for tobacco prevention [21]. The findings suggest that gaming elements can be combined to design an effective and engaging tool that covers the complexities of different tobacco products and addresses unique topics pertaining to this risky behavior.

A Social Game-based Intervention

This line of research on gaming elements for tobacco prevention led to the design of a social game-based intervention, called Storm-Heroes, which is ideal for education systems (e.g., schools and after-school programs). As a social game, Storm-Heroes offers adolescents the opportunity to witness and model healthy behaviors, such as rejecting tobacco, thereby promoting tobacco risk education [21]. With social gaming, Storm-Heroes relies on the social learning theory by promoting interpersonal discussions and boosting self-efficacy through the practice of skills to stay tobacco-free. Additionally, Storm-Heroes conveys normative feedback,

influencing adolescents' risk perceptions regarding tobacco use [21]. This aligns with the health beliefs model, which posits that psychosocial factors such as social interaction and peer pressure can promote risk perception and ultimately encourage behavior change [22]. Through these mechanisms, Storm-Heroes serves as a tool for tobacco prevention, leveraging peer influence and normative feedback to positively impact adolescents' perceptions of tobacco use risks and improve knowledge.

Study Objectives

The purpose of the current pilot study is to (1) compare the social game-based program Storm-Heroes to a non-social program with respect to adolescents' personal and social experience with the program, and (2) examine the role of adolescents' experience with the program in predicting higher perceived risk of vaping, perceived risk of conventional tobacco use, and knowledge by follow-up. Table 1 clarifies the hypotheses tested in the current study.

Table 1: List of hypotheses

Type of Hypotheses	Hypotheses Statements
Personal experience	Engagement with Storm-Heroes will result in higher attention, lower distraction, and higher recognition of program imagery than engagement with a non-social equivalent program. Engagement with Storm-Heroes will result in perceptions of better usability, higher level of fun, better narrative quality, more enjoyment, and more creative freedom, than engagement with a non-social equivalent program
Social experience	Engagement with Storm-Heroes will result in higher engagement in peer-to-peer discussions and better quality of discussions, than engagement with a non-social equivalent program.
Tobacco-related outcomes	Engagement with Storm-Heroes will result in improved perceived risk of vaping, higher perceived risk of conventional tobacco use (cigarettes, cigars, and little cigars) than engagement with a non-social equivalent program. Engagement with Storm-Heroes will result in improved tobacco knowledge than engagement with a non-social equivalent program.
User experience mechanisms of change	Personal experience factors and social interactivity will predict higher perceived risk of vaping, perceived risk of conventional tobacco use, and tobacco knowledge by follow-up, while controlling for program allocation.

Methods

Study Design

In order to pilot test adolescents' experience with Storm-Heroes, this study involved a 2-arm single-blinded cluster-randomized comparative trial. The pilot study was conducted in June of 2021 at 4 after-school sites in Florida, and it was registered at the ClinicalTrials.gov registry, as part of a larger study (identifier: NCT02703597). Its components adhere to the CONSORT (Consolidated Standards of Reporting Trials) and CONSORT-EHEALTH (Consolidated Standards of Reporting Trials of Electronic and Mobile Health Applications and Online Telehealth)

guidelines [23,24]. We assessed demographic information at baseline and program experience at immediate follow-up. We measured perceived risk of vaping, perceived risk of combustible tobacco use, and tobacco knowledge at baseline and 1.5-month follow-up.

A Brief Description of The Interventions

We made the comparison between Storm-Heroes and ASPIRE, a non-social program that is equivalent to Storm-Heroes in the order of sessions and type of health content. Table 2 describes the differences and similarities in design elements for Storm-Heroes and ASPIRE. For a detailed description of the intervention, please refer to Appendix 1, which follows the Template for Intervention Description and Replication (TIDieR) checklist [25].

Table 2: Differences and Similarities in Elements for Each Condition

Elements	Storm-Heroes	ASPIRE
Health content based on TTM[a]	Yes	Yes
Entertainment-education videos	Yes	Yes
Human-computer interaction	Yes	Yes
Gameplay	Yes	No
Social interaction	Yes	No
Hybrid format	Yes	No
Dosage and Frequency	5 weekly sessions, 45 minutes each	5 weekly sessions, 45 minutes each

[a]TTM stands for the transtheoretical model.

ASPIRE is a computer-guided intervention, using entertaining videos and computer-based activities across five sessions over five weeks, each about 45 minutes long. It aims to enhance information retention and guide adolescents toward a tobacco-free lifestyle by engaging users through text, animations, videos, and activities. ASPIRE is evidence-based and tested for tobacco prevention. The intervention program is freely accessible online [26,27].

The Storm-Heroes intervention was developed collaboratively, involving a game designer, a research team with tobacco education expertise, and a youth design committee. Messages were designed using scientific evidence and message-framing strategies to impact tobacco risk perception, knowledge, and intention to use. The intervention aims to educate adolescents about tobacco risks, environmental consequences, and impacts on social and mental well-being, incorporating 367 unique anti-tobacco messages based on the transtheoretical model (TTM) [28] and empowerment theory. The design process resulted in a dynamic and socially engaging educational program, Storm-Heroes, combining digital and in-person elements. It seamlessly integrates online components with game-based tabletop activities, including ASPIRE-derived videos and game-based social activities for group interaction (Figure 1).

In Storm-Heroes, adolescents engage within a narrative. They play the role of friends on an island struck by a storm bringing tobacco products, harmful chemicals, and disease. To combat the storm's effects and save their island, teams embark on quests, participating in entertainment-education videos and activities. Before engaging in the program, adolescents are grouped using a validated social network algorithm. The grouping process ensures that each participant with high intentions to use tobacco is grouped with close friends who do not intend to use tobacco, facilitating constructive support during activities. Storm-Heroes offers adolescents five main activities, delivered on validated board game material. These include

trivia with multiple-choice questions, acting where one member silently acts as others guess, drawing for guessing from sketches, speaking out for verbal clues, and teamwork scenarios presenting group dilemmas. The activities aim to engage teams in collaborative problem-solving around tobacco-related topics. Multimedia Appendix 1 describes the activities and how they are presented to players. The materials of Storm Heroes include informative background information in game-based social activities, such as scripts and task instructions, a tabletop game board, decks for board game cards, dice, tokens, and pons. The materials can be accessed by reaching out to the researchers.

Both ASPIRE and Storm-Heroes cover a comprehensive list of health topics related to tobacco, including its composition, effects on the body and brain, environmental impact, and strategies for tobacco prevention and advocacy (Multimedia Appendix 1). The content is structured consistently across both programs, covering aspects from understanding tobacco to building skills for a tobacco-free lifestyle and community activism.

Study Procedures

The institutional review board for human subject research at the University of Florida approved this study. A total of 4 after-school sites located in Florida were randomly selected for recruitment. After approval from the program directors, a verbal announcement reached adolescents at these sites, and interested adolescents completed child assent and parental permission. For participation, adolescents needed to be 11 through 18 years of age and students in a middle school or high school. Adolescents also needed to be comfortable using a computer and the internet.

