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User experience evaluation of a 3D virtual reality educational program for illegal drug use prevention among high school students: Applying the decomposed theory of planned behavior

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Abstract

Objective: To evaluate user acceptability of an immersive three-dimensional virtual reality program for preventing illegal drug use and identify factors associated with continuous usage intention of three-dimensional virtual reality learning among high school students based on the decomposed theory of planned behavior.

Methods: In this cross-sectional observational study, we developed five educational modules and serious games based on three-dimensional virtual reality technology. Ninety student-participants' experiences were assessed by a structured questionnaire based on the decomposed theory of planned behavior variables. We applied partial least squares structural equation modeling to examine the correlates of continuous usage intention.

Results: The proposed model demonstrated an acceptable fit to the observed data. Eight of the 11 hypotheses based on the decomposed theory of planned behavior were supported. Continuous usage intention was significantly associated with attitudes, subjective norms, and perceived behavioral control; these variables explained 55.4% of the variance in continuous usage intention. Perceived usefulness and compatibility were significant antecedents of attitude. The significant antecedent of subjective norms was support from school staff. Self-efficacy and resource-facilitating conditions were significant antecedents of perceived behavioral control.

Conclusions: Our findings support the applicability of the decomposed theory of planned behavior as a framework for evaluating a three-dimensional virtual reality program for illegal drug use. We recommend that the program be included as teaching material for illegal drug prevention education in senior high schools.

Keywords

Adolescent health, technology for adolescents, virtual reality, continuous usage intention, decomposed theory of planned behavior

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Introduction

Illegal drug use has become a crucial issue worldwide as well as in Taiwan. In particular, preventing substance use in adolescents is a major global public health challenge because initiating substance use during adolescence is a significant predictor of later substance abuse, delinquency, and detrimental health effects.[1,2] Curiosity, boredom, and pursuit of popularity are the primary reasons for drug use among adolescents.[3] A population-based survey of 15,754 senior and vocational high school students in Taiwan revealed prevalence rates of 2.79%, 1.91%, and 1.72% for lifetime, past-year, and past-month illegal drug use, respectively.[4]

A nationwide population-based study in Taiwan revealed an emerging problem among the youth—the use of drugs hidden within coffee and tea bags, rainbow cigarettes, and so on.[5] These disguised drugs are marketed toward students by making them look appealing and easy to taste. Drug use not only has negative impacts on physical and mental health but also academic performance, increasing the likelihood of dropping out of school.[6] With the increasing usage of alternative forms of illegal drugs, such as novel psychoactive substances,[7] numerous senior high schools are now providing illegal drug use prevention education in an attempt to minimize the potential detrimental health effects and social burdens among adolescents. Thus, it is important to raise students' awareness of how to recognize disguised drugs and risk situations.

In Taiwan, illegal drug prevention programs are delivered through official high school health education courses.[8] However, it is often difficult to engage students in learning about the harms associated with substance use through didactic teaching. Innovative approaches using three-dimensional (3D) virtual reality (VR) technology may be a possible solution. Recent studies have reported 3D VR as an effective tool for drug prevention programs,[9,10] with it being more effective for adolescents than didactical teaching.[11] The development of alternative approaches, such as 3D VR games, may be more promising in this regard.[12]

Game-based learning (GBL) is a practical and useful approach in this context. A recent study indicated that GBL approaches can promote health behaviors among adolescents.[13] Studies have also demonstrated the use of immersive VR as a medium for learning and teaching and reported its usefulness with regard to designing smoking prevention programs.[12] Immersive VR allows users to perform actions in a virtual environment and provides opportunities for contextual practice.[14] Learners wear helmets and operate joysticks to observe and interact with virtual educational scenes to engage in GBL, thus enabling situational learning. As insufficient engagement may undermine learning effectiveness,[15] providing an interactive learning environment could increase learners' engagement with the learning content. A meta-analysis revealed that engaging young students through serious educational games would be beneficial to their learning outcomes.[16] Engaged learners have a higher likelihood of performing expected behaviors, promoting favorable learning outcomes.[17] These findings suggest that VR-based educational games may be a useful and feasible option for campus-based illegal drug prevention programs.

