More Aware of the Consequences: A Mixed Methods Evaluation of a Virtual Reality Game to Enhance Teen Distracted Driving Education

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Abstract

Background: Inexperienced adolescent drivers are particularly susceptible to engaging in distracted driving behaviors (DDB) such as texting while driving (TWD). Traditional driver education approaches have shown limited success in reducing motor vehicle crashes among young drivers.

Objective: We test an innovative approach to help address the critical issue of DDB among teenagers. We investigated the effectiveness of using a novel virtual reality (VR) game "Distracted Navigator" to educate novice teenage drivers about DDB.

Methods: The game consisted of maneuvering a spaceship around asteroids while engaging in simulated DDB (e.g., inputting numbers into a keypad). Facilitated discussion, based on the Theory of Planned Behavior, linked gameplay to real-life driving. Teenagers were recruited and divided into intervention (VR gameplay/discussion) and control (discussion only) groups in a ratio of 2:1. Pre-post surveys measured the impact on TWD-related beliefs and intentions. Focus group interviews elicited feedback on the utility of the VR gameplay and discussion.

Results: The majority of participants were male (62.5%), ranging 14-17 years old (M(SD) =15.8(0.92)), with universal cell phone ownership. Approximately 60% reported never texting while driving and 29% said they rarely did. Compared to the control group (n=7), the intervention group (n=17) was more likely to report that the programming had changed how they felt about texting and driving overall (P=.015). However, specific TWD attitudes and intentions were not different by treatment status. Irrespective of the treatment, pre-and post-scores indicated reduced confidence in safely texting while driving (perceived behavioral control; P=.005). Thematic analysis revealed: 1) the VR gameplay adeptly portrayed real-world consequences of texting and driving; 2) participants highly valued the interactive nature of the VR game and discussion; 3) both the VR game and facilitated discussion were deemed as integral and complementary components, and 4) feedback for improving the VR game and discussion.

Conclusions: Our findings show the novel use of immersive VR experiences with interactive discussions can raise awareness of DDB consequences and is a promising method to enhance driving safety education. Widespread accessibility of VR technology allows for scalable integration into driver training programs, warranting a larger, prospective randomized study.

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Abstract

Introduction: Inexperienced adolescent drivers are particularly susceptible to engaging in distracted driving behaviors (DDB) such as texting while driving (TWD). Traditional driver education approaches have shown limited success in reducing motor vehicle crashes among young drivers.

Objective: We test an innovative approach to help address the critical issue of DDB among teenagers. We investigated the effectiveness of using a novel virtual reality (VR) game "Distracted Navigator" to educate novice teenage drivers about DDB.

Methods: The game consisted of maneuvering a spaceship around asteroids while engaging in simulated DDB (e.g., inputting numbers into a keypad). Facilitated discussion, based on the Theory of Planned Behavior, linked gameplay to real-life driving. Teenagers were recruited and divided into intervention (VR gameplay/discussion) and control (discussion only) groups in a ratio of 2:1. Pre-post surveys measured the impact on TWD-related beliefs and intentions. Focus group interviews elicited feedback on the utility of the VR gameplay and discussion.

Results: The majority of participants were male (62.5%), ranging 14-17 years old (M(SD) =15.8(0.92)), with universal cell phone ownership. Approximately 60% reported never texting while driving and 29% said they rarely did. Compared to the control group (n=7), the intervention group (n=17) was more likely to report that the programming had changed how they felt about texting and driving overall (*P*=.015). However, specific TWD attitudes and intentions were not different by treatment status. Irrespective of the treatment, pre-and post-scores indicated reduced confidence in safely texting while driving (perceived behavioral control; *P*=.005). Thematic analysis revealed: 1) the VR gameplay adeptly portrayed real-world consequences of texting and driving; 2) participants highly valued the interactive nature of the VR game and discussion; 3) both the VR game and facilitated discussion were deemed as integral and complementary components, and 4) feedback for improving the VR game and discussion.

Conclusions: Our findings show the novel use of immersive VR experiences with interactive discussions can raise awareness of DDB consequences and is a promising method to enhance driving safety education. Widespread accessibility of VR technology allows for scalable integration into driver training programs, warranting a larger, prospective randomized study.

Keywords:

Safety, virtual reality, distracted driving, intervention, inattention, smartphone, novice drivers, risky driving

Introduction

Motor vehicle crashes remain the leading cause of mortality among teenagers worldwide [1] and unintentional death in persons aged 15-24 in the U.S. [2]. Young novice drivers are especially vulnerable to crashes or near crashes related to distracted driving behaviors (DDB) such as texting while driving (TWD) because of their inexperience, poor risk assessment skills, and ubiquitous use of cell phones [3,4]. DDB, and TWD in particular, have negative effects on driving performance through the detrimental effects of shared attention, task-switching, inattention blindness, and increased cognitive load while driving distracted [5]. To mitigate these harms, nearly all U.S. states have implemented laws prohibiting TWD in some way, often imposing more restrictions for younger or more inexperienced drivers (i.e., graduated licensing restrictions) [6].

Teen Distracted Driving Paradox

Despite teens acknowledging the dangers and generally supporting laws limiting TWD [7], they also continue to engage in DDB [8,9] and are more likely to be in crashes involving distracted driving [10,11]. While phone blocking apps have been found to be more effective than a control condition at reducing TWD amongst teen drivers, they do not eliminate it [12], in part because of a lack of motivation to use the apps [13]. Unfortunately, even if motivated, novice teen drivers often lack the ability to comply with texting bans due to poor impulse control [14] and problematic cell phone use [15]. These issues, combined with the perceived advantages of TWD and perceived utility of compensatory strategies [8], may outweigh acknowledged risks encouraging young novice drivers to persist in engaging in DDB [16].

Potential for Virtual Reality

The educational paradigm for teenage driver's education has remained static, with most evaluation research demonstrating its limited effectiveness in reducing crashes among young novice drivers [17,18]. Despite the pervasiveness of technology, driver's education still relies on classroom-style textbooks, lectures, videos, and low-tech simulation (e.g., a video screen connected to a simple wheel and pedal). Our goal was to develop an intervention to augment traditional in-person driver's education.

Head mounted display based virtual reality (hereafter VR) is an exciting technology used for gamification and is increasingly used for learning in multiple fields [19–23]. Providing immersive, experiential evidence of how distractions adversely affect performance through VR could help address problematic teenage driving behaviors [24]. Research on using VR games in driver's education is limited, but there is substantial potential for VR's application in addressing TWD [25]. By experiencing the consequences of in-game distractions, young novice drivers may reevaluate their beliefs about TWD, perceived ability/skill to text while driving, and reassess their perceived evaluation of the risks they take when engaging in TWD, which affects their attitudes and intention to engage in TWD.

VR-based games have several potential advantages over traditional video or low-tech simulators as a teaching tool: 1) Presence, or the idea that the user is physically present in the virtual environment; 2) Embodiment, when the user feels they are genuinely inhabiting the virtual character and having their actions mirrored within the virtual environment; and 3) Physicality, where the user's actual degree of physical activity is substantially increased during gameplay, creating an increased immersive experience [19,26].

Methods

Distracted Navigator Intervention

By having teens experience a novel VR game featuring DDB (*Distracted Navigator)* and engage in a facilitated educational discussion relating gameplay to real-world consequences, we sought to make more effective education on how DDB and TWD impacts driving performance.

Distracted Navigator is played on a VR head mounted display [27]. A player is placed virtually inside a spaceship cockpit and has control of the speed and the direction of the ship, which they navigate through an asteroid field (see Figure 1). Distracted Navigator provides vibrational haptic feedback via the player controller when asteroids hit the spaceship with noticeable damage to the spaceship's windshield.