During recruitment, adolescents and their parents were informed offline that the study aimed to improve adolescent health through an interactive program in Florida after-school sites, that the study may take about two months and one week, and that they will engage in activities, surveys, and interviews. The incentive was described to potential participants, and they were informed that participation is voluntary and confidential, and the data would be securely stored at the University of Florida. Recruitment and data collection took 3 months to complete.

Participants started their experience with the intervention three to seven days after they completed the baseline survey. The statistical team generated the random allocation of sites to each condition. In ASPIRE and Storm-Heroes, participants used similar computers and had private classrooms for participation. A study team member was available for technical assistance and supervision. A volunteer site staff trained in youth engagement was present to make sure that participants did not deviate from the requested data collection procedures. Participants completed surveys within a classroom setting and under supervision, immediately after the intervention and 1.5 months after the intervention. Participants completed other survey assessments at follow-up (data not included in this paper). Each participant was offered a total of 50 US Dollars in value of compensation for participation in the study.

Implementation of Each Intervention

Our study staff were trained to implement the program at the after-school sites. They traveled to each study site location to administer the ASPIRE and the Storm-Heroes programs. Participants were not told which intervention was of interest to the researchers. During the site visits, study staff recorded attendance, ensured the appropriate regimen was implemented, and addressed any questions or concerns participants had during the sessions.

At each site designated to receive ASPIRE, adolescents engaged in five one-hour sessions exclusively focused on the full ASPIRE program. This regimen was conducted similarly to previous work on ASPIRE. At each site designated to receive Storm-Heroes, participants were first organized into groups comprising 3-6 individuals, determined by the outcomes of the social network survey conducted at baseline. With the aid of the social network algorithm, the study team grouped each at-risk adolescent (those indicating the highest intention to use tobacco) with two to five of their closest peers exhibiting lower intention to use tobacco. Unexpectedly, it was noticed that some participants would end up absent during a session. As a result, the grouping was reevaluated using the algorithm for the sessions when participants were absent. Within their groups, participants were instructed to engage in ASPIRE activities followed by game-based social activities within the board game. The duration of board game play varied for each session depending on the length of the assigned ASPIRE activity.

Measures

We assessed the measures through Web-based closed surveys in a classroom setting, and a study staff was available for assistance. Survey measures have been previously tested and validated. Table 3 includes a detailed description of the main measures, measure references, and Cronbach alpha values when applicable.

At both baseline and 1.5-month follow-up, we measured perceived risk of vaping, perceived risk of using conventional tobacco products (cigarettes, cigars, and little cigars), and tobacco knowledge (Table 3).

At baseline only, we included survey questions pertaining to potential confounders and demographic characteristics, including age, sex at birth, ethnicity, race, average grade at school, the number of detentions at school, parents' highest level of education, and perceived skills in playing board games. At baseline, we also measured the status of using vaping products, cigarettes, and cigars or little cigars, using the Minnesota smoking index [29].

At immediate follow-up, we collected data regarding participants' experience with each of the programs, using validated measures. First, to check for expected differences and similarities between the ASPIRE and the Storm-Heroes conditions, we assessed measures pertaining to key program features. We expected group differences with respect to perceived social interactivity, and group similarities with respect to attitude toward the program, visual aesthetics, and emotional involvement. Next, to assess engagement, we measured recognition of program imagery, attention to the program, and distraction from the program. To capture user experience, we assessed participants' perceptions regarding the usability of the program, level of fun, narrative quality, program enjoyment, and creative freedom. Considering the role of social interaction in the success of Storm-Heroes, we asked participants to indicate if they engaged in any discussions with their peers after the program. If they confirmed they engaged in discussions, they were then asked to share the content of their discussion through an open-ended qualitative question. With a mixed-methods approach, the qualitative responses were analyzed and coded to identify if participants discussed the program or tobacco (coded 1) or not (coded 0).

Table 3: Main study measures

Measures (α^a)	Description
Tobacco-related Measures	
Ever use of vaping	Using the Minnesota smoking index (MSI), we measured the status of vaping,

products; Ever use of cigarettes; Ever use of cigars or little cigars	smoking cigarettes, and smoking cigars or little cigars. We presented respondents with a figure and description of each product and asked them to pick a choice between never having used the product, not even in part, to using the product for more than five sessions. Considering that a vaping product can be continuously used, a session for vaping was defined as one minute straight of vaping [29]. "Ever use" was assigned automatically to those who picked any choice but "never use".
Perceived risk of vaping (0.88); Perceived risk of conventional tobacco use (0.96)	Five items for each outcome: The first item on a 4-point Likert scale, from no risk to great risk, asks respondents how much they think people risk harming themselves if they use each of the tobacco products (vaping products, cigarettes, cigars, and little cigars). The four remaining items on a 4-point Likert scale, from strongly disagree to strongly agree, presenting statements concerning the likelihood of these products contributing to medical issues like reproductive problems, respiratory ailments, or heart disease [30,31]. Perceived risk of vaping is the average score on these items for vaping products, and perceived risk of conventional tobacco use is the average score on these items for cigarettes, cigars, and little cigars.
Tobacco Knowledge (0.68)	We developed a list of 22 questions with multiple-choice and true-or-false answers, testing respondents on their knowledge regarding tobacco in general, vaping products, and conventional products. The questions were based on the health messages within Storm-Heroes and ASPIRE.
Manipulation Check Measures	
Perceived social interactivity (0.98)	Measured with 17 items from Coursaris and Sung (2012), such as "The program seemed to facilitate communication between people" and "The program allowed for conversation [32]"
Attitude toward the program (0.95)	We used an 11-point semantic differential scale for attitude with four items (eg, dislike/like and not well designed/very well designed) [33].
Visual aesthetics (0.97)	We measured the aesthetic attributes of the program (eg, enjoyment of the colors and graphics) [34,35]. With a set of four items, answer choices ranged from 0=not at all to 10=very much.
Emotional involvement	We used a single item asking participants how much they felt emotionally involved in the program [36]. Answer choices ranged from 0=not at all to 10=very much.
Attention Measures	
General attention	To differentiate between attention and distraction, we presented respondents with a single statement: "I paid attention to the program more than to what was happening around me". Answer choices ranged from 0=not at all to 10=very much.
Distraction	We presented respondents with a single statement: "When I was going through the program, I was distracted by activity around me". Answer choices ranged from 0=not at all to 10=very much.
Recognition of program images	We presented participants with a set of images from ASPIRE, images from Storm-Heroes, and images irrelevant to the programs. With a single question, we asked respondents which images they recall from the program. This method has been commonly used in health media campaigns [37-39].
Personal Experience with The Program	
Perceived usability (0.92)	Perceived usability was measured using three items from the usability-playability dimension of the game user experience satisfaction scale (GUESS) [34,35]. Examples of statements included: "it was easy to learn how to play

	the game" and "I found the material of the game to be straightforward". Answer choices ranged from 0=not at all to 10=very much.	
Level of fun	We used a single item, with an 11-point semantic differential scale ranging from "not at all fun" to "fun" [33]. Answer choices ranged from 0=not at all to 10=very much.	
Narrative quality (0.97)	This measure included three items from the narrative dimension of GUESS (eg, "The story was well developed" and "I could identify with the characters") [34,35]. Answer choices ranged from 0=not at all to 10=very much.	-
Program enjoyment (0.98)	This measure included three items related to enjoyment and entertainment value of the program, such as "I enjoyed the program" [26]. Answer choices ranged from 0=not at all to 10=very much.	-
Creative freedom (0.91)	This measure included three items related to the freedom of being creative during the program [34,35], such as "I felt creative during the program" and "The program gave me enough freedom to act how I want". Answer choices ranged from 0=not at all to 10=very much.	-
Communication Measures		
Engagement in discussions about tobacco or the program	With "yes" and "no" as answer choices, we asked respondents if they talked to other people during the program. If the answer was "yes", respondents were then asked an open-ended question: "In a few words, what is the topic that stood out the most in your conversations?" Engagement in the discussion was coded 1 if respondents reported talking about the program or tobacco in a positive light. It was coded 0 otherwise.	