The theory of planned behavior (TPB), previously used to predict human behavior, examines the influences of attitudes, subjective norms, and perceived behavioral control on behavioral intentions.[18] However, the TPB may fail to fully explain technology-enhanced human behavior in the context of a VR-based preventive education program. Accordingly, Taylor and Todd developed the decomposed TPB (DTPB) by integrating the TPB and the technology acceptance model.[19] Numerous studies have used the DTPB as a research framework to evaluate participants' intention to use technology-enhanced programs.[20]

According to the DTPB, the contributors of behavioral intentions in terms of attitudes, subjective norms, and perceived behavioral control are decomposed into several corresponding antecedents associated with technology acceptance.[21] Attitudes refer to individuals' positive or negative feelings about performing a target behavior.[22] Antecedents of attitudinal beliefs are decomposed into relative advantages (perceived usefulness, e.g., learning effects enhanced by 3D VR), complexity (ease of use, e.g., ease of using 3D VR for learning), and compatibility (perceived compatibility, e.g., learning by 3D VR similar to past learning experience).[21]

In addition, based on the GBL literature, we included perceived enjoyment as an antecedent of attitudes.[16] Perceived enjoyment of 3D VR may affect attitude formation toward using technology for learning. Subjective norms refer to social pressure to perform or not perform a target behavior, such as the influence of important people in one's life. The antecedent of subjective norms is superior influence and is represented by perceived support from school staff in this study. Perceived behavioral control was decomposed into self-efficacy, technology-facilitating conditions, and resource-facilitating conditions. Self-efficacy refers to being confident in one's ability to perform a target behavior successfully. The facilitating conditions reflect the availability of technology and resources needed to perform the target behavior.[21] The success of a technology-enhanced drug prevention program depends on its continued usage rather than one-time use. The DTPB provides a comprehensive framework to understand the antecedents of individuals' attitudes, subjective norms, and perceived behavioral control. Therefore, it may help examine the influencing pathway of continuously using technology-enhanced learning. We applied the DTPB to evaluate user acceptability of a 3D VR program meant for learning about illegal drug prevention and identify factors associated with continuous usage intention of 3D VR learning among high school students.

Based on the DTPB, we propose the following hypotheses:Hypothesis 1 (H1)

Ease of use is associated with attitudes.Hypothesis 2 (H2)

Perceived usefulness is associated with attitudes. Hypothesis 3 (H3)

Perceived enjoyment is associated with attitudes. Hypothesis 4 (H4)

Perceived compatibility is associated with attitudes. Hypothesis 5 (H5)

Perceived support from school staff is associated with subjective norms.Hypothesis 6 (H6)

Self-efficacy is associated with perceived behavioral control.Hypothesis 7 (H7)

Resource-facilitating conditions are associated with perceived behavioral control.Hypothesis 8 (H8)

Technology-facilitating conditions are associated with perceived behavioral control.Hypothesis 9 (H9)

Attitudes are associated with continuous usage intention. Hypothesis 10 (H10)

Subjective norms are associated with continuous usage intention.Hypothesis 11 (H11)

Perceived behavioral control is associated with continuous usage intention.

All hypotheses of the proposed model are summarized in Figure 1.