Figure 1. VR Game Sample Screenshots

Note. The images represent A) Navigating around asteroids; B) Task switching by pulling levers; C) Multi-tasking by inputting numbers into a keypad; and D) Inattention blindness when a rooster flies across space.

After a 5-minute onboarding tutorial and a practice session, the user then plays their first round of the game (without any distractions) for ~5 minutes, navigating the spaceship to avoid oncoming asteroids. They receive a score depending on how successfully they avoided damage to the ship. In round two of the game, distractions are introduced as the player is exposed to several "emergency" tasks. While still navigating the ship around incoming asteroids for ~5 minutes, players must manage emergency tasks including 1) typing in a specific number sequence into a keyboard; 2) looking at orbs of lights on the sides of the cockpit to reactivate the ship's lighting system; 3) pulling a specific sequence of overhead levers; and 4) plugging devices into the console. The game ends with comparing the round one (without distractions) and round two scores (with distractions) with an illustration of a spaceship demonstrating the level of damage received during round two of play.

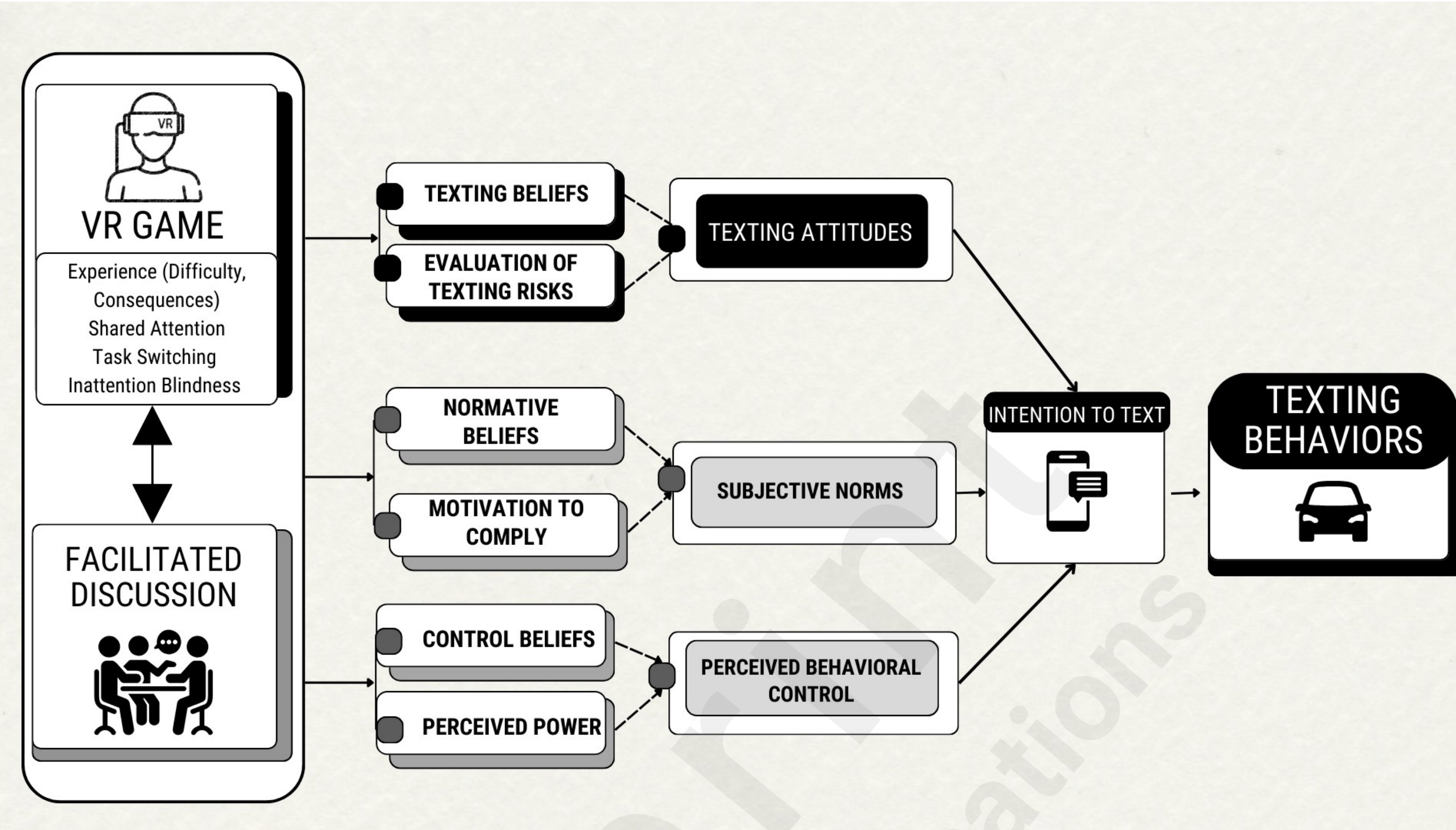
Distracted Navigator was designed specifically to be 1) immersive and fun while experiencing the performance-reducing effects of DDB; 2) not incentivize players to improve their score while engaging in DDB; and 3) leverage the familiar-to-teen experience of watching live streaming gameplay by broadcasting individual play to other group members. Collectively, *Distracted Navigator* tasks simulate the effects of 1) texting; 2) taking eyes off the road; 3) multitasking; and 4) plugging in devices to demonstrate the negative effects of shared attention, task-switching, inattention blindness, and increased cognitive load while driving distracted [5]. The game also features a cartoon rooster that flies across the screen during gameplay to demonstrate inattention blindness like the classic ‘invisible gorilla’ experiment [28].

Facilitated Discussion

Both the intervention and the control group participated in the discussion, facilitated by a content expert familiar with working with teens (author TV), which educated participants on the dangers of DDB. Importantly, the facilitated discussion was implemented using an interactive approach akin to motivational interviewing to elicit the teens’ own perspectives and to better engage them in collaborative, thoughtful discussion [29].

Content was adapted from the AAA didactic educational material [30] on distracted driving and the *DriveSmart* campaign [31]. The material was further enhanced by inclusion of Theory of Planned Behavior concepts related to TWD (see Figure 2) [32,33]. For example, perceived texting norms (e.g., it’s not a big deal) and faulty teen perceptions of their ability to multi-task and employ risk-compensation strategies so they can drive distracted were discussed (i.e., normative beliefs, motivation to comply). Also, the pressure to reply to messages and habitual phone use that can make distracted driving hard were acknowledged, and empowerment strategies were discussed to enhance perceived control (i.e., control beliefs and perceived power). The intervention group had additional material that tied their *Distracted Navigator* gameplay experiences to everyday driving situations and the facilitator referred to the gameplay throughout the discussion to further reinforce its connection to these TWD concepts.

Figure 2. VR Game and Discussion Theory of Planned Behavior Conceptual Model



The primary aim of the present study was to evaluate the utility of *Distracted Navigator* and facilitated discussion using a mixed approach in a pre-post randomized controlled trial. We sought to test the following hypotheses:

1. That intervention group participants who experience the VR game will have significantly reduced intentions to engage in TWD.
2. The intervention group will have statistically significant changes in other theory of planned behavior constructs regarding TWD.