[a]Reliability coefficients with Cronbach's α were calculated when applicable, from baseline data except for measures with data collected at post-test only.

Statistical Analysis

We conducted statistical analyses using Stata version 14 (StataCorp LP). Considering cluster-randomization, we used multilevel generalized linear mixed-effect models (GLMMs). For all GLMMs, we identified demographic characteristics that may need to be included in the models. In every GLMM, an after-school site was modeled as a random effect nested within the intervention condition, and the intervention condition and time (and their interaction) were modeled as fixed effects. GLMMs use maximum likelihood estimation, producing unbiased estimates when data is assumed to be not missing completely at random.

To conduct GLMMs using a target power of 0.85 and an effect size of 0.23 to perceived risk of vaping with an alpha value of .05, the estimated sample size was 45 participants [31]. We estimated that 75 adolescents would be needed to test the hypotheses, with an anticipated completion rate of approximately 60% (45/75). Considering the pilot nature of this study, this sample size was considered sufficient for the study of short-term secondary outcomes.

First, with GLMMs, we tested for any baseline differences between the 2 conditions with respect to demographic characteristics (eg, age, sex at birth, gender identity, grades at school, number of detentions, parental education level, and perceived skills playing board games). Second, with one-way analyses of variance (ANOVA) and chi-square tests, we examined attrition by testing differences between those retained and those lost to follow-up with respect to the outcome variables at baseline and other potential confounding factors.

Next, with GLMMs, we examined group differences for outcomes of interest. We conducted GLMMs predicting five types of outcomes. Manipulation check outcomes included perceived

social interactivity, attitude toward the program, visual aesthetics, and emotional involvement. Outcomes pertaining to participants' attention to the program included general attention, distraction from the program, and recognition of imagery from the program. Personal experience with the program included perceptions regarding program usability, level of fun, narrative quality in the program, program enjoyment, and creative freedom. Communication outcomes included engagement in discussions and quality of discussions. Tobacco-related outcomes included perceived risk of vaping, perceived risk of conventional tobacco use, and tobacco knowledge. Models predicting tobacco-related outcomes included group assignment, time, and the group-by-time interaction term as predictors. Following these models, we examined the role of attention to the program and personal experience factors in predicting tobacco-related outcomes.

For qualitative data, we conducted a thematic analysis of participants' responses to the open-ended question on engagement in discussion. We aimed to look for themes pertaining to tobacco, the program, or both. Next, we generated a binary variable that indicates if participants positively discussed tobacco or the program.

Results

Participants

In demographics, the average age was 13.55 (SD 1.65) years with 55.56% being 13 years or younger, 58.11% (43/74) being female at birth, and the majority being black or African American (56/72, 77.78%). Approximately 37% (26/70) reported having at least one friend who vapes, and about 13% (9/69) reported having at least one friend who smokes a combustible product. Table 3 presents the demographic characteristics by group.

Table 4: Baseline participants' characteristics

Characteristics	Total Sample (n = 74)	Storm-Heroes	ASPIRE	*P* [a]
Age, n (%)				
13 years or under	40 (55.56%)	19 (48.72%)	21 (63.63%)	0.958
Over 13 years	32 (44.44%)	20 (51.28%)	12 (36.36%)	
Sex at birth, n (%)				
Male	31 (41.89%)	21 (53.85%)	10 (28.57%)	0.826
Female	43 (58.11%)	18 (46.15%)	25 (71.43)	
Race				
Being Black or African American	56 (77.78%)	35 (89.74%)	21 (63.64%)	0.167
Not Black or African American	16 (22.22%)	4 (10.26%)	12 (36.36%)	
Ethnicity, n (%)				
Being Hispanic/Latino	16 (22.22%)	6 (15.38%)	10 (30.30%)	0.963
Not being Hispanic/Latino	56 (77.78%)	33 (84.62%)	23 (69.70%)	
Grades at school, n(%)				
Mostly A	35 (47.95%)	16 (41.03%)	19 (55.88%)	0.310
Mostly B or C	38 (52.05%)	23 (58.97%)	15 (44.12%)	
Parents' Level of Education				
Received a college degree	53 (72.60%)	27 (69.23%)	26 (76.47%)	0.503
Did not receive a college degree	20 (27.40%)	12 (30.77%)	8 (23.53%)	
		Values in M (SD)		*P* [b]

Perceived board game skills	3.45 (0.91)	3.49 (0.84)	3.41 (0.99)	0.820
Number of school detentions				
Number of friends who vape	3.14 (12.32)	1.29 (2.83)	5.34 (17.86)	0.113
Number of friends who smoke	0.68 (2.54)	0.55 (2.390)	0.84 (2.76)	0.522
Perceived risk of vaping	3.15 (0.95)	3.07 (0.97)	3.25 (0.93)	0.493
Perceived risk of conventional tobacco use	3.31 (0.82)	3.26 (0.81)	3.37 (0.84)	0.409
Tobacco Knowledge	10.30 (3.07)	10.45 (3.19)	10.14 (2.99)	0.580

[a]Significance testing with χ^2 test (categorical variables)
[b]Significance testing with ANOVA (continuous variables)

Attrition

No harm or unintended effects occurred in this study. In this study, over 100 adolescents expressed interest, and 79 enrolled, with the 4 sites randomly assigned to either Storm-Heroes or ASPIRE. Of these, 93.67% (74/79) completed the baseline survey. Among baseline participants, 55.40% (41/74) participated in the post-test experience survey, and 60.81% (45/74) participated in the 1.5-month follow-up survey (Figure 2). Participants who did not complete surveys had left the after-school site or did not attend the site on the day of data collection.

Participants in Storm-Heroes were as likely to continue to follow-up assessment as those in ASPIRE (X2(1)=3.24, P=0.072). There were no significant differences between participants who did and those who did not continue to the 1.5-month follow-up with respect to baseline perceived risk of vaping ($F_{1,73}$=3.74, P=0.057), perceived risk of conventional tobacco use ($F_{1,73}$=2.43, P=0.123), tobacco knowledge ($F_{1,58}$=2.40, P=0.127), gender identity (χ^2_2=1.76, *P*=.415), sex at birth (χ^2_1=0.45, *P*=.504), age ($F_{1,76}$=0.94, P=0.335), or perceived skills in playing board games ($F_{1,70}$=0.57, P=0.453).

