HHS Public Access
Author manuscript
Virtual Real. Author manuscript; available in PMC 2018 September 01.

Published in final edited form as:
Virtual Real. 2017 September ; 21(3): 145–152. doi:10.1007/s10055-016-0304-x.

Using smartphone technology to deliver a virtual pedestrian environment: usability and validation

David C. Schwebel[1,iD], **Joan Severson**[2], and **Yefei He**[2]

[1]Department of Psychology, University of Alabama at Birmingham, 1720 2nd Ave. S., HHB 560, Birmingham, AL 35294-1152, USA

[2]Digital Artefacts, LLC, Iowa City, IA, USA

Abstract

Abstract Various programs effectively teach children to cross streets more safely, but all are labor- and cost-intensive. Recent developments in mobile phone technology offer opportunity to deliver virtual reality pedestrian environments to mobile smartphone platforms. Such an environment may offer a cost- and labor-effective strategy to teach children to cross streets safely. This study evaluated usability, feasibility, and validity of a smartphone-based virtual pedestrian environment. A total of 68 adults completed 12 virtual crossings within each of two virtual pedestrian environments, one delivered by smartphone and the other a semi-immersive kiosk virtual environment. Participants completed self-report measures of perceived realism and simulator sickness experienced in each virtual environment, plus self-reported demographic and personality characteristics. All participants followed system instructions and used the smartphone-based virtual environment without difficulty. No significant simulator sickness was reported or observed. Users rated the smartphone virtual environment as highly realistic. Convergent validity was detected, with many aspects of pedestrian behavior in the smartphone-based virtual environment matching behavior in the kiosk virtual environment. Anticipated correlations between personality and kiosk virtual reality pedestrian behavior emerged for the smartphone-based system. A smartphone-based virtual environment can be usable and valid. Future research should develop and evaluate such a training system.

Keywords

Pedestrian; Safety; Injury; Virtual reality; Simulation; Mobile smartphone

1 Introduction

Recent estimates suggest road traffic injuries are the ninth-leading cause of death in the world, killing almost 1.4 million individuals annually (Haagsma et al. 2016; World Health Organization [WHO] 2016). Pedestrians comprise roughly 20% of all road traffic mortalities (World Health Organization 2013). Multiple strategies have been demonstrated effective to

David C. Schwebel schwebel@uab.edu.
David C. Schwebe http://orcid.org/0000-0002-2141-8970

reduce pedestrian injuries globally; among these are efforts to teach children to cross streets more safely (Schwebel et al. 2014).

Scientific research to identify strategies to train children in pedestrian safety and reduce injuries has a long history, dating at least to classic work in Sweden by Sandels (1968/1975). A recent meta-analysis indicates promise for a number of intervention strategies to teach children to cross the road safely, including most prominently individualized or small group training of children by an experienced adult pedestrian and use of computer and virtual reality technology for training (Schwebel et al. 2014).

One significant limitation to effective pedestrian safety training is the transition from identifying successful programs to broad implementation of those programs. Individualized or small group training is labor-intensive, often beyond the capacity of school and community organizations. Implementation of training via virtual reality can be child-operated so may not tax the personnel resources of organizations as much, but traditional, multiscreen virtua reality remains technically complex, expensive, and inaccessible in most facilities.

The transition from identification of an effective health intervention strategy to broad dissemination and implementation of that strategy is of great interest to many stakeholders and ultimately is a necessary step for health behavior change to occur (Glasgow et al. 2012; Grimshaw et al. 2012; Zerhouni 2005). Thus, efforts to identify pedestrian safety training programs that are both effective and feasible for broad dissemination comprise a public health priority. Recent technological advances permit virtual reality environments to be delivered not only to large apparatuses or specialized virtual reality goggles, but also directly to mobile smartphones. Given the ubiquity of mobile phones worldwide, including increasing presence of smartphones in low- and middle-income countries (Bastawrous et al. 2012), smartphone-based virtual reality technology offers an intriguing opportunity as a tool to broadly train children in child pedestrian safety. Training within a smartphone-based virtual environment overcomes the financial and labor barriers of individualized or small group training as well as the financial and logistical barriers of larger virtual reality environments.