Additionally, we used open-ended and focus group interview data to:

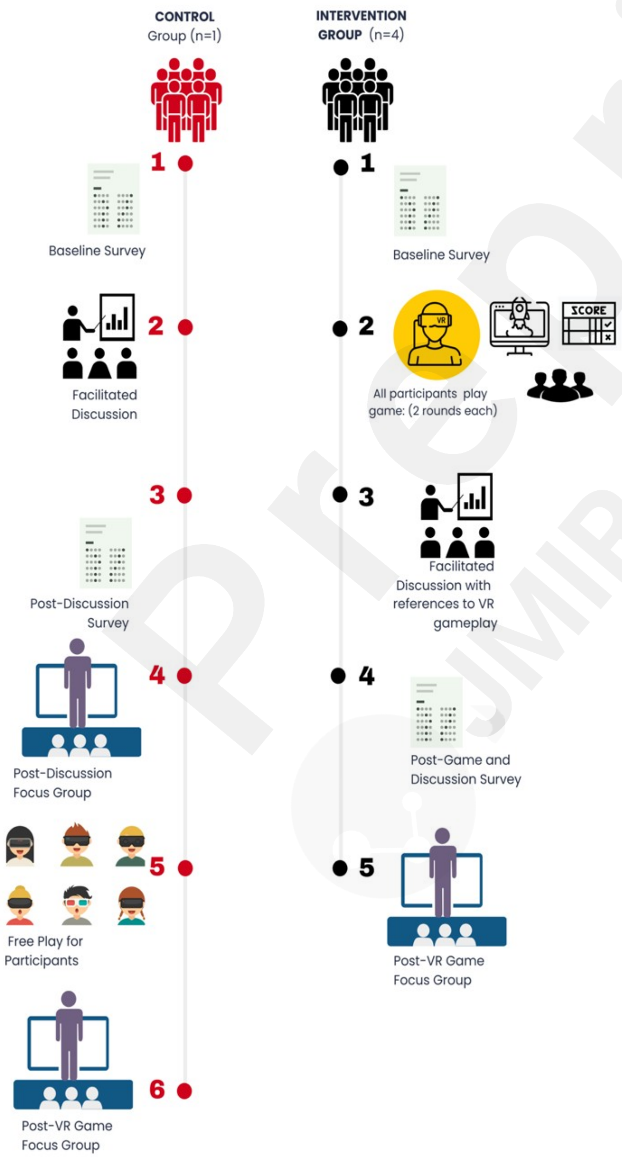
1. Gain participant insight into the utility of their VR experiences and themes supporting the quantitative data.
2. Identify qualitative themes for future development and enhancements to the VR game.

Participants and Procedure

Game onboarding and facilitated discussion were beta tested with two teens recruited from a local children's hospital volunteer patient advisory committee. We then recruited future and novice teen drivers from a Michigan high school to pilot test the effect of a virtual gaming intervention and accompanying discussion on TWD perceptions and attitudes over July-Aug 2022 and July 2023. Authors ANH and VC liaised with a local high school to recruit teen drivers. Teens were eligible if they were 14-17 years old. Email contact was collected for both the students and a parent or guardian. Author VC met with the teens and their parent/guardian via a virtual meeting room where eligibility was assessed, study procedures were reviewed, and written participant assent and parent/guardian consent were obtained.

Teens were recruited in blocks of up to seven and assigned at the block level to intervention and control groups approximating a 2:1 ratio. All teens were asked to complete the baseline survey before the session. In the intervention group, participants played the *Distracted Navigator* VR game and engaged in the facilitated driver's education curriculum on the effects of distracted driving with references to their gameplay experiences, completed the post-session survey, and then participated in the focus group to provide additional feedback. As described above, the control group engaged in a similar moderator-facilitated driver's education curriculum on the effects of distracted driving with no reference to the gameplay. They then completed the post-session feedback survey and were then allowed a free period to play the VR game for fun. Following this gameplay, the control group engaged in a 2nd focus group session to provide feedback on the VR game. See participant study flow in Figure 3.

Figure 3. Participant Study Flow



Participants were offered a $100 gift card and provided with food and beverages during the session as incentives. The study was approved by the University of Michigan Institutional Review Board #HUM00213233. All study staff and investigators completed the University of Michigan Minors as Research Participants and followed the participant contact protocols.

Measures

Surveys for both pre-session (baseline) and post-facilitated discussion (follow-up) were emailed to the students to complete on the Qualtrics platform. Intervention and control participants received the same survey materials. The intervention focus group was conducted after the facilitated gameplay discussion and after participants finished the follow-up survey. The main outcomes of interest were the TPB constructs (intention, etc.) with intervention and time (baseline, follow-up) as the primary independent predictor variables. We also assessed overall perceptions of the session.

Demographics and Driving Behaviors

Demographics included gender, age, race and ethnicity, and grade in school. We assessed typical hours spent driving, seatbelt habits, level of Michigan driving license, TWD frequency (typically and past week), and whether they had experienced a variety of consequences of different severities due to TWD (e.g., drifted into another lane, ran stop sign or stop light). We also asked if they used text dictation software (e.g., SIRI) to text while driving, and had played any VR games before. Full items are available in Table 1.

Intervention Assessment Overall

The follow-up survey asked participants to assess the program they experienced overall. Specifically, they were asked “Did the program change how you feel about texting and driving?” and “Did the program change how likely you are to text and drive?” Response options for both questions were yes, maybe, or no. Questions were phrased to refer to the “program” generally so both intervention and control participants received the same questions and could be compared. An initial subset of surveys was distributed without this question included in error (n=5).

Texting while Driving Theory of Planned Behavior Constructs

Pre- and post-session, participants were asked how strongly they agreed or disagreed with statements regarding their perceived behavioral control to text and drive, general TWD attitude, subjective norms, perceived disadvantages and advantages of not engaging in TWD, and intention to TWD in the next week. Response options ranged from strongly disagree to strongly agree (1=strongly disagree, 2=agree, 3=neither agree nor disagree, 4=disagree, 5=strongly disagree). These TPB items were derived from [34–36] and identified as having sufficient reliability and validity in a large sample of teen drivers [33]. The TPB as well as the TWD consequences questions were used with permission. Full items are available in Table 3.

Semi-Structured Focus-Group Interview Questions

Semi-structured prompts engaged the participants in a discussion of their general impression of the game and the facilitated discussion, their likes and dislikes of the game and its components, main takeaways of the program, and whether they would recommend it to others. Specific questions also addressed gamification and the utility of watching others play rather than experiencing the game themselves (i.e., live streaming). Focus group procedures followed Krueger & Casey’s [37] guidance and the facilitator emphasized honesty, confidentiality, and desire for negative feedback in order to avoid social desirability biases. Focus group audio was transcribed by a HIPAA-compliant third-party company. Full script guidance is available in the Appendix (A1).

Analysis Plan

Quantitative Analysis

We compiled descriptives and conducted randomization equivalency tests using either t-tests or χ^2-tests, as appropriate. For TPB items and overarching constructs, we conducted pre-post cluster analysis tests of the treatment condition with a time interaction using mixed effect hierarchical modeling with restricted maximum likelihood (REML) and the residuals df method specified given the continuous outcomes; Group assignment and individuals (by IDs) were included as random effects. The interaction with time accounted for differences in the conditions present at baseline. Models controlled for typical texting frequency, which was differential by treatment group ($p<.05$; see Table 1). Given the distribution of responses, how often teens typically read or send texts while driving was dichotomized into 'never' and 'ever'.

Treatment assignment was assessed with the proper degrees of freedom for a cluster randomized trial [#conditions(#groups-1)=8 df] using the lincom (linear combinations of parameters) postestimation procedure. Because the test for group level effects (intraclass correlation coefficients) with this multilevel modeling was near zero, procedures were replicated using a standard linear regression approach to explore pre-post effects with enhanced power(degrees of freedom). All quantitative analyses were conducted by author CMP using Stata/SE 18.0 [38].