Manipulation Checks

We checked to make sure that participants expressed positive attitudes towards both interventions equally. There was no significant difference between the two conditions with respect to attitude scores (B=0.76, P=0.072) or visual aesthetics of the program (B=1.28, P=0.138). With both interventions being entertainment-based, there was no significant difference between the conditions with respect to being emotionally involved in the content (B=0.31, P=0.565). As expected, participants who received Storm-Heroes perceived the program to be more socially interactive than those who received ASPIRE (B=5.33, P=0.019).

Checking for Confounders

We tested potential confounding effects of demographic characteristics. There were no significant differential effects on perceived risk of vaping as a function of perceived board game skills, race, and number of detentions. Being younger (P<0.001), being male (P=0.001), being non-Hispanic (P=0.021), having friends who vape (P=0.001), having friends who smoke (P<0.001), and having parents with lower education level (P=0.043) moderated the effect of Storm-Heroes on perceived risk of vaping.

There were no significant differential effects on perceived risk of conventional tobacco use as a function of age, perceived board game skills, ethnicity, race, and number of detentions. Being male (P<0.001), having friends who vape (P<0.001), and having friends who smoke (P<0.001),

and having parents with lower education level (P=0.043) moderated the effect of Storm-Heroes on perceived risk of conventional tobacco use.

There were no significant differential effects on tobacco knowledge as a function of age, ethnicity, race, and number of detentions. Having lower boardgame skills (P<0.001), being female (P=0.001), being non-Hispanic (P<0.001), having friends who vape (P<0.001), and having friends who smoke (P=0.010), and having parents with lower education level (P<0.001) moderated the effect of Storm-Heroes on tobacco knowledge.

Personal Experience

Mixed-effects models controlling for confounders showed that participants who received Storm-Heroes were significantly more likely to be distracted during the program (B=1.36, P=0.002) and less likely to recognize images from the program (B=1.68, P<0.001). However, they were more likely to pay attention to the program than those who received ASPIRE (B=1.30, P=0.016). By examining the interaction between intervention groups and distraction, we found that distraction weakened the effect of Storm-Heroes on recognition of program imagery (B=-0.49, P=0.005).

Participants who received Storm-Heroes found the program to have significantly better usability (B=0.88, P=0.001), higher level of fun (B=4.14, P=0.001), better narrative quality (B=2.66, P=0.001), more enjoyment (B=2.16, P=0.047), and more creative freedom (B=1.90, P=0.047), than participants who received ASPIRE.

Communication Outcomes

Participants who received Storm-Heroes were significantly more likely to talk to others during the program (OR=4.99, P=0.044). They also experienced a better quality of peer-to-peer discussions (B=2.16, P=0.047). According to the open-ended questions about the content of their discussions, participants in Storm-Heroes were significantly more likely to discuss the program and the negative effects of tobacco with their peers than those who received ASPIRE (OR=5.63, P=0.024). By examining the role of social interactivity, it was found that participants who found the program to be socially interactive were almost twice as likely to talk about the program and the negative effects of tobacco (OR=1.98, P=0.002).

Tobacco-related Outcomes

Mixed-effect models indicated that group allocation by time was significantly related to perceived risk of vaping (Group-by-time: B=0.35, P=0.001; Figure 3a). Participants who received Storm-Heroes were significantly more likely to exhibit a higher perceived risk of vaping at follow-up than participants in the ASPIRE condition, controlling for perceived risk of vaping at baseline (B=0.40, P=0.021; Table 5).

Participants in Storm-Heroes were significantly more likely to increase in perceived risk of conventional tobacco than participants in ASPIRE (Group-by-time: B=0.40, P<0.001; Figure 3b). They were significantly more likely to exhibit higher perceived risk of conventional tobacco use at follow-up than participants in the ASPIRE condition, controlling for perceived risk of conventional tobacco at baseline (B=0.35, P=0.046; Table 5).

Participants in Storm-Heroes were significantly more likely to increase in tobacco knowledge than participants in ASPIRE (Group-by-time: B=1.63, P<0.001; Figure 3c). Participants in Storm-Heroes were significantly more likely to exhibit higher tobacco knowledge at follow-up

than participants in the ASPIRE condition, controlling for tobacco knowledge at baseline (B=0.53, P=0.011; Table 5).

Table 5. Multi-level models predicting perceived risk and tobacco knowledge

	Model 1: Predicting perceived risk of vaping at follow-up		Model 2: Predicting perceived risk of conventional tobacco use at follow-up		Model 3: Predicting tobacco knowledge at follow-up	
	B(SE)	P value	B(SE)	P value	B(SE)	P value
Receiving Storm-Heroes	0.40(0.17)	0.021	0.35(0.18)	0.046	1.75(0.56)	0.002
Perceived risk of vaping at baseline	0.60(0.17)	<0.001	-	-		
Perceived risk of conventional tobacco use at baseline	-		0.68(0.19)	<0.001		
Tobacco knowledge at baseline	-		-	-	0.53(0.21)	0.011
Number of detentions	-0.44(0.31)	0.156	-0.28(0.15)	0.062		
Average grades at school	-		-	-	0.93(0.21)	<0.001
Parents' Level of Education	-		-	-	0.76(1.84)	0.679

Note. The models were fitted based on identified key covariates.

Experience Factors Predicting Tobacco-related Outcomes

Controlling for group allocation, the results showed that the usability level of the program was related to a higher perceived risk of vaping (B=0.16, P=0.003) and conventional tobacco use (B=0.16, P=0.025) by follow-up. Attention to the program was also related to higher perceived risk of vaping (B=0.12, P=0.002) and conventional tobacco (B=0.14, P<0.001). Distraction was not related to either perceived risk of vaping (P=0.149) or perceived risk of conventional tobacco use (P=0.709). On the other hand, both, more attention (B=0.60, P<0.001) and less distraction (B=-0.37, P<0.001), were related to higher tobacco knowledge. A follow-up exploratory analysis of moderation indicated that distraction weakened the effect of receiving Storm-Heroes on tobacco knowledge by follow-up (Group-by-distraction: B=-6.67, P<0.001).

Discussion

Conclusions

This paper describes a pilot cluster-randomized comparative trial examining the short-term effectiveness of Storm-Heroes, a social game-based intervention, in improving secondary

tobacco-related outcomes, including perceived risk of tobacco use and tobacco knowledge. The paper also presents results from adolescents' experience with the intervention and its prediction of such outcomes. We hypothesized that adolescents' engagement with Storm-Heroes would result in (1) better quality of program experience, (2) improved perceived risk of vaping and conventional tobacco use, and (3) improved tobacco knowledge compared with the engagement in ASPIRE, a non-social, non-game-based equivalent program.