With the long-term goal of developing training programs that can be broadly disseminated, the present study presents data on the usability and feasibility to deliver an immersive virtual reality pedestrian safety environment via smartphone. Since no other published research has examined the feasibility of delivering virtual reality pedestrian environments via smartphone, and since motion sickness may be more common among children compared to adults (Reason and Brand 1975; Turner and Griffin 1999); but note alternative findings that simulator sickness which is somewhat different from motion sickness, may be less common among children than adults, (Arns and Cerney 2005; Brooks et al. 2010; Liu et al. 1999), ethical standards guided us to conduct this initial research with a sample of adults. We tested four hypotheses: (a) A smartphone-based virtual reality environment would demonstrate feasibility and usability among a sample of young adults, (b) the system would be rated by users as realistic and would not cause significant simulator sickness, (c) the system would demonstrate convergent validity with behavior in an existing semi-immersive virtual pedestrian environment, and (d) the system would demonstrate convergent validity with self-reported personality traits. We felt it important to demonstrate convergent validity with both an existing validated virtual environment (Schwebel et al. 2008) and with external behavior traits (personality) to provide empirical evidence that behavior in a virtual pedestrian environment delivered via smartphone might represent real-world pedestrian behavior.

2 Methods

2.1 Participants

We recruited 68 college students from introductory psychology courses at University of Alabama at Birmingham. The participants were 74% women and had a mean age of 21.66 years (SD = 5.71). They were racially diverse (24% African-American, 62% Caucasian, 7% Asian-American, 2% Hispanic, and 6% multiracial) and participated as one way to earn course credit. The protocol was reviewed and approved by the university IRB.

2.2 Protocol

Following consent procedures, participants were asked to complete a short demographic questionnaire and a personality assessment (detailed below) and then were randomly assigned to complete street crossings either using the immersive smartphone-based virtual reality (VR) or within a semi-immersive kiosk virtual reality platform environment first. In both cases, participants completed orientation trials to become accustomed to the virtual environment, took a short (3-min) break if desired, and then completed 12 test trials of crossing the virtual street on that platform. Following completion of the trials, participants completed short self-report measures assessing their perceived realism of the virtual environment and their self-reported simulator sickness symptoms (detailed below). Another short (3 min) break was offered, and then, participants moved to a different room to complete orientation, 12 test trials, and then realism and simulator sickness questionnaires for the second virtual reality platform. Prior to leaving, participants were debriefed concerning the research goals and given documentation of their participation to earn course credit.

2.3 Experience within the virtual reality environments

The two systems use the same underlying software library based on the Unity game engine by Unity Technologies for delivering the real-time virtual environment, as well as the same game play logic and data collection mechanism, complete with their own platform-specific software developer kits (see Fig. 1 for photographs of the virtual environments). They depict the same actual street environment in the local community, adjacent to a local elementary school. Participants cross a two-lane bidirectional street. Prior to crossing, participants stand on the simulated curb and look at traffic in both directions (in the smartphone-based VR environment, by moving their head left and right; in the kiosk, while standing on an actual wooden curb within the semi-immersive virtual environment). Traffic speed and density can be programmed by the researcher; for this study, we used settings of 13.41 m/s (30 MPH) for vehicle speed and 10 vehicles per minute per lane for average traffic density. Walking speed also can be programmed by the researcher; for this study, we used a setting of 1.35 m/s (3.02 MPH). A realistic suburban street environment appears in the background including trees and shrubs, homes, buildings and a local school, and lawns. Ambient sound (birds tweeting) as well as Doppler-based traffic sounds are produced. When the user deems it safe to cross, they initiate movement (in the smartphone-based VR by pushing a button; in the kiosk, by stepping down off the virtual curb). In the kiosk VR, at this point, their perspective becomes third person and they view themselves crossing the street. In the smartphone-based VR, the users' perspective remains first-person view, as the viewpoint follows the avatar across the street. In both setups, the ambient environment remains and traffic continues to move in both directions. The system provides feedback concerning the safety of crossing (one of two positive remarks after a safe crossing, a warning after a close call, and a frozen screen and warning after a collision). The switch from first person to third person in the kiosk VR was developed to assist with training children to cross the street and happens quite seamlessly; in fact, most users do not even notice the switch unless they are explicitly informed about it.