Qualitative Analysis

Authors CMP, ANH, and TV implemented thematic content analysis following procedures from Braun & Clark [39] of the survey feedback and focus group transcripts. Content analysis aimed to identify themes on the VR game and facilitated discussion's utility and areas for improvement. Authors independently read focus group transcripts and open-ended survey responses. Together they reviewed commonalities and any exceptions they noted to develop codes and identify overarching themes. Themes and emblematic quotes are presented. Points of convergence and divergence between the qualitative themes and quantitative results are discussed.

Results

Demographics and Driving Behaviors

A total of 25 teen drivers were recruited and assigned to intervention (n=17) or control (n= 7) across 5 groups (four intervention groups of varying sizes, one large control group), approximating the 2:1 assignment target. No baseline data were available from one participant and follow-up was missing from another participant. Teen participants were 62.5% male and averaged 15.8 years old. They were 61.9% White (n=13), 28.6% Asian (n=6), 4.8% Black/African-American (n=1) , 4.8% American Indian or Alaska Native (n=1). They were entering 10th (25%), 11th (41.7%), and 12th (33.3%) grades. All had their own cell phone and 76.5% had played a VR game before.

Teens were about evenly distributed by what kind of license they held: none (29.1%), level 1 (29.1%), level 2 (25.0%), and level 3 (16.7%). Nearly 60% said that they typically never send a text while driving and another 29.2% said they rarely do. About the same said they never typically read a text while driving (58.3%) or rarely (20.8%). These frequencies were unevenly distributed by treatment and intervention group. Compared to the intervention group, the control group members reported reading (85.7% vs. 23.5%) or sending a text (71.4% vs. 29.4%) more often than ‘never’. See Table 1 for full demographic and comparison details.

Table 1. Baseline Characteristics of the Sample and Treatment Comparison

	Total		**Control (n=7)**		**Intervention (n=17)**		p-value
	n	**%**	**n**	**%**	**n**	**%**	
Female	9	37.5	4	57.1	5	29.4	0.202
Age, M(SD)	15.8	0.9	16.0	0.6	15.7	1.0	0.247
Race							0.818
White	13	61.9	3	60.0	10	62.5	
Asian	6	28.6	2	40.0	4	25.0	
Black/African-American	1	4.8	0	0.0	1	6.3	
American Indian or Alaska Native	1	4.8	0	0.0	1	6.3	
Hispanic-origin	1	4.8	0	0.0	1	6.3	0.567
Grade							0.191
10th	6	25.0	0	0.0	6	35.3	
11th	10.0	41.7	4	57.1	6	35.3	
12th	8	33.3	3.0	42.9	5	29.4	

Driving behaviors							
Hours driving per week (typical)							0.791
0	7	29.2	2	28.6	5	29.4	
1-2	4	16.7	2	28.6	2	11.8	
3-5	7	29.2	2	28.6	5	29.4	
6-10	4	16.7	1	14.3	3	17.7	
11 or more	2	8.3	0	0.0	2	11.8	
Michigan license level							0.993
None	7	29.2	2	28.6	5	29.4	
Level 1	7	29.2	2	28.6	5	29.4	
Level 2	6	25.0	2	28.6	4	23.5	
Level 3	4	16.7	1	14.3	3	17.7	

How often do you text on your cell phone? (in general)							0.664
Never	1	4.2	0	0.0	1	5.9	
Rarely	0	0.0	0	0.0	0	0.0	
Sometimes	2	8.3	0	0.0	2	11.8	
Often	17	70.8	6	85.7	11	64.7	
All the time	4	16.7	1	14.3	3	17.7	
How often do you typically SEND a text message while driving?							*0.032*
Never	14	58.3	2	28.6	12	70.6	
Rarely	7	29.2	5	71.4	2	11.8	
Sometimes	2	8.3	0	0.0	2	5.9	
Often	1	4.2	0	0.0	1	5.9	
All the time	0	0.0	0	0.0	0	0.0	
Within the *past week*, how often did you use your cell phone to SEND text messages while driving?							0.235
Never	21	87.5	7	100.0	14	82.4	
A few times	3	12.5	0	0.0	3	17.7	

Several times	0	0	0	0	0		
Many times	0	0	0	0	0		
How often do you typically READ a text message while driving?							*0.018*
Never	14	58.3	1	14.3	13	76.5	
Rarely	5	20.8	3	42.9	2	11.8	
Sometimes	4	16.7	3	42.9	1	5.9	
Often	1	4.2	0	0.0	1	5.9	
All the time	0	0.0	0	0.0	0	0.0	
Within the *past week*, how often did you use your cell phone to READ text messages while driving?							0.535
Never	20	83.3	6	85.7	14	82.4	
A few times	2	8.3	1	14.3	1	5.9	
Several times	2	8.3	0	0.0	2	11.8	
Many times	0	0.0	0	0.0	0	0.0	
Because they were TWD, had they ever…(responded yes)							

Drifted into another lane	2	8.3	1	14.3	1	5.9	0.498
Knew were being reckless	2	8.3	0	0.0	2	11.8	0.343
Sped more than 10mph	2	8.3	0	0.0	2	11.8	0.343
Ticketed for TWD	0	0.0	0	0.0	0	0.0	-
Run a stop sign or red light	0	0.0	0	0.0	0	0.0	-
Hit something	0	0.0	0	0.0	0	0.0	-
Injured someone	0	0.0	0	0.0	0	0.0	-
How often do you wear a seatbelt while driving?							0.111
Never	0	0.0	0	0.0	0	0.0	
Rarely	0	0.0	0	0.0	0	0.0	
Sometimes	0	0.0	0	0.0	0	0.0	
Often	1	4.2	1	14.3	0	0.0	
All the time	23	95.8	6	85.7	17	100.0	
How often do you use dictation software (such as SIRI) to text while driving?							0.181
Never	16	66.7	4	57.1	12	70.6	

Rarely	3	12.5	1	14.3	2	11.8	
Sometimes	2	8.3	2	28.6	0	0.0	
Often	1	4.2	0	0.0	1	5.9	
All the time	2	8.3	0	0.0	2	11.8	
Played VR games before	17	70.8	4	57.1	13	76.5	0.344
Own cell phone	24	100.0	7	100.0	17	100.0	-

Note. We are missing race and ethnicity data for earlier groups. License Level 1= Supervised, can only drive with parent or designated licensed adult age 21 or older; Level 2 = Intermediate, has limits passengers and unsupervised nighttime driving; Level 3 = Full, all driving privileges with no restrictions.

Intervention Assessment Overall

Recalling that some participants did not receive this question due to error, we have a smaller number of providing their overall assessment of the program they experienced. Considering the program overall, nearly 80% (11 of 14) of the treatment group said the VR game and facilitated discussion had changed how they *felt* about texting and driving and how *likely* they were to engage in it (see Table 2). For the control group, 50% (2 of 4) said their discussion-only program 'maybe' changed how they *felt* about texting and driving, and the other half said it did not change how they *felt* about TWD. The control group was also split in terms of how their program changed how *likely* they were to text and drive, with half saying 'maybe' and half reporting 'yes' it changed how *likely* they were to text and drive.

Bivariate analyses indicated that people in the intervention group were more likely to say the intervention changed how they felt about texting and driving ($\chi^2(18)$=- 8.35, P=.015), but this difference was no longer statistically significant when modeling controlled for 'ever' texting frequency. Overall program impact on intentions was not significantly different by group in either statistical approach.