The increased perceived risk of vaping and conventional tobacco among Storm-Heroes participants aligns with the program's goals of improving participants' awareness of the risks associated with tobacco use. With anti-tobacco messages designed to communicate tobacco risk, Storm-Heroes may have effectively presented the severity of tobacco-related harm. The comprehensive content in Storm-Heroes is designed with key risk communication strategies, including emotionally involving gain-framed and loss-framed messages that cover the psychological, physiological, medical, and environmental consequences of tobacco use [40]. In addition, along with other theoretical frameworks, the program design is grounded in the health belief model and empowerment theory, promoting perceived susceptibility [41] and self-efficacy [42,43]. The game-based social activities in Storm-Heroes allow adolescents to engage in interactive learning experiences that empower them to recognize and internalize the harms of tobacco, motivating them towards tobacco-free lifestyles [21].

The Storm-Heroes group showed a significant increase in tobacco knowledge scores from baseline to 1.5-month follow-up. Knowledge gained among Storm-Heroes participants compared to ASPIRE may be the outcome of both exposure to information within the program and increased motivation to seek information elsewhere (from school teachers, the Internet, etc.). First, by integrating multimedia resources and a proactive learning approach, Storm-Heroes aimed to equip adolescents with comprehensive knowledge. As supported by previous research [40], the program's tobacco education content was carefully designed to cover several key topics (See Multimedia Appendix 1) and promote a holistic understanding of information from a wide array of tobacco products [40]. In addition, the gameplay aspect of Storm-Heroes encourages structured information retention that can support knowledge gain. Second, gameplay and other entertainment-based programming have been shown to stimulate interest in understanding health issues and ultimately promote health information seeking beyond the content of a program [12,44,45]. This information-seeking behavior may ultimately contribute to increased knowledge. In addition to the tobacco-related outcomes, we identified user experience differences between the two programs.

In the context of program experience, our results indicate that participants expressed similar positive attitudes towards both programs, with no significant difference in attitude scores or perceived visual aesthetics. Emotional involvement in the content was also similar between the two groups. However, Storm-Heroes was perceived as more socially interactive than ASPIRE. Supportive of previous research, the similar attitude towards both interventions suggests that entertainment-based approaches, regardless of social interactivity can effectively engage adolescents. However, Storm-Heroes was perceived as more socially interactive than ASPIRE, which aligns with previous findings indicating that interactive elements enhance program appeal [21,46,47]. As supported by the social learning theory and a systematic review of tobacco education programs, incorporating social features into interventions can promote health behavior change by fostering a sense of peer-support for adolescents [48]. Our results suggest that while entertainment-based approaches effectively engage adolescents, perceived social interactivity of Storm-Heroes may play a unique role in its success.

Our results further indicated that participants in the Storm-Heroes program were more likely to engage in conversations with others during the program and experienced better-quality peer-to-peer discussions compared to those in the ASPIRE program. They were more likely to discuss the program and the harm of tobacco use. This suggests that Storm-Heroes may have included strategies that successfully encourage healthy dialogues among participants. Theoretical frameworks such as the extended-elaboration likelihood model [49] support the ability of entertainment-based programming to promote healthy interpersonal discussions. This has been particularly evident when it comes to sensitive health topics such as contraceptive use, organ donation, and underage tobacco use [45,50-52]. Our results show that participants who found the program to be socially interactive were more likely to engage in healthy discussions. In line with the social learning theory, social interaction can facilitate social modeling and promote healthy learning [53,54]. Future research could further investigate the mechanisms that allow Storm-Heroes to drive these communication outcomes.

Participants who received Storm-Heroes were more likely to be distracted during the program and less likely to recall images from it. Nevertheless, they were more attentive overall compared to ASPIRE recipients. While Storm-Heroes led to more distractions and lower image recall, its higher attention levels imply deeper engagement despite potential distractions. However, the challenge lies in balancing engagement with lower distractions, as distractions may undermine the program's effectiveness. While distraction did not significantly impact perceived risk of vaping or conventional tobacco use, it was negatively associated with tobacco knowledge, thereby hindering adolescents' learning and retention of information. Future research should focus on implementation strategies to minimize distraction for Storm-Heroes. For example, using a flipped classroom approach can allow adolescents to receive tobacco-related information at home through entertaining videos, and engage in social activities in class to practice what they learned [55] .This implementation strategy can reduce cognitive load, thereby optimizing engagement without compromising health education [56].

Limitations

This study ended with a relatively low retention rate (45/74, 60.8%). By the time this study reached 1.5-month follow-up, adolescents were at a transition out of the after-school summer period, entering the fall semester, and ultimately, several of them were not available to continue in the study. However, this did not stop 45 participants from reaching the 1.5-month follow-up assessment, and providing acceptable power for data analysis. In addition, our use of repeated-measures mixed effect modeling allowed us to account for missing data. Nevertheless, future work with adolescents may need to consider a larger sample size with a more suitable timing for data collection and a more controllable environment, such as school class sessions.

While this study showed a change in short-term outcomes (i.e., tobacco risk perception and knowledge), we did not examine a long-term change in tobacco use behavior. It must be noted, though, that this early pilot trial was meant to test the potential for adolescents' experience with Strom-Heroes to drive risk perception and knowledge. The current study did not inspect specific types of discussions engaged by adolescents as a result of their interaction. However, the results indicated relationships between exposure to Storm-Heroes and engagement in discussions related to the program and against tobacco.

From an implementation perspective, this study required the staff members to deliver the program to each classroom and moderate the sessions. This approach can limit wider reach

and dissemination. Future efforts should adapt the procedures to allow teachers to deliver the program. Using Proctor's Framework for Implementation Outcomes, we can assess the program by evaluating teachers' adherence to key steps, engagement quality, satisfaction, and perceived feasibility.

Implications

The results of this study suggest that Storm-Heroes can be a promising intervention for tobacco prevention. Nevertheless, we must further examine strategies that may allow us to minimize distractions while maximizing engagement to boost the success of this intervention. Once the design of this program is clear, it becomes possible to further investigate its success by examining its long-term effects on actual tobacco use. Additionally, promoting peer-to-peer interactions can improve the impact of such interventions by facilitating knowledge dissemination and perceived tobacco risks. In the long run, going beyond these short-term outcomes, randomized trials with longitudinal data collection can provide valuable insights into the success of Storm-Heroes in preventing actual initiation of tobacco use and identify the factors that may promote long-term prevention outcomes. Second, future researchers can work to identify the specific program components and delivery methods that contribute to enhancing adolescents' experience and improving tobacco-related outcomes. Also, by identifying effective components responsible for an improved program experience, we can design novel interventions that can be tailored to target specific groups of adolescents and address their unique needs concerning different tobacco products.

Acknowledgements

We would like to thank all research members from the University of Florida for their contributions to the success of this trial. Research reported in this publication was supported by the National Institute on Drug Abuse of the National Institutes of Health under Award Number R00DA044277 (Principal Investigator: Georges Khalil, MPH, PhD). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Authors' Contributions

GK is responsible for the design of the study; NR and PB provided guidance on the design of the study; GK was responsible for the data collection, acquisition, and analysis; MK and ER participated in the data collection and implementation of the study procedure; GK, ER, MK, BZ, NR, and PB contributed to the conceptualization and design of the paper; GK drafted the paper; GK, ER, MK, BZ, NR, and PB critically revised the paper. All authors read and approved the final version.

Conflicts of Interest

There are no conflicts of interest for this study.

Data Availability

The data sets generated during and analyzed during this study are available from the corresponding author upon reasonable request.