The smartphone-based VR hardware consisted of a Samsung Galaxy S6 smartphone, running on Android 5.0 Lollipop operating system, with 3 GB RAM, 32 GB internal memory capacity, Exynos 7420 Octa chipset, 2.1 GHz 8-core CPU and Mali-T760MP8 8-core GPU, 5.1" diagonal AMOLED display with 2560 × 1440 pixels. It was inserted into a Cardboard viewer, which is a commercially available piece of folded cardboard fitted with lenses and magnets. Participants were seated while using the smartphone-based VR to avoid unintentional slips while immersed into the environment. The kiosk system runs on a standard Windows 7 PC with an Intel Core i5-3330 3.0 GHz Quad-Core desktop processor and GeForce GT 640 video card. Displays appear on 3 vertically mounted Samsung MD55C 55" Direct-lit LED monitors (see Schwebel et al. 2016). Both systems deliver ambient background and Doppler-accurate traffic noise.

2.4 Assessment of simulator realism and simulator sickness

Perceived realism of the virtual environments was reported immediately after engaging in the virtual environment. Participants rated 6 facets of the simulation, plus provided an overall score of realism, all using a 5-point scale from 1 ("not realistic at all") to 5 ("completely realistic"). Higher scores imply higher perceived realism.

Motion sickness was assessed immediately after engaging in each virtual environment using the Simulator Sickness Questionnaire (Kennedy et al. 1993), which includes 16 items rated on a 5-point scale from 0 ("no symptoms") to 4 "(severe symptoms"). The items assess various aspects of simulator sickness, and an "overall sickness" rating is also provided. Higher scores implying greater experienced simulator sickness.

2.5 Assessment of personality

Self-reported personality was assessed using the 44-item Big Five Inventory (BFI; Benet-Martinez and John 1998), a widely used adult personality screening. The BFI has strong internal consistency and convergent validity with other measures of adult personality (Benet-Martinez and John 1998; John and Srivastava 1999).

2.6 Pedestrian behavior outcomes

We considered three outcomes of pedestrian behavior: unsafe crossings, start delay, and missed opportunities.

2.6.1 Unsafe crossings—Unsafe crossings were those when the pedestrian avatar was struck by a vehicle, or was within 1 s of being struck, while crossing the virtual street. Unsafe crossings were computed as the percentage of unsafe crossings across the 12 crossings in each virtual environment.

2.6.2 Start delay—Start delay refers to the time, in seconds, between the traffic gap the pedestrian chose to cross within appearing (that is, the last vehicle passes the crosswalk) and the pedestrian entering the crosswalk to cross. Previous research indicates start delay is an excellent proxy measure of the cognitive process of deciding to enter the road (Thomson et al. 2005). The average start delay across the 12 crossings was computed.

2.6.3 Missed opportunities—Missed opportunities to cross were tallied when there was a safe traffic gap to cross within (defined as a gap 1.5 times the time required to traverse the road), but the pedestrian chose not to cross within that gap. It was possible for more than one missed opportunity to occur in a single crossing, so this variable was tallied as a count variable across the 12 crossings.

2.7 Data analysis

Usability and feasibility of the smartphone-based virtual environment was assessed qualitatively. User ratings of realism and simulator sickness were examined descriptively, and ratings across the two virtual environments were assessed using related-samples *t*-test as well as nonparametric Wilcoxon signed rank tests given potential concerns about computing parametric tests with scaled response survey data. Finally, convergent validity of behavior in the smartphone-based system was computed by correlating it with behavior in the kiosk system and with self-reported personality traits.

3 Results

Our first hypothesis was that the smartphone-based environment would be feasible and usable. Qualitative evidence supports this hypothesis, as all (100%) participants successfully used the environment following system-driven instructions. None requested to stop the protocol due to simulator sickness or other reasons, and none had difficulty understanding how the system functioned.