Methods

Design of the 3D VR program

An immersive 3D VR-based illegal drug use prevention program was developed. We designed the program to function as supplementary material for illegal drug use prevention programs for adolescents. Lin et al.[23] demonstrated that highly immersive technology was accepted among adolescents, who might be motivated to use the technology with a head-mounted display (HMD). The VR HMD enables users to have immersive experiences with 3D images of illegal drug use situations that are rare in traditional didactic teaching. The program included five educational activities and five serious games in a virtual environment, as shown in multimedia Appendix 1. To complete the educational activities and game tasks, the participants operated joysticks to interact with the virtual environments; they also received in-game guidance from the research staff if they had any inquiries or operational problems. Participants were able to experience: (1) a high-risk situation: a trap in a party—an introduction to high-risk situations and learning to recognize disguised drugs; (2) harmfulness of illegal drugs: drugs affect your life—explaining the physiological and psychological harms accompanying drug use that are connected to critical life problems in adolescents; (3) zero tolerance: avoiding regret for drug use—adolescents who are involved in drug use, possession, and transportation could encounter serious criminal responsibility; (4) determination to quit: back to the days without drugs—encouraging health decisions by presenting a prison scenario; and (5) healthy lifestyle: regaining a new life—cultivating skills for interpersonal relationships and participating in healthy recreation.

Participants and recruitment

This study employed a cross-sectional observational design. The participants were students from a senior high school in Taipei City, Taiwan. The inclusion criteria were (1) currently enrolled high school students, (2) willingness to participate in the study, and (3) ability to provide written informed consent. There were no specific exclusion criteria. The research team visited the school personnel responsible for implementing illegal drug prevention at the school. During the visit, we introduced the study information and presented the 3D VR program. School personnel provided approval for conducting the study given their motivation to offer innovative illegal drug use prevention education to increase students' interest in learning. After consensus was reached regarding the manner in which the 3D VR program would be implemented, the school personnel announced the program to all students and distributed an information sheet. Students who volunteered to participate in the study informed the school personnel and were gathered in a quiet room to participate in the program. Participating students received a small gift (i.e. stationery) to compensate them for their time.

Measurements

Demographic variables included grade, gender, substance use experience (i.e. smoking, drinking, betel nut chewing, and illegal drugs), and previous experience with 3D VR immersive games. Based on the DTPB, the questionnaire contained 12 variables including attitudes, subjective norms, perceived behavioral control, continuous usage intention, perceived ease of use, perceived usefulness, perceived enjoyment, perceived compatibility, support from school staff, self-efficacy, resource-facilitating conditions, and technology-facilitating conditions. There were 1–6 items for each of the 12 variables, with a total of 37 items. These items were adapted from a 3D VR program for students with ketamine use developed based on the DTPB framework.[9] Content validity was used to justify the validity of the questionnaire, which was reviewed by six professionals.

A sample item for continuous usage intention was "I am willing to practice the VR activities in the future to learn about drug prevention." The DTPB instrument included a series of five-point Likert-scale items from 1 to 5 (strongly disagree to strongly agree) to collect data on the correlates of continuous usage intention in terms of attitudes, subjective norms, and perceived behavioral control. The higher the score, the more positive students' attitudes, social norms,

