PEDESTRIAN SAFETY WITH PERSONAL LISTENING DEVICES

FINAL REPORT

SOUTHEASTERN TRANSPORTATION CENTER

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JULY 2019

US DEPARTMENT OF TRANSPORTATION GRANT DTRT13-G-UTC34

DISCLAIMER

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle Pedestrian Safety with Personal Listening Devices	5. Report Date July 2019
	6. Source Organization Code $100,203
7. Author(s) Horton, Janelle; McBride, Maranda; Smith-Jackson, Tonya; Schwebel, David C.; Stavrinos, Despina; Kim, Hyung	8. Source Organization Report No. STC-2018-S3.NCAT
9. Performing Organization Name and Address Southeastern Transportation Center UT Center for Transportation Research 309 Conference Center Building Knoxville TN 37996-4133	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. DTRT13-G-UTC34
12. Sponsoring Agency Name and Address US Department of Transportation Office of the Secretary of Transportation–Research 1200 New Jersey Avenue, SE Washington, DC 20590	13. Type of Report and Period Covered Final Report: April 2017 – December 2018
	14. Sponsoring Agency Code USDOT/OST-R/STC

15. Supplementary Notes:

This final report consists of excerpts of the master degree thesis of Janelle Horton. The project was completed in partial fulfillment of her thesis requirements at North Carolina Agricultural and Technical State University. The additional authors listed on this report were members of her thesis committee and contributors to the overall project.

16. Abstract

Listening to music while wearing headsets can prevent pedestrians from perceiving critical environmental safety cues. This research investigated whether the use of a different type of listening device can improve pedestrian safety. In addition, the effects of other factors such as music volume, music genre, music type, and pedestrian gender were also assessed. Study participants were immersed in a virtual reality environment where they crossed a busy intersection while listening to music under different conditions. Sixty adults ranging from 18-25 years old participated in this study. Participants selected either hip-hop or pop music to listen to during the task and were required to make 7 street crossing under each of the following conditions: no music, music played through earbuds at 55 dBA, music played through earbuds at 65 dBA, and music played through a bone conduction headset at 65 dBA. Two music types were used in the study – wideband and narrow band. The independent variables for the study were the number of hits, misses, close calls, and missed opportunities as well as the wait time. Based on the results of the study, only the gender of the participant and genre of the music appeared to influence any of the outcomes.

17. Key Words Pedestrian Safety Bone Conduction, Music, Distraction, Personal Listening Devices	18. Distribution Statement Unrestricted; Document is available to the public through the National Technical Information Service; Springfield, VT.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 54	22. Price …

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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EXECUTIVE SUMMARY

Pedestrian safety broadly, and reducing the negative effects of distractions on pedestrian safety specifically, have been of rising concern. Normally, pedestrians use their visual and auditory senses to analyze the roads by checking for vehicles before crossing the street. However, when cell phones or personal listening devices (PLDs) are in use, attention can be taken away from the important task of monitoring the environment. There are many individuals who cross busy intersections while wearing headsets that prevent them from perceiving critical environmental sounds that could warn them of potential hazards. This study investigated whether the use of a different type of listening device (i.e., a bone conduction headset) can improve pedestrian safety.

Participants were immersed in a virtual reality (VR) environment where they crossed an intersection while listening to music under different conditions. Sixty young adults ranging from 18-25 years old were recruited from Greensboro, North Carolina to participate in this study. Participants were instructed to cross a simulated virtual street 7 times using a VR viewer under four conditions: (a) no auditory distraction, (b) while listening to music through earbuds at approximately 55 dBA, (c) while listening to music through earbuds at approximately 65 dBA, and (d) while listening to music through a bone conduction headset at approximately 65 dBA. Each participant was assigned to a music genre (i.e., R&B or Pop) and exposed to the four conditions twice, once each for two music types (i.e., narrowband and wideband).

The virtual street crossing environment was projected to participants by an Android smartphone inserted into a VR viewer. The system depicts an actual street crossing in a suburban community incorporating ambient background and Doppler-accurate traffic noise. The independent variables associated with this study included the listening device (ear buds or a bone conduction headset), music genre (R&B or Pop), music type (narrowband or wideband), music sound level (55dbA or 65dbA), and participant gender (male or female). The dependent variables captured by the VR environment software included the number of hits, close-calls, and missed opportunities, as well as the wait time.