Our second hypothesis was that users would rate the smartphone-based system as realistic and that it would not cause significant simulator sickness. As shown in Table 1, users rated the smartphone-based system as highly realistic in all aspects. Their overall rating of realism was 3.98 (SD = .77) on the 5-point scale, where 4.00 signified “quite realistic”. Ratings for the smartphone-based system tended to be slightly higher than the kiosk system, though not at a statistically significant level in all but one case (motion of pedestrians).

We also assessed self-reported simulator sickness following engagement in both virtual environments (Table 2). Average ratings were in the no-to-minimal simulator sickness range; the average "overall" simulator sickness rating for the smartphone-based system was .41 (SD = .49) on the 4-point scale, where 0 represented "no symptoms" and 1 represented "slight symptoms". When ratings across the two systems were compared, we found simulator sickness scores to be moderately higher in the smartphone-based system compared to the semi-immersive kiosk system, but not at an ethically concerning level. We conclude both systems produce minimal simulator sickness and would be appropriate for broad distribution and use.

Our third hypothesis was that the smartphone-based virtual reality system would demonstrate convergent validity with behavior in the kiosk system. As shown in Table 3, the number of missed opportunities across the two virtual environments coincided closely (r (66) = .52, p <.01). There was a trend for start delay to coincide across the two systems (r (66) = .24, p = .06). Unsafe crossings did not correlate significantly (r (66) = −.01, ns), perhaps partly because these adult pedestrians tended to be safe pedestrians and unsafe crossings were relatively rare (M = .14, SD = .11 for smartphone; M = .11, SD = .09 for kiosk), creating a poor variance ceiling effect in the correlation analysis.

Finally, we considered correlations between behavior in the smartphone-based virtual reality system and self-reported personality. As shown in Table 4, unsafe crossings were correlated with higher levels of agreeableness (r (66) = .29, p <.05) and trended toward significance with higher levels of extraversion (r (66) = .24, p = .06) and openness to experience (r (66) = .25, p = .05).

4 Discussion

Identification of an effective mechanism to train children in pedestrian safety that can be broadly and cost-effectively disseminated worldwide has the potential to contribute substantially to improving public health. Existing pedestrian safety training programs that have been demonstrated effective are resource intensive, both in terms of personnel and finances (Schwebel et al. 2014). Mobile smartphone-based virtual environments hold promise for cost- and labor-efficient delivery if they can be demonstrated usable and effective.

Extending earlier results that behavior in an immersive virtual reality environment replicated behavior in the real world among both children and adults (Schwebel et al. 2008), our results offer initial evidence that delivery of a virtual pedestrian environment to a smartphone platform is usable and valid. Adult participants were able to use the program without difficulty and rated the simulation as realistic. Their ratings of realism—which hovered around a "quite realistic" rating—were comparable to those reported in previous research with adult and child samples (Schwebel et al. 2008). Both self-reported sickness and observed simulator sickness were minimal, again matching previous findings (Schwebel et al. 2008). Convergent validity with behavior in a large semi-immersive virtual environment and with self-reported personality was demonstrated; this finding is comparable to previous reports between child temperament and pedestrian behavior in a simulator (Schwebel et al.

2008) as well as research using other virtual pedestrian environments that demonstrate evidence of convergent validity based on developmental trends whereby younger children take greater risks in simulated pedestrian settings than older children (e.g., Morrongiello et al. 2016) and both older children and adults (e.g., Meir et al. 2015). Public health theorists conceptualize four steps to successful prevention of negative health outcomes (Mercy et al. 1993). Early steps—defining the problem, identifying the causes, and developing and testing interventions—have been accomplished already in child pedestrian injury prevention, but the field has stalled somewhat at the stage of implementing interventions and measuring the effectiveness of prevention strategies. Dissemination through use of pedestrian safety training by retired individuals in the United Kingdom (Thomson and Whelan 1997) and Safety Town placements in the 1970s and 1980s United States (Adesso 1974) have some success in isolated geographic regions, but not large geographic areas nor in economically disadvantaged regions. Smartphone technology offers potential to overcome this challenge, including in lower-income regions of the world with the greatest risk of child pedestrian injury and mortality.