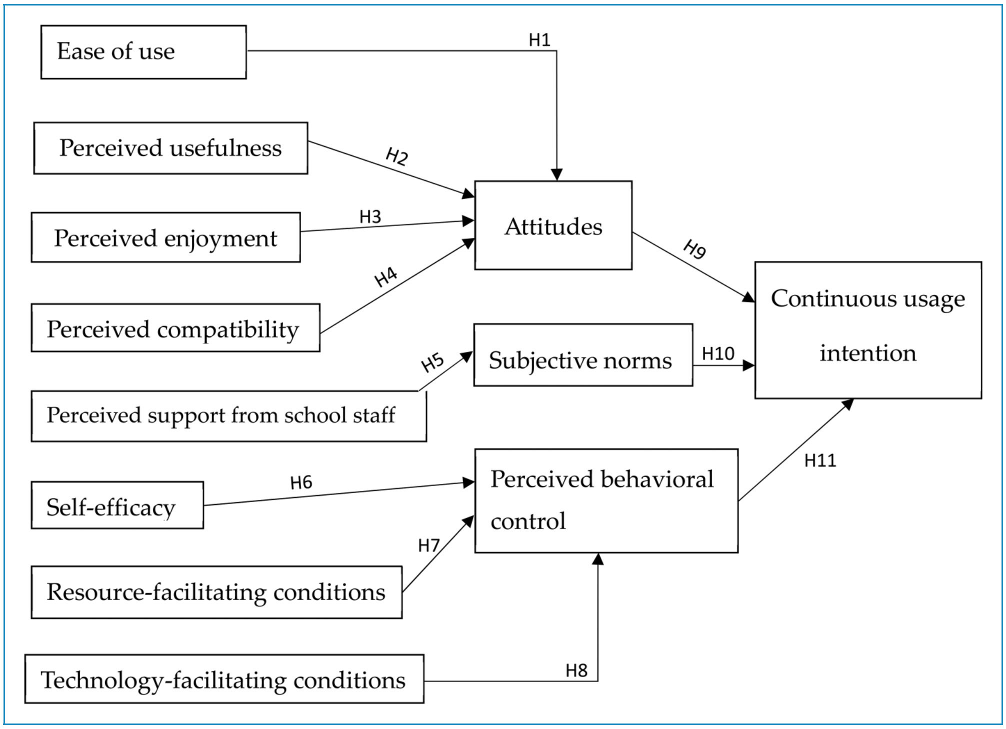

Figure 1. The hypotheses of the proposed model.

and perceived behavioral control toward learning about drug prevention through 3D VR. In addition, the corresponding antecedents associated with attitudes, subjective norms, and perceived behavioral control were measured. Higher scores for these antecedents indicated more positive beliefs related to attitudes, social norms, and perceived behavioral control.

Data analysis

Participants' characteristics were presented by counts and percentages. Partial least squares structural equation modeling (PLS-SEM) was used to examine the proposed hypotheses using Smart-PLS version 3.0. The use of PLS-SEM is ideal when the analysis is concerned with testing a theoretical framework from a prediction perspective with a small sample size.[24] The minimum recommended sample size for PLS-SEM is 10 times the largest number of structural paths directed at a particular latent variable in the model.[25] Thus, the minimum sample size for the model in this study was 40 because there were four paths directed to attitudes (Figure 1).

PLS-SEM was conducted in two stages.[26,27] The reliability and validity of all the variables were examined in the first stage. Then, the structural model was applied in the second stage of analysis to examine the goodness-of-fit of the DTPB model. Estimates were calculated for the path coefficients, which represent the hypothesized relationships linking the variables.[26] Fit measures of model estimation included standardized root mean square residual (SRMR), squared Euclidean distance (d_ULS), and geodesic distance (d_G) using PLS-SEM software. These criteria's values with a certain threshold (e.g. SRMR < 0.08) was used to examine the goodness-of-fit of the model.[28] For the bootstrap-based test for the exact overall model fit measures d_ULS and d_G, the upper bound of the confidence interval should be larger than the original value of the d_ULS and d_G fit criteria to indicate that the model has a good fit. Bootstrap estimation with 5000 samples was conducted to assess the significance of the coefficients using *t*-tests. R^2 (determination square) was used to examine the proportion of variance. An R^2 value of 0.75, 0.50, and 0.25 indicates a substantial, moderate, and weak level of predictive accuracy, respectively.[29]

Ethical considerations

This study was approved by the Research Ethics Review Committee of En Chu Kong Hospital. All participants provided written informed consent.

Results

Participants' characteristics and responses

A total of 90 students participated in the study, with 61 (67.77%) being boys and 41.11% being first graders. The majority (61.11%) did not use any substance and 55.56% had no previous experience with 3D VR.

The mean scores for the 12 DTPB variables revealed a general trend of positive responses (Table 1). Most participants stated that they enjoyed the VR program because they found interactive activities plausible and interesting compared to traditional didactic teaching. Participants' feedback suggests that their user experience of the VR program was enhanced by wearing the HMD and operating joysticks to interact with the virtual avatars and objects.