Table 2. Overall Change in Texting While Driving Perceptions Based on Programming

	Control	Intervention	Total
Did the program change how you *feel* about texting and driving?			
No	2	2	4
Maybe	2	1	3
Yes	0	11	11
Did the program change how *likely* you are to text and drive?			
No	0	1	1
Maybe	2	2	4
Yes	2	11	13

Texting while Driving Theory of Planned Behavior Constructs

Full cluster mixed model analyses (controlling for ‘ever’ sending and ‘ever’ reading texts while driving) accounting for proper group randomized trial degrees of freedom showed no significant interactions between treatment assignment and time (pre-post), indicating no statistically significant effects from the trial. Higher-powered regression analyses that disregard the cluster effects, which were negligible, also showed no statistically significant interactions between time and treatment.

Exploratory analyses

Because there were no differences by treatment group and cluster effects were minimal, we conducted exploratory pre-post regression analyses (still controlling for sending/reading texts while driving). Perceived behavioral control (PBC) item #1 (“I am confident that I could text while driving and still drive safely.”) was statistically significantly different before and after the session, b=-0.78, $t(46) = -2.66$, P=.011. Relatedly, the PBC sum score, which included PBC item #2 (“It would be easy for me to text while driving in the next week.”) was also significant, b=-1.28, $t(46) = -2.49$, P=.017, but not item #2 by itself.

In these same models, many TPB items were significantly associated with texting frequency but not the time factor: Reporting ‘ever’ sending texts while driving was a significant predictor of many TPB items (perceived behavior control sum, both attitude items, subjective norm item #2, intent items #1 and #3, and its sum), while ‘ever’ reading texts while driving significantly predicted change in just perceived disadvantage item #2 and its construct sum). Before and after TPB construct descriptives (with simplified t-tests) are in Table 3 and the exploratory full pre-post regression models are available in the Appendix (A2)

Table 3. Pre-Post Session Changes in Texting While Driving Theory of Planned Behavior Constructs

	Variables	**Pre-Session**	**Post-Session**	**t-test p-value**
Label	*Perceived behavioral control*			
pbc1	I am confident that I could text while driving and still drive safely.	2.4 (1.1)	1.6 (0.9)	*.016*
pbc2	It would be easy for me to text while driving in the next week.	2.1 (1.2)	1.6 (1.0)	.122
pbc_sum	PCB sum score	4.5 (2.2)	3.2 (1.6)	*.029*
	General TWD attitude			
attitude3	Texting while driving can be dangerous, but I am going to do it anyway.	1.8 (1.2)	1.5 (0.8)	.310
attitude4	It is my business if I want to text while driving.	1.6 (0.9)	1.4 (0.7)	.476
att_sum	Attitude sum score	3.3 (1.6)	2.9 (1.3)	.282
	Subjective norm			

snorm1	Most people important to me would want me to text while driving in the next week.	1.1 (0.4)	1.1 (0.4)	1.000
snorm2	Most people important to me would approve of me texting while driving in the next week.	1.2 (0.6)	1.1 (0.3)	.353
snorm3	Most people important to me would think that I should text while driving in the next week.	1.2 (0.5)	1.0 (0.2)	.248
snorm_sum	Norm sum score	3.5 (1.4)	3.2 (0.9)	.461
	Perceived disadvantages of abstention			
perdis1	I could not check with someone if I got lost or forgot something.	3.0 (0.9)	2.7 (1.3)	.357
perdis2	I would not be able to tell people where I am or when I will arrive.	2.9 (1.3)	2.6 (1.2)	.428
perdis3	My mom or dad could not call me when they need me.	2.8 (1.3)	2.6 (1.3)	.660
perdis4	I would be different from all my friends.	1.9 (1.1)	2.0 (1.1)	.608
perdis_sum	Disadvantage sum score	10.5 (3.7)	9.9 (3.7)	.588
	Perceived advantages of abstention			
peradv1	I would be able to pay better attention to my driving.	4.8 (0.8)	4.6 (1.1)	.568
peradv2	I would be less likely to get into an accident.	4.9 (0.3)	4.5 (1.1)	.125

peradv3	I would be following the law.	4.9 (0.3)	4.6 (1.1)	.171
peradv4	I would make my parents happy.	4.9 (0.3)	4.5 (1.1)	.177
peradv5	I would be calmer when I drive because I would not have conversations that might upset me.	4.5 (0.9)	4.4 (1.2)	.685
peradv6	I would not get a ticket.	4.8 (0.5)	4.5 (1.1)	.395
peradv7	My friends would think I was responsible.	4.6 (0.6)	4.4 (1.2)	.462
peradv_sum	Advantage sum score	33.3 (2.5)	31.6 (7.3)	.272
	Intention			
intent1	I intend to text while driving in the next week.	1.4 (0.7)	1.2 (0.4)	.326
intent2	It is likely that I will text while driving in the next week.	1.5 (0.9)	1.4 (0.8)	.867
intent3	I am willing to text while driving in the next week.	1.8 (1.0)	1.7 (0.9)	.561
intent_sum	Intention sum score	4.7 (2.6)	4.3 (1.9)	.566

Note. Item labeling from McBride et al. validity testing of the scale noted for comparison and ease of reference.

Qualitative Themes

The primary themes that emerged from the qualitative dataset were 1) the VR gameplay adeptly portrayed real-world consequences of texting and driving; 2) participants highly valued the interactive nature of the VR game and discussion; and 3) both the VR game and facilitated discussion were deemed as integral and complementary components in cultivating awareness about risks of DDB. Finally, participants offered 4) feedback for improving the distracted navigator game and facilitated discussion for further intervention development.

VR Gameplay Adeptly Portrayed Real-World Consequences of Texting and Driving

The immersive *Distracted Navigator* gameplay achieved one of its educational aims, as participants recognized how the game's distracting tasks and declining game performance related to real-world consequences of DDBs.

> *"It makes more apparent with how dangerous distractions really are…This represented different things that are on the road as well, not just you, but also other cars, and animals, and pedestrians. I feel like also with the typing, with the buttons, that reminded me of texting. I was hitting five things—five asteroids when I was texting. It reminds me of that. It took about the same amount of time of pushing the buttons as a text would take. It really shows you how you can hit so many things or cause that many accidents in such a short amount of time. It was like two seconds."*

This was taken further by multiple participants who reported that the consequences experienced in the game lessened their intention to engage in TWD behaviors.

> *"For me, I'm less likely to text now. I'm not gonna lie, I've text and drove before, it's happened. I think now, seeing for example, you can see the ship on the side and see how damaged it gets. I think that also helps a lot with showing what can happen in real life scenarios."*

The haptic feedback and sounds via the VR equipment also helped create an immersive world.

Participants Highly Valued the Interactive Nature of the VR Game and Discussion

In discussion of the *Distracted Navigator* in particular, participants agreed that the engaging nature of the game enhanced the educational value.

> *"This worked for me 'cause I like to interact with things. I like being able to work with the things, and playing a game made me wanna focus more."*

This was true for the facilitated discussion as well. Multiple participants favorably compared this discussion to traditional driver's education.

> *"I like it being more of a conversation than just a teacher or somebody showing it to you."*

By comparison, our facilitated discussion based on TPB concepts was "*more engaging*," and "*interactive*." The value of this engagement was seen, and perhaps made more prominent, when the game and discussion were paired together.

> *"It was a fun educational experience. You were having fun at the same time while learning things. Enjoying, you're able to enjoy it."*

Both the VR Game and Facilitated Discussion were Deemed as Integral and Complementary Components in Cultivating Awareness About Risks of DDB

Finally, the participants made note of the synergy between the gameplay and facilitated discussion. While our groups discussed both favorably, the combination of the two was identified as necessary for maximal learning.

> *"I think it made the connection better between the game and then the slides. I think on their own, each one would have done worse, but combined, I think it did a lot better."*

There was consensus that teens should play the VR game first and then engage in the discussion because this provided context and augmented, in a timely manner, exactly what had just been experienced in the game.