Abbreviations

ASPIRE: a smoking prevention interactive experience
CONSORT: consolidated standards of reporting trials
CONSORT-EHEALTH: consolidated standards of reporting trials of electronic and mobile health applications and online telehealth
TIDieR: template for intervention description and replication
TTM: transtheoretical model
MSI: Minnesota smoking index
GUESS: game user experience satisfaction scale

Multimedia Appendix Captions

Multimedia Appendix 1. A description of the interventions based on the template for intervention description and replication (TIDieR) checklist.
Multimedia Appendix 2. CONSORT-EHEALTH.

References

1. CDC. Tobacco Product Use Among U.S. Middle and High School Students — National Youth Tobacco Survey, 2023. https://www.cdc.gov/mmwr/volumes/72/wr/mm7244a1.htm.
2. Perez A, N'Hpang R S, Callahan E, et al. Age at Initiation of Cigarette Use in a Nationally Representative Sample of US Youth, 2013-2017. *JAMA Netw Open*. Feb 1 2021;4(2):e210218. doi:10.1001/jamanetworkopen.2021.0218
3. Richmond-Rakerd LS, Slutske WS, Wood PK. Age of initiation and substance use progression: A multivariate latent growth analysis. *Psychol Addict Behav*. Sep 2017;31(6):664-675. doi:10.1037/adb0000304
4. Albaugh MD, Ottino-Gonzalez J, Sidwell A, et al. Association of Cannabis Use During Adolescence With Neurodevelopment. *JAMA Psychiatry*. Jun 16 2021;78(9):1-11. doi:10.1001/jamapsychiatry.2021.1258
5. Hansen K, Lindstrom M, Rosvall M. Age at smoking initiation and self-rated health among second grade high school boys and girls in Scania, Sweden, a cross-sectional study. *BMC Public Health*. Nov 18 2015;15:1143. doi:10.1186/s12889-015-2457-z
6. CDC. Fast facts and fact sheets. https://www.cdc.gov/tobacco/data_statistics/fact_sheets/youth_data/tobacco_use/index.htm
7. CDC. Youth and Tobacco Use. Centers for Disease Control and Prevention. https://www.cdc.gov/tobacco/data_statistics/fact_sheets/youth_data/tobacco_use/index.htm.
8. Singhal A, Cody MJ, Rogers EM, Sabido M. *Entertainment-education and social change: History, research, and practice*. Routledge; 2003.
9. Khalil GE. When Losing Means Winning: The Impact of Conflict in a Digital Game on Young Adults' Intentions to Get Protected from Cancer. *Games Health J*. Aug 2012;1(4):279-86. doi:10.1089/g4h.2012.0017
10. Khalil GE. Fear and Happiness in “Re-Mission”: Teasing Out Emotional Gaming Events Responsible for Cancer Risk Perception. Springer Fachmedien Wiesbaden; 2013:27-44.
11. Watson AM, Alber JM, Barnett TE, Mercado R, Bernhardt JM. Content Analysis of Anti-Tobacco Videogames: Characteristics, Content, and Qualities. *Games Health J*. Jun 2016;5(3):216-23. doi:10.1089/g4h.2015.0096
12. Khalil GE, Beale IL, Chen M, Prokhorov AV. A Video Game Promoting Cancer Risk Perception and Information Seeking Behavior Among Young-Adult College Students: A Randomized Controlled Trial. *JMIR Serious Games*. Jul 28 2016;4(2):e13. doi:10.2196/games.5793
13. Peskin MF, Markham CM, Shegog R, Baumler ER, Addy RC, Tortolero SR. Effects of the It's Your Game . . . Keep It Real program on dating violence in ethnic-minority middle school youths: a group randomized trial. *Am J Public Health*. Aug 2014;104(8):1471-7. doi:10.2105/ajph.2014.301902
14. Tortolero SR, Markham CM, Peskin MF, et al. It's Your Game: Keep It Real: delaying sexual behavior with an effective middle school program. *J Adolesc Health*. Feb 2010;46(2):169-79. doi:10.1016/j.jadohealth.2009.06.008
15. Wise K, Kobayashi K, Magnusson J, Welch D, Searchfield GD. Randomized Controlled Trial of a Perceptual Training Game for Tinnitus Therapy. *Games Health J*. Apr 2016;5(2):141-9. doi:10.1089/g4h.2015.0068
16. Pentz MA, Hieftje KD, Pendergrass TM, et al. A videogame intervention for tobacco product use prevention in adolescents. *Addict Behav*. Apr 2019;91:188-192. doi:10.1016/j.addbeh.2018.11.016
17. Derksen ME, van Strijp S, Kunst AE, Daams JG, Jaspers MWM, Fransen MP. Serious games for smoking prevention and cessation: A systematic review of game elements and game

effects. *J Am Med Inform Assoc*. May 1 2020;27(5):818-833. doi:10.1093/jamia/ocaa013
18. Guo JL, Hsu HP, Lai TM, Lin ML, Chung CM, Huang CM. Acceptability Evaluation of the Use of Virtual Reality Games in Smoking-Prevention Education for High School Students: Prospective Observational Study. *J Med Internet Res*. Sep 28 2021;23(9):e28037. doi:10.2196/28037
19. Weser VU, Duncan LR, Sands BE, et al. Evaluation of a virtual reality E-cigarette prevention game for adolescents. *Addict Behav*. Nov 2021;122:107027. doi:10.1016/j.addbeh.2021.107027
20. Hieftje KD, Fernandes CF, Lin IH, Fiellin LE. Effectiveness of a web-based tobacco product use prevention videogame intervention on young adolescents' beliefs and knowledge. *Subst Abus*. 2021;42(1):47-53. doi:10.1080/08897077.2019.1691128
21. Khalil GE, Kim J, McLean D, Ramirez E, Zhao B, Salloum RG. Identifying adolescents' gaming preferences for a tobacco prevention social game: A qualitative study. *PLoS One*. 2023;18(7):e0289319.
22. Orji R, Vassileva J, Mandryk R. Towards an effective health interventions design: an extension of the health belief model. *Online J Public Health Inform*. 2012;4(3)doi:10.5210/ojphi.v4i3.4321
23. Eysenbach G. Improving the quality of Web surveys: the Checklist for Reporting Results of Internet E-Surveys (CHERRIES). *J Med Internet Res*. Sep 29 2004;6(3):e34. doi:10.2196/jmir.6.3.e34
24. Eysenbach G, Group C-E. CONSORT-EHEALTH: improving and standardizing evaluation reports of Web-based and mobile health interventions. *J Med Internet Res*. Dec 31 2011;13(4):e126. doi:10.2196/jmir.1923
25. Hoffmann TC, Glasziou PP, Boutron I, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *BMJ : British Medical Journal*. 2014;348:g1687. doi:10.1136/bmj.g1687
26. Khalil GE, Wang H, Calabro KS, Mitra N, Shegog R, Prokhorov AV. From the experience of interactivity and entertainment to lower intention to smoke: A randomized controlled trial and path analysis of a web-based smoking prevention program for adolescents. *J Med Internet Res*. 2017;19(2):e44.
27. Prokhorov AV, Kelder SH, Shegog R, et al. Impact of A Smoking Prevention Interactive Experience (ASPIRE), an interactive, multimedia smoking prevention and cessation curriculum for culturally diverse high-school students. *Nicotine Tob Res*. Sep 2008;10(9):1477-85. doi:10.1080/14622200802323183
28. Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. *Am J Health Promot*. 1997;12(1):38-48.
29. Shete SS, Wilkinson AV. Identifying demographic and psychosocial factors related to the escalation of smoking behavior among Mexican American adolescents. *Prev Med*. Jun 2017;99:146-151. doi:10.1016/j.ypmed.2017.02.018
30. Johnston LD, O'Malley PM, Bachman JG. Monitoring the future: National results on adolescent drug use: Overview of key findings. *Focus (Madison)*. 2003;1(2):213-234.
31. Prokhorov AV, Calabro KS, Arya A, et al. Mobile Text Messaging for Tobacco Risk Communication Among Young Adult Community College Students: Randomized Trial of Project Debunk. *JMIR Mhealth Uhealth*. Nov 24 2021;9(11):e25618. doi:10.2196/25618
32. Coursaris CK, Sung J. Antecedents and consequents of a mobile website's interactivity. *New Media & Society*. 2012;14(7):1128-1146. doi:10.1177/1461444812439552
33. Brunet J, Fredette M. Brand Placement in Virtual Environments: Impact of Flow on Brand Recognition and Recall A. Forest-Boucher. *Les Cahiers du GERAD ISSN*. 2008;711:2440.
34. Keebler JR, Shelstad WJ, Smith DC, Chaparro BS, Phan MH. Validation of the GUESS-18: a short version of the Game User Experience Satisfaction Scale (GUESS). *Journal of Usability*

