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Effectiveness of a web-based tobacco product use prevention videogame intervention on young adolescents' beliefs and knowledge

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ABSTRACT

Background: Preventing tobacco product initiation in youth is a critical need. While cigarette smoking among youth has been on the decline, tobacco use in other forms, such as e-cigarettes and vaping, continue to be a major concern. The purpose of this study was to conduct a real-world, quasi-experimental test of the effectiveness of a web-based videogame, *smokeSCREEN*, aimed at developing healthy beliefs and knowledge associated with tobacco product use prevention, including electronic cigarettes. **Methods:** Adolescents ($N=560$) aged 10–16 years were enrolled from schools and afterschool programs in a single-group pre–post study. Measures included a pre- and post-survey of beliefs and knowledge about tobacco product use. At post-survey, participants were asked questions regarding their gameplay experience. Paired responses for the tobacco product use in the beliefs and knowledge survey before and after the *smokeSCREEN* videogame intervention were compared using McNemar's test. Descriptive statistics were generated to assess overall participant gameplay experience. **Results:** McNemar's test showed significant differences in the proportions of correct answers before (pre-survey) and after (post-survey) the intervention in seven out of eight belief questions ($p < .0001$). It also suggested significant differences in the proportions of correct answers before (pre-survey) and after (post-survey) the intervention in all six knowledge questions ($p < .0001$). Several gender and age differences were noted for belief and knowledge questions related to e-cigarettes and vaping. There was no association between gameplay duration at post-survey or to the answers of the beliefs or knowledge questions. Overall, participants reported that they enjoyed playing the game. **Conclusions:** Findings suggest that the videogame intervention, *smokeSCREEN*, has a promising effect on participants' beliefs and knowledge about tobacco product use, including electronic cigarettes and vaping, and is well accepted by adolescents.

KEYWORDS



Adolescent; tobacco; videogame; electronic cigarettes; vaping; intervention

Introduction

Tobacco use is the leading cause of preventable disease and death in the United States and is linked to cancer and cardiovascular diseases. Nicotine delivery systems include cigarettes, cigars, smokeless tobacco, electronic cigarettes (e-cigarettes), vaping devices, hookahs, pipe tobacco, and bidis.¹ While there has been a decline in the prevalence of combustible cigarette smoking among youth and adults,² tobacco use in other forms remains a major concern among adolescents. In 2016, 3.9 million middle/high school students used at least one tobacco product in the past 30 days and approximately 45% of middle/high school students used two or more tobacco products in the past 30 days.¹ Of particular interest, e-cigarettes have emerged as an appealing tobacco product among youth³ due, in part, to their appealing flavors^{4–6} and perception that they are safer than other products.^{7–9} E-cigarette and vaping devices, including the

popular brand, JUUL, deliver nicotine, flavorings, and other additives to users via an inhaled aerosol.² These devices, such as JUUL, are not necessarily replacing cigarette smoking but rather encouraging it. A 2017 study found that non-smokers were four times more likely to start smoking traditional cigarettes after only 18 months of vaping, which includes the use of JUUL.¹⁰ The increased harm of JUUL compared to other e-cigarettes is important to emphasize, given its high concentration of nicotine. This increases the risk of addiction, with nicotine being as addictive as cocaine and even more addictive than alcohol and barbiturates.¹¹ Given that more than 80% of adult smokers begin using some type of tobacco product before the age of 18, there is a critical need for prevention interventions targeting adolescence.

With 90% of adolescents aged 13–17 playing videogames on computers, game consoles and cellphones,¹² videogaming

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has emerged as a promising approach in education and has been shown to improve health and safety behaviors in youth.^{13,14} For this reason, videogame interventions, such as *smokeSCREEN*,¹⁵ an evidence-informed and theory-based tobacco use prevention intervention for adolescents, may positively impact psychological factors associated with behavior change. Developed as a prototype of a web-based videogame intervention focused on the prevention of tobacco use, *smokeSCREEN* was designed to increase knowledge and improve refusal skills. While earlier versions of *smokeSCREEN* have been evaluated in pilot studies within controlled settings,^{15,16} the purpose of this real-world, quasi-experimental study was to examine the effectiveness of the game on several outcomes, including participants' beliefs and knowledge of tobacco product use. Another important focus of this study was to examine feasibility and data collection procedures in order to further modify the game for a subsequent larger study. A secondary outcome was to collect data on participants' gameplay experience to also inform further modification of the game.