Feedback for Improving the Distracted Navigator Game and Facilitated Discussion

Focus group feedback from teens offered several areas for modifying the VR game and discussion to be more engaging and relatable to driving risks. Nearly universally, teens said they preferred more realism in the game, especially in the tasks. For example, unlike the keypad digit entering task, the lever pulling task did not have a good real-world analog. Some of the distraction tasks were confusing in terms of what to do and could be simplified. For the facilitated discussion, teens recognized the utility of incorporating more compelling statistics and narratives. They also suggested more surface level changes such as more engaging graphics.

Discussion

Although there was no statistically significant impact on novice drivers' DDB attitudes and intentions, our findings show success toward our goal of developing an intervention to augment traditional driver's education. Participant feedback suggests that the addition of an immersive experience through *Distracted Navigator* reinforced the negative effects of TWD and other DDB in ways that standard drivers' education lectures cannot. This was particularly highlighted in the focus group data and is novel to the existing literature on driver's education. However, the lack of empirical group differences indicates that thoughtfully engaging teen drivers in discussion of these behaviors and related impairments may still heighten awareness of their dangers, with or without the VR gameplay.

Most participants reported never experiencing consequences of DDB (e.g., ticketed, injured someone). According to the Protection Motivation Theory [40,41], these novice drivers may have an inaccurate perception of the risks or consequences and therefore may engage in behaviors like TWD more often. VR gaming may provide the driving experience and personal experience of DDB consequences that novice teen drivers ' lack that influence their perceived risk of TWD behavior (e.g., Protection Motivation Theory) [40].

Our feedback suggests *Distracted Navigator* was successful in providing a safe and immersive experience for teens to experience such consequences, with participants connecting the “emergency tasks” to the real world while recognizing the outcomes. Another potential benefit of the VR approach is the capability to live stream VR gameplay, a popular and familiar format for teens to engage in the play by proxy [42,43]. Streaming active VR play in a drivers’ education classroom enhances the scalability of the intervention.

While our focus group feedback underscored the efficacy of the combined programming - facilitated discussion and *Distracted Navigator* - in demonstrating the repercussions of DDB and changing participants’ intentions, the quantitative data did not show analogous statistically significant outcomes. Further investigation into participants’ experiences hinted at several possible explanations for this discrepancy.

The first is the possible confounding effect of the facilitated discussion in isolation. All groups, control and intervention, agreed that the facilitated discussion was superior to traditional classroom-based drivers’ education. While the synergistic effect when paired with the game was clear, the benefit of the discussion alone, as reported by our participants, may suggest why a statistically significant outcome was not found.

The second is the potential contribution of a floor effect on the data. In both the pre-intervention survey and the focus groups, most participants expressed that their baseline intention and self-reported habits were to not text and drive. This allowed for little movement toward a statistically significant impact. Most participants already said they did not intend to text while driving at baseline (87.5% said they strongly or somewhat disagreed that they would intend to or that they would likely text while driving in the next week). Even so, nearly three-quarters of participants had said the program changed how likely they were to text and drive when asked outside of the TPB items.

The issue of historical confounding was explored given that a Michigan hands-free law went into effect for all drivers June 2023, which was in between VR sessions [44]. This law made it illegal to hold or physically use a cell phone while driving and may have been advertised heavily along with warnings on the potential consequences (legal or safety) of TWD. However, post-hoc analyses indicate no difference in TPB constructs based on timing of sessions (pre-post full ban).

As a pilot study, our findings show promise for *Distracted Navigator* as a novel educational tool for novice drivers. Though our study was limited by size and the possible confounding effects of a specifically designed discussion, the feedback was positive with concrete recommendations for future improvements, highlighting potential areas for future research. Larger studies, with higher power and a more longitudinal perspective may shed more light on the potential for VR to have a lasting impact on driver’s education.

Limitations

Our study was constrained by the small pilot sample size, compounded by missingness for the ‘overall’ question, that limited the statistical power to discern subtle differences between the groups. Moreover, the small sample size contributed to the imbalance in the baseline differences in important TWD behaviors. However, through focus groups, we were able to capture candid feedback that offered valuable insights into participants’ experiences with both the VR game and/or the facilitated discussion. Self-reported data on texting behavior could have been susceptible to demand characteristics, potentially affecting accuracy, alongside missing responses from a few unanswered questions in an early version of the survey.

Conclusion

The growing availability of VR systems enables the easy integration of educational VR games like Distracted Navigator to enhance driver training education programs. Insights gained from participant feedback will be used to improve the VR game and associated discussion, preparing for a larger, prospective randomized control trial to test its specific influence on DDB beliefs and intentions.

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Conflicts of Interest:

None declared.

References

1. World Health Organization. Global Status Report on Road Safety 2018. World Health Organization; 2019. Report No.: 9789241565684.

2. National Center for Injury Prevention and Control, CDC. Web-based Injury Statistics Query and Reporting System (WISQARS). 2022.

3. Ehsani JP, Gershon P, Grant BJB, Zhu C, Klauer SG, Dingus TA, Simons-Morton BG. Learner driver experience and teenagers' crash risk during the first year of independent driving. JAMA Pediatr 2020 Jun 1;174(6):573–580. doi: 10.1001/jamapediatrics.2020.0208

4. Klauer SG, Guo F, Simons-Morton BG, Ouimet MC, Lee SE, Dingus TA. Distracted driving and risk of road crashes among novice and experienced drivers. N Engl J Med 2014 Jan 2;370(1):54–9. doi: 10.1056/NEJMsa1204142

5. Levine LE, Waite BM, Bowman LL. Mobile media use, multitasking and distractibility. Int J Cyber Behav Psychol Learn US: IGI Global; 2012;2(3):15–29. doi: 10.4018/ijcbpl.2012070102

6. Governors Highway Safety Association. Distracted driving. State Laws. 2022.

7. Pope CN, Nwosu A, Rudisill TM, Zhu M. Support for distracted driving laws: An analysis of adolescent drivers from the Traffic Safety Culture Index from 2011 to 2017. Transp Res Part F Traffic Psychol Behav 2021 Apr;78:424–432. doi: 10.1016/j.trf.2021.02.022

8. Kaviani F, Young KL, Robards B, Koppel S. "Like it's wrong, but it's not that wrong:" Exploring the normalization of risk-compensatory strategies among young drivers engaging in illegal smartphone use. J Safety Res 2021;78:292–302. doi: 10.1016/j.jsr.2021.06.010

9. McDonald CC, Sommers MS. Teen drivers' perceptions of inattention and cell phone use while driving. Traffic Inj Prev 2015;16 Suppl 2(0):S52-8. doi: 10.1080/15389588.2015.1062886

10. National Center for Statistics and Analysis. Distracted driving in 2021. Washington, DC: National Highway Traffic Safety Administration; 2023. Report No.: DOT HS 813 443. Available from: https://crashstats.nhtsa.dot.gov/Api/Public/Publication/813443

11. Centers for Disease Control and Prevention. Distracted driving. 2022. Available from: https://www.cdc.gov/transportationsafety/distracted_driving/index.html

12. Creaser JI, Edwards CJ, Morris NL, Donath M. Are cellular phone blocking applications effective for novice teen drivers? J Safety Res 2015 Sep;54:75–8. doi: 10.1016/j.jsr.2015.06.014

13. Oviedo-Trespalacios O, Vaezipour A, Truelove V, Kaye S-A, King M. "They would call me, and I would need to know because it is like life and death": A qualitative examination of the acceptability of smartphone applications designed to reduce mobile phone use while driving. Transp Res Part F Traffic Psychol Behav 2020;73:499–513. doi: 10.1016/j.trf.2020.06.007