Studies. 2020;16(1):49.
35. Phan MH, Keebler JR, Chaparro BS. The Development and Validation of the Game User Experience Satisfaction Scale (GUESS). *Hum Factors*. Dec 2016;58(8):1217-1247. doi:10.1177/0018720816669646
36. Hess U, Kleck RE. Differentiating emotion elicited and deliberate emotional facial expressions. *Eur J Soc Psychol*. 1990;20(5):369-385.
37. Collins RL, Eberhart NK, Estrada-Darley I, Roth EA. *Evaluation of Los Angeles County's Fall 2020 WhyWeRise Mental Health Campaign and WeRise 2021*. RAND; 2022.
38. Davis KC, Shafer PR, Rodes R, et al. Does digital video advertising increase population-level reach of multimedia campaigns? Evidence from the 2013 tips from former smokers campaign. *J Med Internet Res*. 2016;18(9):e5683.
39. Duke JC, Alexander TN, Zhao X, et al. Youth's awareness of and reactions to the real cost national tobacco public education campaign. *PLoS One*. 2015;10(12):e0144827.
40. Khalil GE, McLean D, Ramirez E, et al. Developing a text-message library for tobacco prevention among adolescents: A qualitative study. *PLoS One*. 2024;19(1):e0296503.
41. Mohammadi S, Ghajari H, Valizade R, et al. Predictors of smoking among the secondary high school boy students based on the health belief model. *Int J Prev Med*. 2017;8(1):24.
42. Park E, Chang Y-P. Using Digital media to empower adolescents in smoking prevention: mixed methods study. *JMIR Pediatrics and Parenting*. 2020;3(1):e13031.
43. Trisnowati H, Ismail D, Padmawati RS. Health promotion through youth empowerment to prevent and control smoking behavior: a conceptual paper. *Health Educ*. Mar 10 2021;121(3):275-294. doi:10.1108/He-09-2020-0092
44. Beale IL, Kato PM, Marin-Bowling VM, Guthrie N, Cole SW. Improvement in cancer-related knowledge following use of a psychoeducational video game for adolescents and young adults with cancer. *J Adolesc Health*. 2007;41(3):263-270.
45. Khalil GE, Rintamaki LS. A televised entertainment-education drama to promote positive discussion about organ donation. *Health Educ Res*. Apr 2014;29(2):284-96. doi:10.1093/her/cyt106
46. Hickey A. *An Adolescents Peer-led Motivational Interviewing Intervention Conducted in Low Socio-Economic Community Youth Organisations to Change Health Risk behaviours (Smoking, Alcohol and Sedentary Behaviours)*. University of Dublin; 2024.
47. Khalil GE, Prokhorov AV. Friendship influence moderating the effect of a web-based smoking prevention program on intention to smoke and knowledge among adolescents. *Addict Behav Rep*. Jun 2021;13:100335. doi:10.1016/j.abrep.2020.100335
48. Peirson L, Ali MU, Kenny M, Raina P, Sherifali D. Interventions for prevention and treatment of tobacco smoking in school-aged children and adolescents: a systematic review and meta-analysis. *Prev Med*. 2016;85:20-31.
49. Moyer-Gusé E, Chung AH, Jain P. Identification with characters and discussion of taboo topics after exposure to an entertainment narrative about sexual health. *J Commun*. 2011;61(3):387-406.
50. Boulay M, Storey JD, Sood S. Indirect exposure to a family planning mass media campaign in Nepal. *Journal of health communication*. 2002;7(5):379-399.
51. Lozare B, Hess R, Yun S, et al. Husband-wife communication and family planning: impact of a national television drama. *American Public Health Association*. 1993;
52. Papa MJ, Singhal A, Law S, et al. Entertainment-education and social change: an analysis of parasocial interaction, social learning, collective efficacy, and paradoxical communication. *J Commun*. 2000;50(4):31-55.
53. Hill JR, Song L, West RE. Social learning theory and web-based learning environments: A review of research and discussion of implications. *The Amer Jrnl of Distance Education*. 2009;23(2):88-103.