Methods

Study design

This real-world, quasi-experimental study was a single-group pretest–posttest design to evaluate the effectiveness of a web-based videogame intervention *smokeSCREEN* played by adolescents from schools and afterschool programs in Rhode Island, Massachusetts, California, and Arizona. Survey data were collected between October 2017 and April 2018 and analyzed in September 2018. Gameplay was conducted during school and afterschool programs. Given that the study was conducted remotely, the number of gameplay sessions or length of gameplay and was not monitored by the research team. A pretest survey was completed by participants individually through a secured, online data collection website (Qualtrics Data Collection Software). After completion of this survey, participants were provided access to the videogame intervention through a private, password-protected website. An online post-survey on the same secured, online data collection website was then completed at the end of each participant's gameplay as instructed by the participants' teacher or afterschool program leader. All procedures were approved by the Human Investigation Committee at Yale University School of Medicine (HIC# 1401013293).

Participants

Inclusion criteria for participants in the study were: (1) English-speaking, (2) 10–16 years of age, (3) willing to sit at a computer, tablet, or smartphone and play a videogame for 45–60 minutes at a time, and (4) enrolled in a school or afterschool youth program in Rhode Island, Massachusetts, California, or Arizona. Participants and parents/guardians received written information about the study with the ability to opt-out of having their child participate. Written assent/consent was waived. Participants were provided unique

identification numbers (IDs) by their teachers and programs leaders and they were used for the duration of the study.

Intervention

smokeSCREEN is a web-based, theory- and evidence-informed videogame intervention focused on tobacco use prevention in adolescents.¹⁵ Guided by the social cognitive theory and the theory of planned behavior, *smokeSCREEN* addresses a range of challenges that teens face involving peer pressure and the use of tobacco products with a focus on combustible cigarettes, electronic cigarettes, and flavored tobacco. The game gives teens the opportunity to develop important skills by playing two mini-games, *Refusal Power* and *Know Sense*. *Refusal Power* allows teens to practice refusing peers in risky situations involving tobacco products, with a targeted emphasis on vaping and the use of JUUL. *Know Sense* provides teens knowledge related to tobacco use and then the opportunity to role play and apply that knowledge in a “battle of the wits” with their peers (Figure 1). In both mini-games, content is focused on correcting participants' misperceptions and misinformation around tobacco use products. Participants were given access to the *smokeSCREEN* game through a private, password-protected website link and instructed to complete the game, which consisted of 10 unique game levels. The total time to complete all of the levels was between 1 and 2 hours and could be completed over several program or class sessions.

Outcome measures

Demographic characteristics (e.g., age, grade, gender, ethnicity, and race) were collected in the pre-survey. Pre- and post-surveys consisted of eight questions related to beliefs and six questions related to knowledge about cigarettes, e-cigarettes, and flavored tobacco, both adapted from the National Youth Tobacco Survey (2014).¹⁷ For beliefs, Likert-type questions were used with four to five choices ranging from “strongly disagree” to “strongly agree” or “definitely yes” to “definitely not,” or five response choices ranging from “very unlikely” to “very likely.” For knowledge, questions had three response choices (yes, no, and not sure). The post-survey included an additional five items on gameplay experience from items designed for a previous videogame study on sexual risk reduction in young adolescents¹⁸ (e.g., “I would tell my friends to play this game,” four response choices, ranging from “strongly disagree” to “strongly agree”).

Statistical analyses

Descriptive statistics were used to generate participant baseline characteristics (e.g., age, grade, gender, race, and ethnicity). Paired responses for the tobacco product use in beliefs and knowledge survey before and after the *smokeSCREEN* videogame intervention were compared using McNemar's test. Generalized Estimating Equations (GEE) model for binary outcome was conducted to assess the association between age, gender, and the answers to the beliefs and knowledge of tobacco product use. Given the use of the



Figure 1. Screenshot from the tobacco use prevention intervention prototype, *smokeSCREEN*.