Findings suggested there was no evidence that the bone conduction headset was a safer alternative to the ear buds for any of the dependent variables. However, there was statistical evidence suggesting significant associations between gender and the number of hits a pedestrian experienced as well as gender and the number of missed opportunities, whereby female

participants had more hits and missed opportunities than expected while male participants had fewer hits and missed opportunities than expected. In addition, a significant association was found for the number of missed opportunities male participants experienced based on the genre of music, whereby fewer missed opportunities than expected occurred when listening to R&B while more missed opportunities occurred when listening to Pop. The same association was found for female participants.

Researchers exploring pedestrian safety with personal listening devices should carefully consider the variables and results obtained from this study to determine in which direction to proceed. Replication of prior experiments can lead to new discoveries in science, yet scientists rarely execute them. A replication of this study could be used to determine whether findings from this experiment hold true for a broader population. While the conditions selected for this study were important for analyzing street crossing behaviors, expanding the selection of genres and song options available for the participants could conceivably open an array of discoveries.

DESCRIPTION OF PROBLEM

In a document published by the National Highway Traffic Safety Administration (NHTSA) in 2004, approximately 68,000 pedestrian injuries were reported (National Highway Traffic Safety Administration, 2004). Even though the NHTSA Traffic Safety Facts statement was published more than a decade ago, pedestrian injuries continue to be a concern as more individuals are distracted while walking. In 2009, nearly 800 Americans ages 16-29 were killed because of pedestrian-related injuries, and approximately 16,000 had to be transmitted to the hospital due to their afflictions (National Highway Traffic Safety Administration, 2009). When dealing with vehicle collisions, pedestrian errors were found in 59% of critical incidents involving both a vehicle and pedestrian (Guo, Wang, Guo, Jiang, & Bubb, 2012; Ulfarsson, Kim, & Booth, 2010). Since pedestrians share the road with motorized vehicles, they hold some responsibility to exercise caution and examine the safety of the road before and while crossing to ensure their own safety.

The concern of pedestrian injuries exemplifies a major public health issue among the population, particularly college students, due to them having an elevated rate of pedestrian incidents compared to other age groups (Byington & Schwebel, 2013). In 2010, it was recorded that 4,280 pedestrians were killed in the United States, while roughly 70,000 pedestrians were injured in traffic-related fatalities. Nearly 75% of these incidents occurred in urban environments (National Highway Traffic Safety Administration, 2012). According to data collected by Nasar and Troyer on pedestrian safety, in 2010, the estimated number of pedestrian injuries involving mobile devices amongst pedestrians was 1,506. Based on their analysis of data from 2004 to 2010, it was estimated that the number of pedestrian fatalities increased annually by approximately 186 casualties while the number of general incidents involving mobile devices also increased (Nasar & Troyer, 2013). With the large number of distractions that can be present while crossing a street, it is important for pedestrians to use both their visual and auditory senses to perform the task safely. When two senses are engaged in different actions while walking, it can result in a delayed motion to cross. This delay can occur due to competing information processing demands and an increase in cognitive workload, making it difficult to execute multiple tasks simultaneously. Wickens' mental workload theory, which pertains to dual tasks that require the use of multiple resources and various dimensions, describes the process stages involved in central processing, encoding, and responding to stimuli from the visual, auditory, and other sensory modalities

(Wickens, 2008). The encoding stage of the workload process involves the perceptual processing of information received through the stimulation of one of the senses, while the responding stage pertains to manual and vocal responses to those stimuli (Eysenck & Keane, 2005). It is believed that when two tasks are performed simultaneously by different parts of the body, the individual's performance of one or both tasks typically declines because attention must be divided to perform multiple actions (Wickens, 2002).

Auditory information and the way individuals process sounds, particularly those made by vehicles, is becoming more important as automotive manufacturers are beginning to produce electric vehicles that do not emit as much noise as older vehicles. In various research articles concerning pedestrian safety (Barton, Heath, & Lew, 2016; Guo et al., 2012; McComas, MacKay, & Pivik, 2002; Schwebel et al., 2012), the two main safety factors that have been analyzed are: 1) if the pedestrians look both ways before entering an intersection and 2) if they continue to check for oncoming vehicles while crossing the street. Crossing the street can be a dangerous task when the individual does not give it their full attention, especially if they are occupied by a mobile or personal listening device (PLD). It is one concern to be visually distracted by a mobile device, but it is an added concern when the individual's auditory senses are obstructed due to headsets used with a PLD.