Measurement model assessment

The original 37-item DTPB questionnaire was adjusted to 30 items. Items with unsatisfactory factor loadings (<0.8), including two items on ease of use, three on perceived usefulness, one on self-efficacy, and one on perceived behavioral control, were removed. In addition to factor loadings, Cronbach's α and composite reliability (CR) should be >0.7 and average variance extracted (AVE) should be >0.5 to meet the convergent validity and reliability requirements.[29,30] After the adjustment, the results of factor loadings, Cronbach's α (ranging from 0.794 to 0.936), CR (ranging from 0.891 to 0.953), and AVE (ranging from 0.732 to 0.849) satisfied the recommended criteria, indicating the adequacy of the proposed measurement model, as shown in Table 2.

We established discriminant validity by using the Fornell–Larcker criterion and heterotrait–monotrait (HTMT) ratio. To satisfy the Fornell–Larcker criterion, the square root of the AVE for each variable should exceed the correlation of the latent variables.[29] An HTMT value of <0.90 establishes the validity of the discriminant.[30] As shown in Tables 3 and 4, the mentioned criterion was met, indicating that discriminant validity was established.

Table 1. Descriptive results for the 12 decomposed theory of planned behavior variables.

Variables	Item average scores	Sum of mean scores
DTPB		
Ease of use (four items)	4.32	17.29
Perceived usefulness (six items)	4.65	27.87
Perceived enjoyment (three items)	4.63	13.90
Perceived compatibility (one item)	N/A	3.94
Attitudes (three items)	4.55	13.64
Support from school staff (four items)	4.53	18.11
Subjective norms (three items)	4.43	13.28
Self-efficacy (three items)	4.46	13.39
Resource-facilitating conditions (two items)	4.50	8.99
Technology-facilitating conditions (two items)	4.62	9.24
Perceived behavioral control (three items)	4.38	13.15
Outcome measure		
Continuous usage intention (three items)	4.64	13.91

DTPB: decomposed theory of planned behavior; N/A: not applicable.

Structural model assessment

The PLS-SEM test exhibited that the fit measures of the proposed model had acceptable correspondence with the study data (SRMR = 0.079). The original values of d_G (3.664) were smaller than the upper bound of the 95% confidence interval (4.937). However, d_ULS (2.925) was larger than the upper bound of the 95% confidence interval (1.492). The perceived ease of use, usefulness, enjoyment, and compatibility explained 35.9% of the variance in attitudes. Support from school staff explained 14.6% of the variance in subjective norms. Self-efficacy, resource-facilitating conditions, and technology-facilitating conditions accounted for 51% of the variance in perceived behavioral control. Attitudes, subjective norms, and perceived behavioral control explained 55.4% of the variance in continuous usage intention. In terms of path analysis, Table 5 lists the path coefficients and the corresponding t-value and *P*-value for each hypothesis. It can be observed that 8 of the 11 hypotheses were supported. The supported hypotheses postulated that perceived usefulness and compatibility were significant antecedents of attitudes (H2 and H4). The significant antecedents of subjective norms were support from school staff (H5). Self-efficacy and resource-facilitating conditions were significant antecedents of perceived behavioral control (H6 and H7). Continuous usage intention was significantly associated with attitudes, subjective norms, and perceived behavioral control (H9, H10, and H11).

Discussion

In this study, we evaluated the acceptability of a 3D VR drug prevention program among high school students. The correlates of continuous usage intention of 3D VR learning were identified from the DTPB perspective. The acceptability of the program was supported as participants reported high scores for continuous usage intention of 3D VR learning (mean = 13.91, range = 3–15). In addition,

Table 2. Convergent validity of the proposed measurement model.

Variables and number of items	Factor loadings	Cronbach's alpha	Composite reliability	Average variance extracted
Ease of use		0.794	0.907	0.829
Ease of use 2	0.916			
Ease of use 3	0.905			
Perceived usefulness		0.822	0.891	0.732
Perceived usefulness 1	0.934			
Perceived usefulness 2	0.823			
Perceived usefulness 3	0.805			
Perceived enjoyment		0.870	0.920	0.793
Perceived enjoyment 1	0.858			
Perceived enjoyment 2	0.918			
Perceived enjoyment 3	0.896			
Perceived compatibility				
Perceived compatibility 1	1			
Attitude		0.911	0.944	0.849
Attitude 1	0.943			
Attitude 2	0.906			
Attitude 3	0.905			
Support from school staff		0.936	0.953	0.836
Support from school staff 1	0.918			
Support from school staff 2	0.916			
Support from school staff 3	0.905			
Support from school staff 4	0.918			
Subjective norms		0.871	0.920	0.793
Subjective norm 1	0.897			
Subjective norm 2	0.873			
Subjective norm 3	0.902			
Self-efficacy		0.729	0.880	0.785

(continued)

Table 2. Continued.