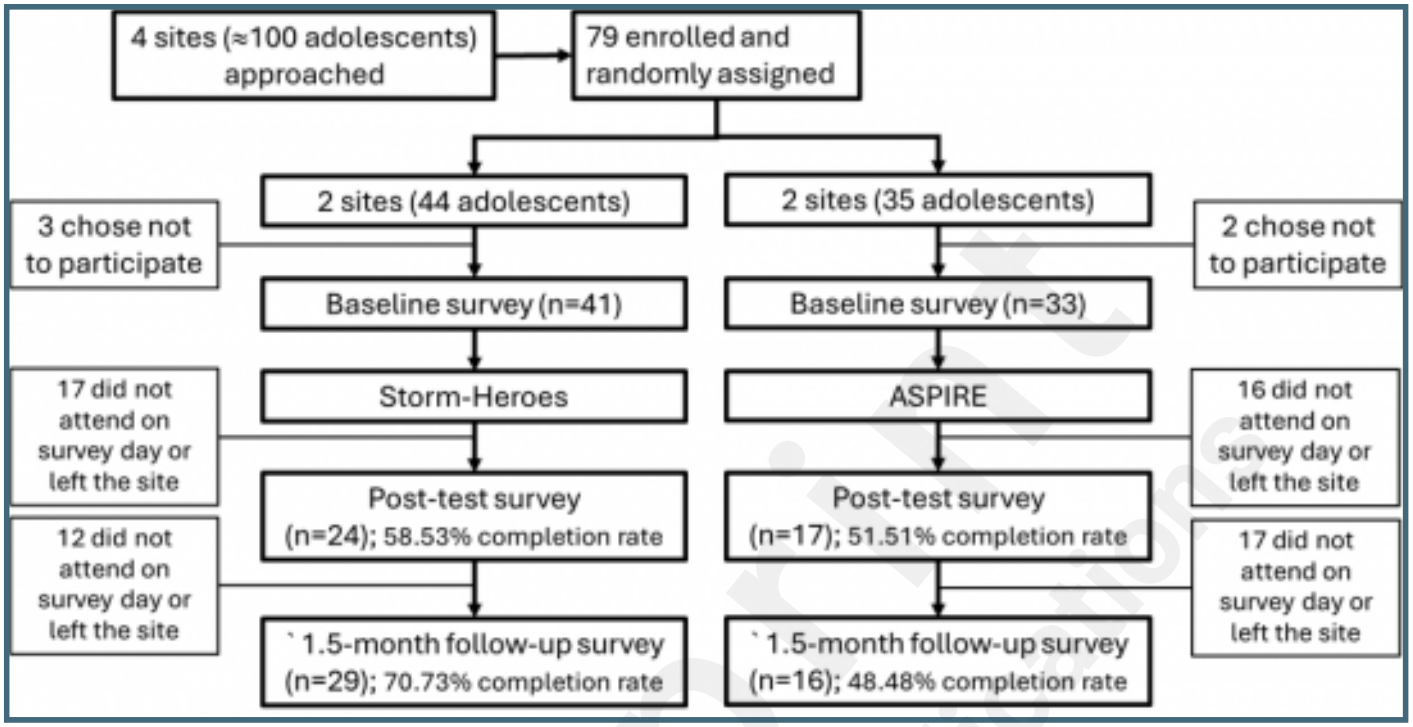
54. Murray FB. Learning and development through social interaction and conflict: A challenge to social learning theory. *Piaget and the foundations of knowledge*. Psychology Press; 2014:231-247.
55. Hew KF, Bai S, Dawson P, Lo CK. Meta-analyses of flipped classroom studies: A review of methodology. *Educational Research Review*. 2021;33:100393.
56. Amorim MBF, de Moraes ARB, de Souza DKD, et al. Benefits of the flipped classroom in health education-a systematic review. *Brazilian Journal of Health Review*. 2020;3(6):17428-17437.

Supplementary Files

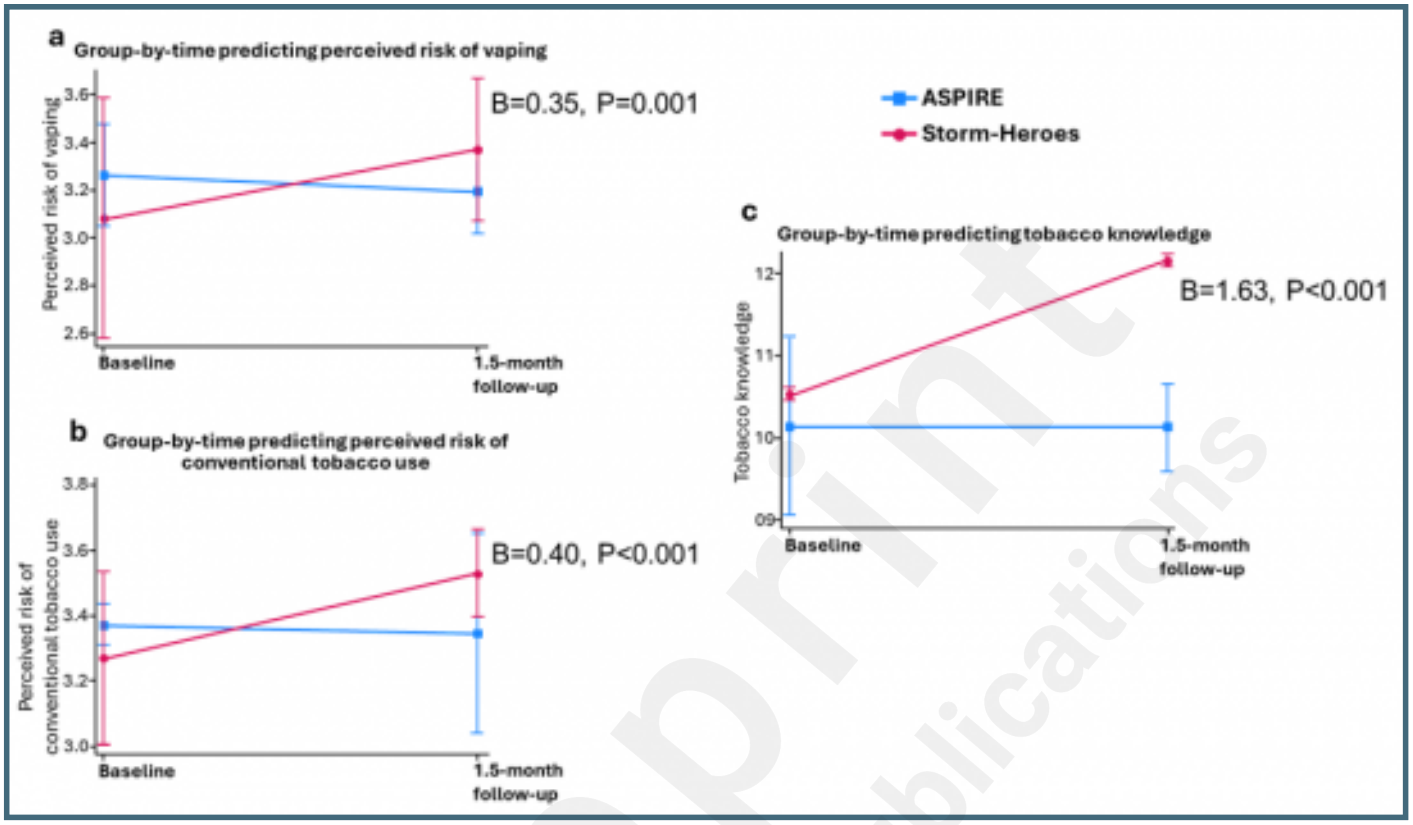
Figures

Depiction of Storm-Heroes activities and game board.

CONSORT (Consolidated Standards of Reporting Trials) flow diagram. ASPIRE: A Smoking Prevention Interactive Experience. Participants were allowed to participate in any survey assessment over time.



Adjusted predictions of condition-by-time. Coefficients and P values show significance of the group-by-time interaction effect. Perceived risk measures can range between 1 and 4, while tobacco knowledge can range between 0 and 22.



Multimedia Appendixes

A description of the interventions based on the template for intervention description and replication (TIDieR) checklist.
URL: http://asset.jmir.pub/assets/b7f6b9c38701146434586534aee2cf75.docx

The CONSORT-EHEALTH checklist.
URL: http://asset.jmir.pub/assets/8bbfa12b96bb8691a285730942cb1c27.pdf

TOC/Feature image for homepages

The cover image of the game Storm-Heroes.