14. Oviedo-Trespalacios O, Truelove V, King M. "It is frustrating to not have control even though

I know it's not legal!": A mixed-methods investigation on applications to prevent mobile phone use while driving. Accid Anal Prev 2020 Mar 1;137:105412. doi: https://doi.org/10.1016/j.aap.2019.105412

15. Sohn SY, Rees P, Wildridge B, Kalk NJ, Carter B. Prevalence of problematic smartphone usage and associated mental health outcomes amongst children and young people: a systematic review, meta-analysis and GRADE of the evidence. BMC Psychiatry 2019 Nov 29;19(1):356. doi: 10.1186/s12888-019-2350-x

16. Cox AE, Cicchino JB, Reagan IJ, Zuby DS. Prevalence of distracted driving by driver characteristics in the United States. J Safety Res 2023 Sep 1;86:346–356. doi: 10.1016/j.jsr.2023.07.013

17. Rodwell D, Hawkins A, Haworth N, Larue GS, Bates L, Filtness A. A mixed-methods study of driver education informed by the Goals for Driver Education: Do young drivers and educators agree on what was taught? Saf Sci 2018 Oct 1;108:140–148. doi: https://doi.org/10.1016/j.ssci.2018.04.017

18. Rodwell D, Watson-Brown N, Bates L. Perceptions of novice driver education needs; Development of a scale based on the goals for driver education using young driver and parent samples. Accid Anal Prev 2023 Oct 1;191:107190. doi: 10.1016/j.aap.2023.107190

19. Hu-Au E, Lee J. Virtual reality in education: a tool for learning in the experience age. Int J Innov Educ 2018 22;4(4):215–226. doi: 10.1504/ijiie.2017.10012691

20. Liu X, Zhang J, Hou G, Wang Z. Virtual reality and its application in military. IOP Conf Ser Earth Environ Sci 2018 01;170:032155. doi: 10.1088/1755-1315/170/3/032155

21. Pandrangi VC, Gaston B, Appelbaum NP, Albuquerque FC, Levy MM, Larson RA. The application of virtual reality in patient education. Ann Vasc Surg 2019 Aug;59:184–189. doi: 10.1016/j.avsg.2019.01.015

22. Schwebel DC, McClure LA. Using virtual reality to train children in safe street-crossing skills. Inj Prev 2010 Feb;16(1):e1-5. doi: 10.1136/ip.2009.025288

23. Semeraro F, Ristagno G, Giulini G, Kayal JS, Cavallo P, Farabegoli L, Tucci R, Scelsi S, Grieco NB, Scapigliati A. Back to reality: A new blended pilot course of Basic Life Support with Virtual Reality. Resuscitation 2019 May;138:18–19. doi: 10.1016/j.resuscitation.2019.02.034

24. Vankov D, Jankovszky D. Effects of using headset-delivered virtual reality in road safety research: A systematic review of empirical studies. Virtual Real Intell Hardw 2021 01; doi: 10.1016/j.vrih.2021.05.005

25. Morley DC, Lawrence G, Smith S. Virtual reality user experience as a deterrent for smartphone use while driving. Proc 9th ACM Int Conf PErvasive Technol Relat Assist Environ New York, NY, USA: Association for Computing Machinery; 2016. p. 1–3. doi: 10.1145/2910674.2910696

26. Desurvire H, Kreminski M. Are game design and user research guidelines specific to virtual reality effective in creating a more optimal player experience? Yes, VR play. In: Marcus A, Wang W,

editors. Des User Exp Usability Theory Pract Cham: Springer International Publishing; 2018. p. 40–59. doi: 10.1007/978-3-319-91797-9_4

27. Preview Labs - Rapid Game Prototyping. Distracted Driving Game Archives. PreviewLabs. 2023. Available from: https://previewlabs.com/category/prototypes/distracted-driving-game/ [accessed Dec 6, 2023]

28. Simons DJ, Chabris CF. Gorillas in our midst: sustained inattentional blindness for dynamic events. Perception 1999;28(9):1059–1074. PMID:10694957

29. Desai N. The role of motivational interviewing in children and adolescents in pediatric care. Pediatr Ann 2019 Sep 1;48(9):e376–e379. PMID:31505012

30. Van Tassel WE. How to Drive: Driver Education Student Textbook. 15th ed. AAA; 2020. ISBN:1-59508-617-X

31. C.S. Mott Children's Hospital Trauma Program - Michigan Medicine. Kohl's Drive Smart initiative - Kohl's Drive Smart Interactive Game. 2021.

32. Bazargan-Hejazi S, Teruya S, Pan D, Lin J, Gordon D, Krochalk PC, Bazargan M. The theory of planned behavior (TPB) and texting while driving behavior in college students. Traffic Inj Prev 2017 Jan 2;18(1):56–62. doi: 10.1080/15389588.2016.1172703

33. McBride M, Carter L, Phillips B. Integrating the theory of planned behavior and behavioral attitudes to explore texting among young drivers in the US. Int J Inf Manag 2020 Feb 1;50:365–374. doi: https://doi.org/10.1016/j.ijinfomgt.2019.09.003

34. Gauld CS, Lewis I, White KM, Fleiter JJ, Watson B. Evaluating public education messages aimed at monitoring and responding to social interactive technology on smartphones among young drivers. Accid Anal Prev 2017 Jul;104:24–35. doi: 10.1016/j.aap.2017.04.011

35. Hafetz JS, Jacobsohn LS, García-España JF, Curry AE, Winston FK. Adolescent drivers' perceptions of the advantages and disadvantages of abstention from in-vehicle cell phone use. Accid Anal Prev 2010 Nov;42(6):1570–1576. PMID:20728605

36. Harrison MA. College students' prevalence and perceptions of text messaging while driving. Accid Anal Prev 2011 Jul;43(4):1516–1520. PMID:21545885

37. Krueger RA, Casey MA. Focus groups: A practical guide for applied research. SAGE; 2009. ISBN:978-1-4129-6947-5

38. StataCorp. Stata statistical software: Release 18. College Station, TX: StataCorp LLC; 2023.

39. Braun V, Clarke V. Using thematic analysis in psychology. Qual Res Psychol 2006;3(2):77–101. doi: 10.1191/1478088706qp063oa

40. Ferrer RA, Klein WMP, Avishai A, Jones K, Villegas M, Sheeran P. When does risk perception predict protection motivation for health threats? A person-by-situation analysis. PloS One 2018;13(3):e0191994. PMID:29494705

41. Sheeran P, Harris PR, Epton T. Does heightening risk appraisals change people’s intentions and behavior? A meta-analysis of experimental studies. Psychol Bull 2014 Mar;140(2):511–543. PMID:23731175

42. Cabeza-Ramírez LJ, Muñoz-Fernández GA, Santos-Roldán L. Video game streaming in young people and teenagers: uptake, user groups, dangers, and opportunities. Healthc Basel 2021 Feb 10;9(2). doi: 10.3390/healthcare9020192

43. Wohn D, Freeman G. Live streaming, playing, and money spending behaviors in esports. Games Cult 2019 01;15:155541201985918. doi: 10.1177/1555412019859184