GEE model for analysis, we used a continuous scale for age and did not define a specific cutoff for older or younger ages. We also used the GEE model to measure the association between gameplay duration and the answers to the beliefs and knowledge of tobacco product use. The model was also used to assess the association between beliefs and knowledge among participants who enjoyed/did not enjoy the game. SAS software (version 9.4; SAS Institute, Cary, NC) was used for all analyses with p -value $< .05$ as significant level. A logistic regression model was used to examine whether gameplay experience varied by gender and/or age. Descriptive statistics were generated to assess overall player experience.

Results

Demographic characteristics

A total of 835 participants completed the pre-survey and 609 participants completed the post-survey. Merging of the pre-survey and post-survey participants resulted in a final sample size of 560 participants who completed both the pre- and post-survey on which the current analysis is based (Figure 2). The baseline demographic characteristics of participants are shown in Table 1. Although inclusion criteria included an age range of 10–16, no participants between the

ages of 14 and 16 were enrolled. Given that the study was a real-world, quasi-experimental study, we did not control the age of participants who were enrolled. Average duration of gameplay provided from the post-survey data was 88.2 min.

Changes in beliefs and knowledge about tobacco product use

There were differences in the proportions of correct answers before (pre-survey) and after (post-survey) the intervention for seven out of eight questions about beliefs (all p -values $< .0001$). There was no change in the belief that smoking cigarettes is harmful to one's health in pre- and post-survey ($p = .06$). There were differences in the proportions of correct answers before (pre-survey) and after (post-survey) the intervention for all six knowledge questions ($p < .0001$) (Table 2).

Impact of gender and age on beliefs and knowledge related to e-cigarettes

We evaluated the impact of gender (male, female and prefer to self-describe) and age (10–13 years) on beliefs and knowledge related to tobacco use. Given the rapid increase of e-cigarette use in youth,³ we focused on important findings regarding questions related specifically to e-cigarettes and vaping.

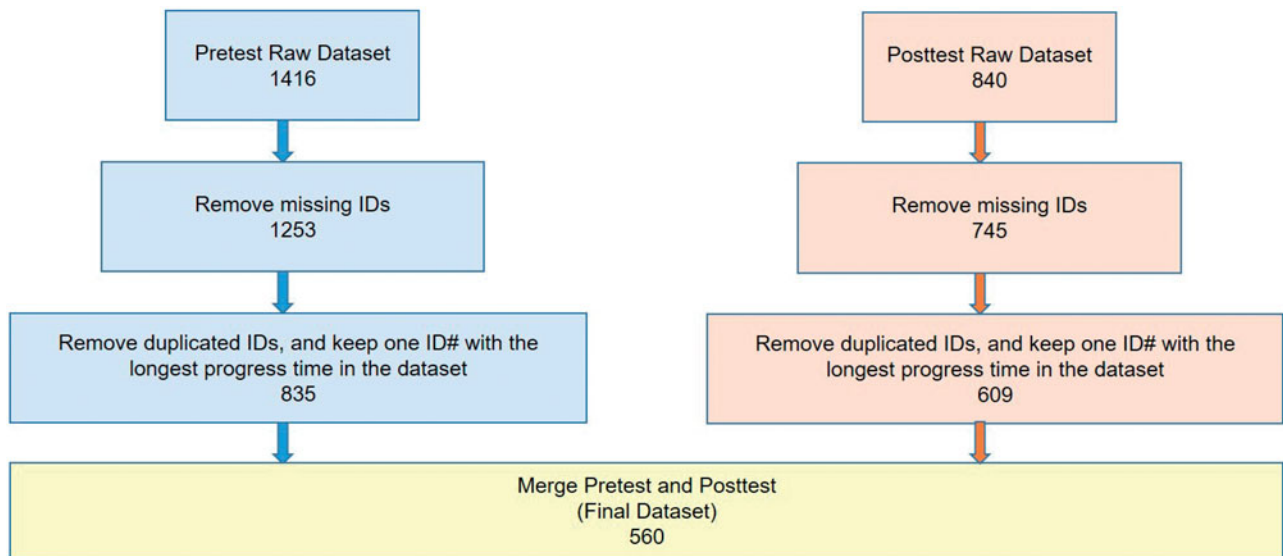


Figure 2. Sample size flow chart.