Variables and number of items	Factor loadings	Cronbach's alpha	Composite reliability	Average variance extracted
Self-efficacy 1	0.908			
Self-efficacy 2	0.864			
Resource-facilitating conditions		0.949	0.975	0.951
Resource-facilitating condition 1	0.978			
Resource-facilitating condition 2	0.972			
Technology-facilitating conditions		0.781	0.897	0.814
Technology-facilitating condition 1	0.859			
Technology-facilitating condition 2	0.944			
Perceived behavioral control		0.826	0.920	0.852
Perceived behavioral control 2	0.914			
Perceived behavioral control 3	0.912			
Continuous usage intention		0.910	0.943	0.847
Continuous usage intention 1	0.909			
Continuous usage intention 2	0.937			
Continuous usage intention 3	0.915			

our findings support the applicability of the DTPB as a framework for evaluating a 3D VR program for illegal drug use. As suggested by the DTPB, participants' attitudes, subjective norms, and perceived behavioral control significantly influence their continuous usage intentions.[31] Consistent with the results of a previous study,[32] we found that attitudes were associated with perceived usefulness and compatibility. In addition, Chen et al.[9] indicated that perceived usefulness influences behavioral intention through attitudes. Users' perceived usefulness significantly influences attitudes, and perceived usefulness and attitudes significantly influence user intentions.[33] Technological advancement has increased interest in 3D VR technology as a research tool for study areas such as aroma therapy,[34] horticultural therapy,[35] volunteer training,[36] and childbirth training.[37]

Differing from the results of a previous study,[19] perceived ease of use and enjoyment were not significantly associated with attitudes. A possible explanation is that some students still needed staff assistance to operate immersive VR devices because they had not used VR devices before. Therefore, the role of on-site instructors in VR user evaluation is critical. As our VR program focuses on helping students learn to refuse illegal drugs, the content is more serious than in entertainment-related VR programs. Compared to other purely game-based VR programs, ours lacks the element of excitement; therefore, it is not surprising that the path effectiveness from performance enjoyment to attitudes was not significant. However, we found that the students were very concerned about practicing the VR program. Therefore, further studies should measure involvement instead of enjoyment. Involvement significantly influenced continuous use intention in a previous VR HMD user evaluation study.[38]

Our participants did not report severe cybersickness symptoms, identified as a problem for VR HMD users in a previous study.[39] Two possible reasons for the same may be that our participants operated VR in a sitting position and under supervision by the research staff. Additionally, we used the latest VR HMD; an up-to-date device may have reduced user discomfort.

Our findings also showed that support from school staff (superior influence) was significantly associated with subjective norms. A previous study indicated that interpersonal relationships influenced subjective norms.[40] The more support from school staff participants receive, the higher their perceived subjective norms toward a target behavior.[41,42] As subjective norms were significantly associated

Table 3. Results for the Fornell–Larcker criterion.

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Ease of use	0.911											
2. Perceived usefulness	0.413	0.856										
3. Perceived enjoyment	0.061	0.489	0.891									
4. Perceived compatibility	−0.092	0.087	0.103	1.000								
5. Attitude	0.257	0.468	0.266	0.391	0.921							
6. Support from school staff	0.249	0.377	0.222	0.031	0.390	0.914						
7. Subjective norms	0.237	0.383	0.217	0.042	0.564	0.383	0.891					
8. Self-efficacy	0.226	0.251	0.249	0.086	0.374	0.382	0.185	0.886				
9. Resource-facilitating conditions	0.191	0.243	0.098	0.163	0.303	0.398	0.065	0.358	0.975			
10. Technology-facilitating conditions	0.289	0.452	0.396	0.118	0.429	0.729	0.337	0.455	0.476	0.902		
11. Perceived behavioral control	0.541	0.518	0.314	0.096	0.450	0.292	0.238	0.581	0.593	0.436	0.923	
12. Continuous usage intention	0.434	0.575	0.534	0.138	0.615	0.564	0.469	0.568	0.348	0.558	0.625	0.920