As an example, we are currently developing research that will deliver pedestrian safety training to children in Changsha, Hunan Province, China. Roughly 321 million children live in China, injury is the leading cause of pediatric death in that nation, and transportation-related injury is the second-leading cause of Chinese children's fatal injuries (Institute for Health Metrics and Evaluation 2016; Linnan 2010). About two-thirds of transportation-related deaths to Chinese children ages 5–9, or 3200 deaths per year, are to pedestrians, and the pedestrian injury mortality rate in China is rapidly increasing (Institute for Health Metrics and Evaluation 2016; Ma et al. 2013).

Given current resources in China, it is unrealistic to imagine widespread dissemination of immersive or head-mounted display pedestrian virtual environments to the large numbers of children who might benefit from VR-based training in pedestrian skills. It is more reasonable, however, to envision delivery of VR-based training using mobile smartphones, which are quickly becoming ubiquitous in nations like China (Statistica estimates over 563 million people, or roughly half the adult population in China, owns smartphones; http://www.statista.com/statistics/467160/forecast-of-smartphone-users-in-china/). In fact, if smartphone-based virtual reality training in pedestrian safety proves effective, it offers a unique and effective means of disseminating pedestrian safety training through much of Asia, Africa, and elsewhere in the world that could not be accomplished through traditional virtual reality hardware. Thus, the present study offers a critical first step toward evaluating and implementing mobile smartphone technology to distribute pedestrian safety training to children broadly. Specifically, it offers evidence that behavior in a virtual reality environment delivered by smartphone has validity among adults and suggests training in that environment might offer the cognitive and perceptual practice needed for children to learn to cross streets more safely. Virtual reality technology is innovative and promising, and empirical evidence of validity with adult participants offers the first step toward using virtual reality for training in a wide range of contexts, including health behavior change.

Like all research, this study suffered from some limitations. These include a focus only on adults and a lack of assessment of pedestrian behaviors in real-world environments. We chose to study adult first for ethical reasons; had the technology caused simulator sickness or other adverse effects, we felt ethically obligated to evaluate the effects on adults prior to conducting research with children. Future research should explore usability and any potential adverse consequences from use of VR delivered by smartphone to pediatric populations, extend previous findings (Schwebel et al. 2008) to validate simulated behavior in comparison to real-world behavior, and evaluate smartphone-based virtual environments as an intervention strategy for child pedestrian safety.

Acknowledgments

Thanks to Anna Johnston and the students of the UAB Youth Safety Lab for their help with data collection, entry, and coding, and to the Digital Artefacts team for VR development and support. The research was supported by the Fogarty International Center and the Office of Behavioral and Social Sciences Research of the National Institutes of Health by Grants R21HD078371 and R01HD088415 (Grant Nos. R21 TW010310, R21 TW010310) from the Eunice Kennedy Shriver National Institute of Child Health and Human Development. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

References

Adesso, NA. Master’s thesis. University of Illinois at Urbana-Champaign; 1974. An evaluation of the Champaign-Urbana Safety Town program. http://files.eric.ed.gov/fulltext/ED104561.pdf

Arns, LL., Cerney, MM. IEEE virtual reality (VR’05). 2005. The relationship between age and incidence of cyberskciness among immersive environment users; p. 267-268.

Bastawrous A, Hennig B, Livingstone I. mHealth possibilities in a changing world: distribution of global cell phone subscriptions. J Mob Technol Med. 2012; 1:22–25.

Benet-Martinez V, John O. Los Cinco Grandes across cultures and ethnic groups: multitrait-multimethod analyses of the big five in Spanish and English. J Personal Soc Psychol. 1998; 75:729–750.