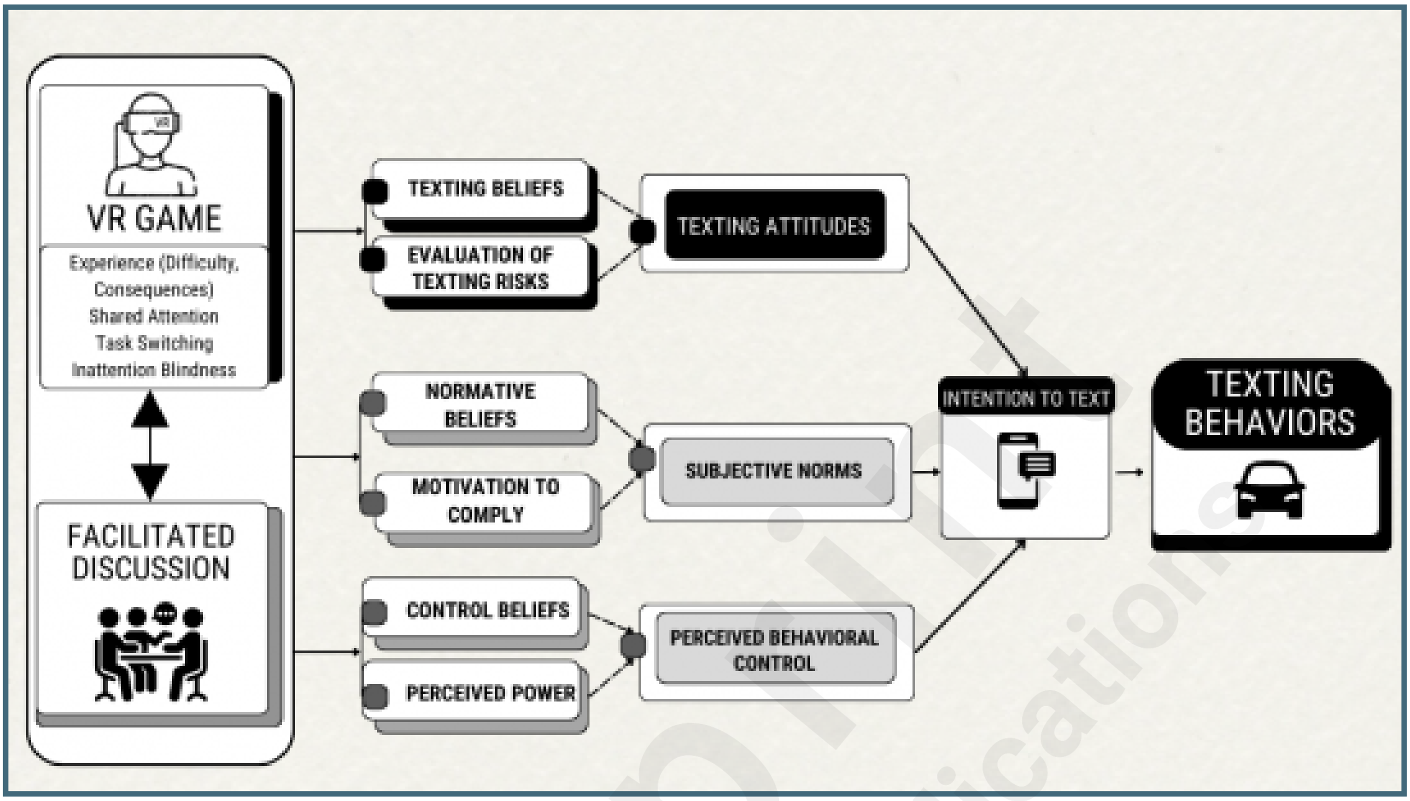
44. Johncox C. Michigan’s new hands-free driving law takes effect Friday: What to know. ClickOnDetroit Detroit, MI; 2023 Jun 29; Available from: https://www.clickondetroit.com/news/michigan/2023/06/29/michigans-new-hands-free-driving-law-take-effect-friday-what-to-know/ [accessed Dec 6, 2023]

Supplementary Files

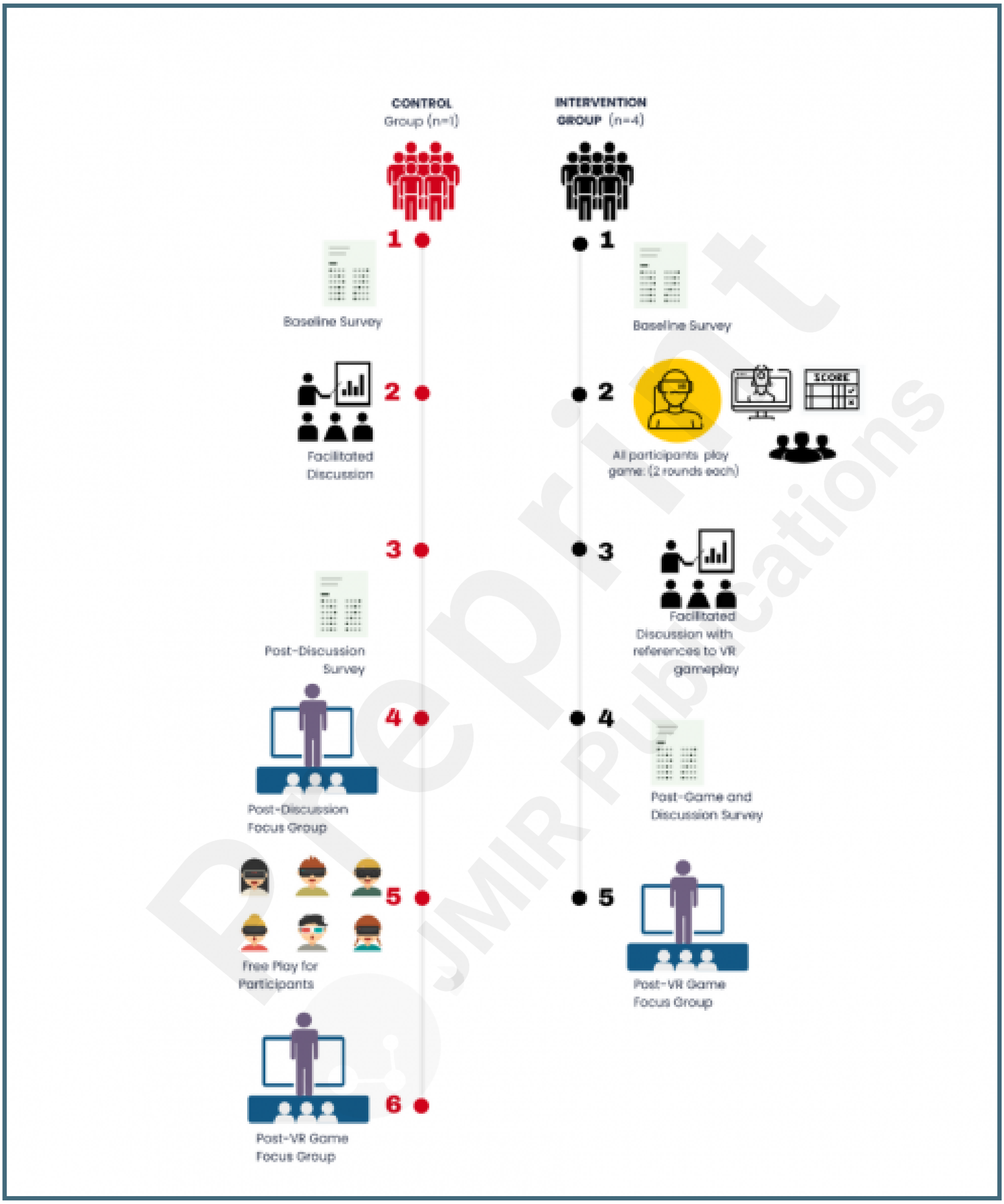
Figures

VR Game Sample Screenshots.

VR Game and Discussion Theory of Planned Behavior Conceptual Model.



Participant Study Flow.



Multimedia Appendixes

A1. Semi-structured Focus Group Guide. A2. Exploratory Full Pre-Post Regression Models.
URL: http://asset.jmir.pub/assets/b92f3f2b8f4a80bc468fb114b4eace96.docx