Note: The Fornell–Larcker criterion refers to a factor's average variance extracted, which should be higher than its squared correlation with all other factors in the model.

Table 4. Results for the heterotrait–monotrait ratio of correlations.

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Ease of use												
2. Perceived usefulness	0.516											
3. Perceived enjoyment	0.119	0.544										
4. Perceived compatibility	0.104	0.104	0.103									
5. Attitudes	0.300	0.507	0.296	0.408								
6. Support from school staff	0.291	0.436	0.255	0.047	0.424							
7. Subjective norms	0.281	0.440	0.237	0.046	0.624	0.408						
8. Self-efficacy	0.295	0.312	0.295	0.100	0.450	0.451	0.219					
9. Resource-facilitating conditions	0.221	0.283	0.109	0.168	0.333	0.422	0.080	0.434				
10. Technology-facilitating conditions	0.362	0.559	0.499	0.111	0.508	0.876	0.431	0.573	0.542			
11. Perceived behavioral control	0.679	0.627	0.364	0.108	0.522	0.326	0.273	0.744	0.662	0.519		
12. Continuous usage intention	0.509	0.638	0.602	0.146	0.674	0.623	0.515	0.681	0.379	0.683	0.717	

Note: Heterotrait–monotrait ratio significantly smaller than 0.9.

Table 5. Results for 11 hypotheses tests.

Hypothesized paths	Path coefficients	t-value	*P-value*
H1 Perceived ease of use→attitudes	0.141	1.394	.164
H2 Perceived usefulness→attitudes	**0.356**	**3.594**	<.001***
H3 Perceived enjoyment→attitudes	0.045	0.496	.620
H4 Perceived compatibility→attitudes	**0.368**	**3.321**	<.001***
H5 Support from school staff→ subjective norms	**0.383**	**4.186**	<.001***
H6 Self-efficacy→perceived behavioral control	**0.407**	**4.195**	<.001***
H7 Resource-facilitating conditions→perceived behavioral control	**0.425**	**3.956**	<.001***
H8 Technology-facilitating conditions→perceived behavioral control	0.048	0.470	.638
H9 Attitudes→continuous usage intention	**0.311**	**2.728**	.006***
H10 Subjective norms→continuous usage intention	**0.188**	**2.215**	.027*
H11 Perceived behavioral control→continuous usage intention	**0.440**	**4.883**	<.001***

Note: *$P < .05$; **$P < .01$; ***$P < .001$; the statistical significance level was <0.05 for the bold values. The eight hypotheses were supported by significant path coefficients.

with participants' continuous usage intention, when designing VR learning content in the future, program designers should consider the relevant beliefs of significant individuals surrounding participants.

We also found that perceived behavioral control was significantly associated with self-efficacy and resource-facilitating conditions, and further, with continuous usage intention. This is concordant with a previous finding that self-efficacy and resource-facilitating conditions significantly influence perceived behavioral control and that perceived behavioral control significantly influences behavioral intention.[19] Based on the items assessing self-efficacy and resource-facilitating conditions, having instructors to guide the participants on using the VR program encompassing expensive gaming notebooks and VR HMD, which are more advanced than school computer equipment, contributed to the positive beliefs about using VR programs.