Table 1. Baseline demographic characteristics of *smokeSCREEN* videogame participants.

Characteristic	Total, $N = 560$
Gender, Female ($n, \%$)	300/560 (53.6%)
Age, mean (SD) (range), years	11.9 (2.0) (10–13)
Race	
White ($n, \%$)	185/559 (33.1%)
Black ($n, \%$)	87/559 (15.6%)
Asian	73/559 (13.1%)
Native Hawaiian/Other Pacific Islander	7/559 (1.3%)
Multi-racial ($n, \%$)	190/559 (34%)
Ethnicity	
Hispanic ($n, \%$)	168/559 (30.1%)
Non-Hispanic ($n, \%$)	391/559 (69.9%)

Beliefs related to e-cigarettes and vaping

For beliefs related to e-cigarettes and vaping, participants who preferred to self-describe, as compared to females, were more likely to think that e-cigarettes were not dangerous [OR = 8.30 (2.60–26.49)]. There was no significant difference in the beliefs of males compared to those of females or to those who preferred to self-describe. Participants who preferred to self-describe were more likely to think that once a teen has started using e-cigarettes, it is difficult for them to quit when compared to females [OR = 8.58 (2.75–26.74)] and males were more likely to have the same belief when compared to participants who preferred to self-describe [OR = 0.18 (0.06–0.56)]. For the same question, older participants were more likely to have the same belief when compared to younger participants [OR = 0.86 (0.75–0.99)]. Older participants, compared to younger participants, were more likely to think that a teen is likely to become addicted to e-cigarettes [OR = 0.84 (0.76–0.92)].

Knowledge related to e-cigarettes and vaping

There was no association between gender and knowledge related to e-cigarettes and vaping. For age, older participants were more likely to know that e-cigarettes have nicotine in

them when compared to younger participants [OR = 0.83 (0.78–0.90)]. For older participants, when compared to younger participants, they were more likely to know that companies that sell tobacco products, including e-cigarettes, target mostly adults by using candy flavors [OR = 0.89 (0.83–0.95)]. Older participants were also more likely to know that teens that use e-cigarettes often use other tobacco products when compared to younger participants [OR = 0.92 (0.88–0.98)].

Impact of gameplay duration

There was no association between gameplay duration and beliefs or knowledge.

Player gameplay experience (post-survey only)

Following gameplay, participants responded to five questions related to their gameplay experience. For player gameplay experience, 59.8% of participants stated that they would play the game again; 69.1% stated that they enjoyed the game; 76.4% stated that they learned something new from playing this game; 55.9% stated that the game was challenging; and, 58.2% stated that they would tell their friends to play the game.

Females were more likely [OR = 1.84 (1.27–2.66)] to enjoy playing the game than males and more likely [OR = 1.59 (1.06–2.38)] to state that they learned something new from playing the game. Males were more likely [OR = 4.11 (1.06–15.88)] to feel that the game was challenging than participants that preferred to self-describe. Multivariate logistic regression model showed that there was no interaction between age and gender on gameplay experience.

Additionally, there was no difference between those who enjoyed playing the game and those that did not enjoy playing for all belief and knowledge questions before and after playing the game.

Table 2. Impact of *smokeSCREEN* gameplay on beliefs and knowledge of tobacco product use.