Brooks JO, Goodenough RR, Crisler MC, Klein ND, Alley RL, Koon BL, et al. Simulator sickness during driving simulation studies. Accid Anal Prev. 2010; 42:788–796. [PubMed: 20380904]

Glasgow RE, Vinson C, Chamber D, Khoury MJ, Kaplan RM, Hunter C. National Institutes of Health approaches to dissemination and implementation science: current and future directions. Am J Public Health. 2012; 102:1274–1281. [PubMed: 22594758]

Grimshaw JM, Eccles MP, Lavis JN, Hill SJ, Squires JE. Knowledge translation of research findings. Implement Sci. 2012; 7:50. [PubMed: 22651257]

Haagsma JA, Graetz N, Bolliger I, Naghavi M, Higashi H, Mullany EC, et al. The global burden of injury: incidence, mortality, disability-adjusted life years, and time trends from the Global Burden of Disease Study 2013. Injury Prev. 2016; 22:3–18.

Institute for Health Metrics and Evaluation (IHME). [Accessed 7 Dec 2016] Global Burden of Disease (GBD) visualizations. 2016. http://www.healthmetricsandevaluation.org/gbd/visualizations/country

John, OP., Srivastava, S. The big five trait taxonomy: history, measurement, and theoretical perspectives. In: Pervin, LA., John, OP., editors. Handbook of personality: theory and research. Guilford; New York: 1999. p. 102-138.

Kennedy RS, Lane NE, Berbaum KS, Lilienthal MG. Simulator Sickness Questionnaire: an enhanced method for quantifying simulator sickness. Int J Aviat Psychol. 1993; 3:203–220.

Linnan, H. [Accessed 5 Dec 2016] 2010 China: summary report and evaluation: child injury prevention project (2005–2010). 2010. http://www.unicef.org/evaldatabase/index_67780.html

Liu L, Watson B, Miyazaki M. VR for the elderly: quantitative and qualitative differences in performance with a driving simulator. Cyberpsychol Behav. 1999; 2:567–576. [PubMed: 19178204]

Ma S, Hu GQ, Li QF, Zhou MeG. Pedestrian mortality between 2006 and 2010 in China: findings from non-police reported data. Biomed Environ Sci. 2013; 26:853–856. [PubMed: 24215880]

Meir A, Oron-Gilad T, Parmet Y. Are child-pedestrians able to identify hazardous traffic situations? measuring their abilities in a virtual reality environment. Saf Sci. 2015; 80:33–40.

Mercy JA, Rosenberg ML, Powell KE, Broome CV, Roper WL. Public health policy for preventing violence. Health Aff. 1993; 12:7–29.

Morrongiello BA, Corbett M, Milanovic M, Beer J. Using a virtual environment to examine how children cross streets: advancing our understanding of how injury risk arises. J Pediatr Psychol. 2016; 41:265–275. [PubMed: 26338980]

Reason, JT., Brand, JJ. Motion sickness. Academic Press; London: 1975.

Sandels, S. Children in traffic. Hartley, J., editor; Mabon, H., translator. Paul Elek; London: 1968/1975.

Schwebel DC, Gaines J, Severson J. Validation of virtual reality as a tool to understand and prevent child pedestrian injury. Accid Anal Prev. 2008; 40:1394–1400. [PubMed: 18606271]

Schwebel DC, Barton BK, Shen J, Wells HL, Bogar H, Heath G, McCullough D. Systematic review and meta-analysis of behavioral interventions to improve child pedestrian safety. J Pediatr Psychol. 2014; 39:826–845. [PubMed: 24864275]

Schwebel DC, Combs T, Rodríguez D, Severson J, Sisiopiku V. Community-based pedestrian safety training in virtual reality: a pragmatic trial. Accid Anal Prev. 2016; 86:9–15. [PubMed: 26479677]

Thomson, J., Whelan, KM. A community approach to road safety education using practical training methods: the Drumchapel project. Department of Transportation; London: 1997. http://strathprints.strath.ac.uk/18700/1/strathprints018700.pdf

Thomson JA, Tolmie AK, Foot HC, Whelan KM, Sarvary P, Morrison S. Influence of virtual reality training on the roadside crossing judgments of child pedestrians. J Exp Psychol Appl. 2005; 11:175–186. [PubMed: 16221036]

Turner M, Griffin MJ. Motion sickness in public road transport, passenger behaviour and susceptibility. Ergonomics. 1999; 42:444–461. [PubMed: 10048305]

World Health Organization. Pedestrian safety: a road safety manual for decision-makers and practitioners. World Health Organization; Geneva: 2013.