Based on our findings, we suggest that an exploratory study, grounded in theory, would be appropriate to investigate the acceptability of VR technology among high school students. Traditional didactic instruction may not sufficiently engage students in drug use prevention efforts, and GBL may provide a promising solution to increase student engagement. Immersive 3D VR technology offers the opportunity to simulate a variety of situations while remaining in a school setting. Our study indicates that the integration of GBL and immersive 3D VR technology was acceptable to high school students. We recommend that health educators consider incorporating similar programs into their drug prevention efforts on campus. Our data also revealed that attitudes, subjective norms, and perceived behavioral control were significantly associated with students' intentions to continue using 3D VR learning. We encourage program designers to incorporate these concepts into the development of learning content and activities. Lastly, we suggest that health centers and hospitals provide 3D VR programs in waiting areas as a means of disseminating health information.

Nevertheless, this study has some limitations that should be considered when interpreting the findings. First, the research staff had to assist some participants in using the 3D VR program as they were first-time users. Prior VR experience may be a confounding factor in our model; however, we could not exclude its influence from the study. Second, we only recruited students from a senior high school in a metropolitan city, limiting the generalizability of the findings. Third, not all the model fit measures met the threshold, thus limiting the generalizability of causal explanations of the structural model across different contexts. Nevertheless, the PLS-SEM approach provides valuable insights into the significance of hypothesized relationships derived from the underlying theory. As scholars have suggested, data usability, which refers to the capacity of data to fulfill the requirements for a specific use situation, should be given adequate attention.[43,44] Although our findings may not yield perfect causal explanations, they do provide insights into the phenomenon of using 3D VR programs to learn about drug prevention.

Conclusions

With the provision of an adequate environment and assistance, we found that a VR HMD antidrug VR educational program may be acceptable for adolescents, even first-time users. Our findings revealed that experiences of using VR programs could be evaluated using the DTPB through PLS-SEM testing. The findings also provide insight into modifying the constructs of the DTPB, such as using involvement instead of enjoyment, when applying the theory to serious VR programs. Few studies have examined user experiences and continuous usage intention for VR programs by applying the DTPB among adolescents. The associations among the 12 DTPB variables, hypothesized at the beginning of the study, were established. Further studies are required to expand the study design to adolescents of diverse ages and locations to verify these relationships.

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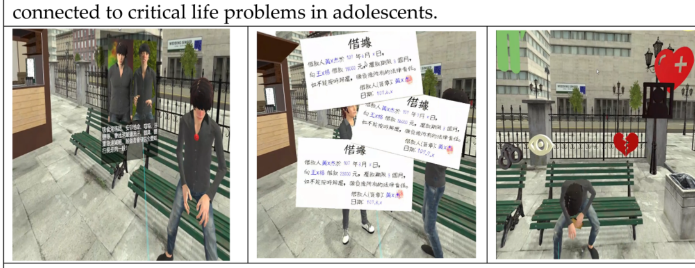
Appendix 1.

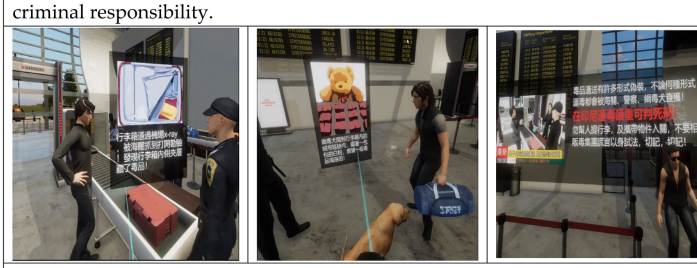
The 3D VR program of five educational activities and five serious games in a virtual environment.

Unit 1: A high-risk situation: a trap in a party—an introduction to high-risk situations and learning to recognize disguised drugs.

Unit 2: Harmfulness of illegal drugs: drugs affect your life—explaining the physiological and psychological harms accompanying drug use that are connected to critical life problems in adolescents.



Unit 3: Zero tolerance: avoiding regretting drug use—adolescents who are involved in drug use, possession, and transportation could face serious criminal responsibility.



Unit 4: Determination to quit: back to the days without drugs—encouraging health decisions by presenting a prison scenario.

Unit 5: Healthy lifestyle: regaining a new life—cultivating skills for interpersonal relationships and participating in healthy recreation.