Beliefs	Pre-game N (%) Yes	Post-game N (%) Yes	From Pre Yes to Post No	From Pre No to Post Yes	p-value
Do you think cigarettes are dangerous?	526 (93.9%)	544 (97.1%)	4 (0.7%)	28 (5.0%)	<.0001
Do you think e-cigarettes are dangerous?	497 (88.8%)	530 (94.6%)	9 (1.6%)	46 (8.2%)	<.0001
Do you think smoking cigarettes is harmful to your health?	531 (94.8%)	536 (95.7%)	12 (2.1%)	22 (3.9%)	.06
Do you think smoking e-cigarettes is harmful to your health?	495 (88.4%)	528 (94.3%)	11 (2.0%)	47 (8.4%)	<.0001
Once a teen has started using e-cigarettes, do you think it would be difficult for them to quit?	467 (83.4%)	514 (91.8%)	22 (3.9%)	71 (12.7%)	<.0001
How likely is a teen to become addicted to cigarettes?	434 (77.5%)	500 (89.3%)	23 (4.1%)	93 (16.6%)	<.0001
How likely is a teen to become addicted to e-cigarettes?	403 (72.0%)	476 (85.0%)	26 (4.6%)	101 (18.0%)	<.0001
How likely do you think teens are influenced by seeing others use cigarettes or e-cigarettes on social media (i.e. Instagram, movies, television)?	408 (72.9%)	485 (86.6%)	24 (4.3%)	104 (18.6%)	<.0001
Knowledge	Pre-game N (%) Correct Answer	Post-game N (%) Correct Answer	From Pre Correct Answer to Post Incorrect answer/not sure	From Pre Incorrect answer/not sure to Post Correct Answer	p-value
Most e-cigarettes have nicotine, the highly addictive drug found in cigarettes, in them.	309 (55.2%)	427 (76.3%)	34 (6.1%)	156 (27.9%)	<.0001
Companies that sell tobacco products, including e-cigarettes, target mostly adults by using candy flavors.	189 (33.8%)	287 (51.3%)	52 (9.3%)	151 (27.0%)	<.0001
Teens that use e-cigarettes don't usually use other tobacco products, like cigarettes.	214 (38.2%)	302 (53.9%)	65 (11.6%)	156 (27.9%)	<.0001
Nicotine does not have much of an impact on a teens brain.	365 (65.2%)	414 (73.9%)	37 (6.6%)	91 (16.3%)	<.0001
Flavored tobacco does not contain nicotine and is not addictive.	323 (57.7%)	408 (72.9%)	37 (6.6%)	128 (22.9%)	<.0001
Most teen smokers will end up smoking into adulthood.	406 (72.5%)	443 (79.1%)	38 (6.8%)	79 (14.1%)	<.0001

For each question, sample size may be different due to missing values.

Discussion

smokeSCREEN was developed as a web-based videogame intervention prototype focused on improving healthy beliefs and increasing knowledge around combustible cigarettes, e-cigarettes and vaping, and flavored tobacco product use. In the current quasi-experimental study, the beliefs and knowledge of participants who played the game, two important factors of behavior change, were changed in the positive direction. These findings are encouraging, given that research suggests that if an intervention can substantially deepen relevant knowledge and bolster life skills (e.g., refusing peer pressure), then the outcome will yield reduced tobacco product use.¹⁹ Studies of interventions, such as those in the Truth Initiative, have demonstrated positive effects on correcting adolescents' misinformation around tobacco use.²⁰ Moreover, there is evidence that exposure to truthful knowledge about tobacco use is associated with an increase in anti-tobacco attitudes and beliefs in young people.²¹

Our findings suggest that gender may be associated with beliefs, but not knowledge, related to e-cigarettes and vaping. Additionally, our findings suggest that age may be associated with both beliefs and knowledge related to e-cigarettes. Older participants were more likely to choose healthier beliefs and correct answers to knowledge questions compared to younger participants. Given that older

adolescents may have had greater exposure to e-cigarettes and vaping prior to playing the game, the content in the game have been more relevant and relatable to them. This may explain why the intervention may have had a greater impact on older adolescents when compared to younger adolescents. These notable gender and age differences stress the importance of creating tailored tobacco use prevention interventions unique to the needs of different adolescent populations,²² especially for interventions that focus on, or include, e-cigarettes such as JUUL. In previous studies focused on the development and testing of an earlier version of *smokeSCREEN*,^{15,16} the impact of gender or age on outcomes was not described nor did the study include a timely and important focus on e-cigarettes or vaping as part of the tobacco use curriculum. Gameplay duration, or how long participants played the game, was not associated with their answers to the questions of beliefs or knowledge. These findings are consistent with prior work conducted¹⁴ and suggest that smaller doses of an intervention may still be impactful, especially if the mastery of the intervention material, and not time spent in the game, influences the acquisition of knowledge.