World Health Organization. The top 10 causes of death. 2016. http://www.who.int/mediacentre/factsheets/fs310/en/

Zerhouni EA. Translational and clinical science—time for a new vision. N Engl J Med. 2005; 353:1621–1623. [PubMed: 16221788]

Fig 1.
Photographs of the virtual environments

Table 1

Ratings of realism in smartphone and kiosk virtual pedestrian environments, $N = 68$

Characteristic	Smartphone *M* (SD)	Kiosk *M* (SD)	*t*	*p*[1]
Cars and other vehicles	3.53 (.95)	3.60 (.85)	−.68	.45
Scenery	3.42 (.99)	3.51 (.92)	−.78	.45
Road and sidewalk	3.97 (.81)	3.82 (.91)	1.43	.15
Traffic and other sounds	4.12 (1.00)	4.07 (1.07)	.70	.46
Time for registering movement	3.62 (1.10)	3.54 (1.26)	.47	.73
Motion of pedestrian	3.62 (1.18)	3.28 (1.14)	2.05*	.04*
Motion of vehicles	3.80 (1.00)	3.78 (1.02)	.32	.85
Overall simulation	3.98 (.77)	3.94 (.73)	.52	.60

[1] *p* value for Wilcoxon signed rank test

* $p < .05$

Table 2

Self-reported simulator sickness following engagement in smartphone and kiosk virtual pedestrian environments, $N = 68$

Symptom	Smartphone *M* (SD)	Kiosk *M* (SD)	*t*	*p*[1]
General discomfort	.64 (.75)	.22 (.55)	4.76**	<.01**
Fatigue	.25 (.59)	.14 (.46)	1.92	.06
Headache	.36 (.67)	.21 (.57)	1.93	.06
Eyestrain	1.07 (.91)	.27 (.48)	7.05**	<.01**
Difficulty focusing	.72 (.85)	.19 (.44)	5.10**	<.01**
Increased salivation	.12 (.51)	.06 (.30)	1.30	.20
Sweating	.22 (.67)	.28 (.57)	−.70	.59
Nausea	.42 (.82)	.10 (.35)	3.13**	<.01**
Difficulty concentrating	.40 (.72)	.12 (.33)	3.26**	<.01**
Fullness of head	.31 (.66)	.16 (.54)	2.49*	.02*
Blurred vision	.90 (.92)	.16 (.48)	6.01**	<.01**
Dizzy (eyes open)	.45 (.83)	.09 (.34)	3.55**	<.01**
Dizzy (eyes closed)	.21 (.59)	.01 (.12)	2.72**	<.01**
Vertigo	.10 (.39)	.04 (.21)	1.16	.23
Stomach awareness	.28 (.69)	.16 (.41)	1.82	.07
Burping	.10 (.50)	.04 (.27)	1.27	.19
Overall sickness	.41 (.49)	.14 (.23)	4.93**	<.01**

[1] *p* value for Wilcoxon signed rank test

* $p < .05$

** $p < .01$

Table 3

Correlation matrix, pedestrian outcomes in the smartphone and kiosk virtual environments, $N = 68$

Kiosk	Smartphone		
	Start delay	**Unsafe crossings**	**Missed opportunities**
Start delay	.24+	.21+	.38**
Unsafe crossings	−.06	−.01	−.04
Missed opportunities	.28*	.42**	.52**

+ $p < .10$;

* $p < .05$;

** $p < .01$

Table 4

Correlation matrix, pedestrian outcomes in the smartphone virtual environment and self-reported temperament, $N = 68$

	Smartphone		
	Start delay	**Unsafe crossings**	**Missed opportunities**
Extraversion	−.03	.24^{+}	.11
Agreeableness	.15	.29*	.17
Conscientiousness	−.12	.07	−.01
Neuroticism	.08	−.17	−.04
Openness	.06	.25^{+}	.14

$^{+}p < .10$;

$^{*}p < .05$