Participant experience is a critical component of intervention and program success.^{23,24} A secondary aim of this study was to collect participants' gameplay experience for the purpose of improving the intervention and to inform a

large-scale implementation study beyond this current study. Overall, the majority of participants reported that they enjoyed the game, would tell their friends to play, and that they learned something new. These findings are important as participants who have a positive gameplay experience may be more likely to fully engage in the intervention and practice important behavioral skills.²⁴

This study had several limitations. First, this study did not include a control group for comparison. Second, given the nature of the real-world, quasi-experimental design of the study, 33% of the 835 participants enrolled in the study did not complete the post-survey, reducing our total sample size. Additionally, the age range for participation in the study was 11–16, participants aged 14–16 did not enroll in the study. For future studies, a better system for assigning IDs and ensuring participants are instructed or reminded to take their post-survey after finishing gameplay may yield a greater sample size and provide more insight into the participants who do not finish the game intervention. Third, because the intervention was brief and took place online, qualitative interview data on participants' gameplay experience were not collected. Collecting qualitative data with participants could have provided important feedback on players' perceptions and experiences with the game, thus contributing additional feedback to future development and refinement of the game, especially in participants that did not complete the game or post-survey. Fourth, additional behavioral data including participant alcohol and other drug use could be important in further understanding the acceptability and effectiveness of the intervention. Finally, participants in this study came from only four states and may not be representative of all U.S. adolescents or be generalizable to other populations.

Despite these limitations, this study provides important data regarding the effectiveness and acceptability of a brief videogame intervention prototype focused on tobacco use prevention in adolescents. Tobacco product use, including e-cigarettes and vaping with a specific focus on the popular e-cigarette brand, JUUL, is a rising concern in the U.S. Using mediums that are popular with adolescents,¹² such as videogames, is key when developing interventions. The current study demonstrates that this type of intervention improves beliefs and knowledge around tobacco product use among adolescents. Additionally, the data provide valuable insight into the impact of gender and age on beliefs and knowledge related specifically to e-cigarettes and vaping. For adolescents, this translates into improved health behaviors and a potential reduction of diseases linked to tobacco use such as cardiovascular disease and asthma.² For society, this translates into a decrease of premature deaths and improvement in annual health-related economic losses related to tobacco product use.²⁵ Given the ubiquity of videogame use in adolescents, an evidence-informed prevention intervention videogame prototype, such as *smokeSCREEN*, has the potential to affect adolescent health with far-reaching impact. Further, these types of electronically-delivered interventions may offer potential advantages over other school-based interventions because they are inexpensive or free to access, do not

involve intensive training requiring significant human and financial resources, and they provide a level of fidelity in the delivery of content.¹⁷ The *smokeSCREEN* videogame intervention not only improves beliefs and knowledge around tobacco use, but it is also easily accessible and highly accepted by adolescents. Further research to compare the effectiveness of *smokeSCREEN* to traditional school-based tobacco use interventions is an important next step.

Conclusion

This study supports previous research that suggests the use of videogames as prevention interventions as an effective approach to health education. Videogame interventions, such as *smokeSCREEN*, offer unique advantages over conventional or traditional school-based interventions in that they cost little to no money to access, do not involve extensive training of teachers or program directors, provide a high level of fidelity, and are enjoyed by adolescents. This study demonstrates that the videogame intervention prototype, *smokeSCREEN*, has a promising effect on participants' beliefs and knowledge about tobacco product use. Interventions such as *smokeSCREEN* are essential in targeting the growing epidemic of tobacco product use including electronic cigarettes and vaping in adolescents, with an emphasis on popular e-cigarette brands within this population, such as JUUL.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Author contributions

Dr. Hieftje contributed to the study design conceptualization, game development, and writing of the manuscript; Dr. Fiellin contributed to the study design conceptualization and writing of the manuscript; Dr. Fernandes contributed through assisting in writing the manuscript; and Dr. Lin contributed through data analysis and writing of the manuscript. CVS Health Foundation did not have any role in study design; collection, analysis, and interpretation of data; writing the report; and the decision to submit the report for publication.

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