The Pew Research Center has indicated three-quarters (75%) of teens and 93% of adults ages 18-29 now have a cell phone at their disposal (Lenhart, Purcell, Smith, & Zickuhr, 2010). In addition to the standard purpose of a cell phone (i.e., to communicate with other), there are many teens and young adults who use their devices for multimedia listening. In a study conducted by Wells et al. (2018), 19% of the students on the two college campuses studies listened to their multimedia devices while walking. Although this action may seem harmless, when the individual sets their music to a high volume, they block out surrounding sounds, possibly resulting in harm to themselves or others. Cellular devices and music applications are supposed to be used for communication and entertainment purposes and are not expected to cause injuries. However, since the use of handheld multimedia devices has increased dramatically over the last 10 to 15 years, there has been an increase in the number of pedestrian incidents and deaths (Retting & Schwartz, 2016; Schaper, 2017). As a result, safety measures that could potentially decrease the percentage of pedestrian injuries occurring due to inattentiveness should be considered.

There have been many studies on divided attention and it is recognized that as people share their attention between multiple tasks, reaction time on any one task tends to increase due to an overload of requests. For instance, one study indicated that when an individual shares their time between tasks using multiple stimuli, insufficient attention might be given to each discrete task, which can interfere with one's overall performance (Duncan, 1980). Considering the increase in the use of cell phones for streaming and downloading music, it is important to investigate how listening to music impacts walking to determine if there are any measures that can be implemented to reduce the occurrence of pedestrian injuries.

Distracted attention and reduced situation awareness in pedestrians using mobile phones has been documented in prior work (e.g., Hatfield & Murphy, 2007; Nasar et al., 2008, Stavrinos et al., 2011). In a study conducted by Stavrinos et al. (2009), results showed that children talking on a cell phone while engaged in a simulated virtual reality street crossing task were less attentive to traffic, took more time to make a decision to cross the street, and experienced more close calls and collisions with traffic. In another study by Schwebel et al. (2012), similar effects were discovered in their evaluation of adult pedestrians distracted by a cell phone. In that study, the impact of not only talking on the phone but also texting and listening to music during a simulated street crossing task was investigated. The results showed that participants listening to music or texting were hit by a vehicle more often in the virtual testing environment than those who were not distracted by the use of a cell phone.

As this research suggests, the use of electronic devices while walking can be hazardous. Much of the research associated with the use of cell phones and other digital media devices while walking focus on the impact of cognitive and visual distraction. The extent to which auditory stimuli influence pedestrian safety is poorly understood. Many assume that wearing earbuds or headphones to listen to cell phone conversations or digital media masks some ambient noise in the surrounding environment, but it is unclear exactly how that masking may or may not influence pedestrian safety because the pedestrian fails to perceive important auditory signals that would otherwise alert them of a potential hazard.

Research does suggest, however, that pedestrians may use auditory feedback from oncoming vehicles quite extensively to determine when it is safe to cross the street (Pfeffer & Barnecutt, 1996; Schwebel et al., 2012; Schwebel, 2013). Specifically, pedestrians use their localization skills to determine from which direction a car is approaching (Barton et al., 2013). In addition, changes in sound along the road enable pedestrians to determine the level of risk

(Bach et al., 2009). Some of the measures that have been evaluated using auditory stimuli include the distance at which a vehicle was detected, the direction from which a vehicle is approaching, and the vehicle's time of arrival at the pedestrian's location. Auditory cues are especially relied upon in situations when visual cues are not available, such as when an object obstructs the view of oncoming traffic or locations such as the crest of hills and areas where the road curves sharply (Ampofo-Boateng & Thompston, 1989; Roberts et al., 1995; Barton et al., 2012). Previous studies have even uncovered age-related differences in pedestrians' ability to detect and localize oncoming vehicles based on these measures. For instance, Barton et al. (2013) found that children age 6 to 9 years old had significantly smaller detection distances than adults age 18 to 40 years old. Adults in their study were also better at correctly identifying the direction of approach than children. In addition, older children (age 8 and 9) correctly identified the direction of approach more often and identified the time of arrival more accurately than younger children (age 6 and 7).

It can be assumed that wearing earbuds or headphones to listen to cell phone conversations or digital media will likely mask some of the ambient noise in the surrounding environment. As a result, pedestrians may not perceive important auditory signals that would otherwise alert them of a potential hazard, such as an oncoming vehicle. An ideal solution may be to restrict the use of earbuds/headphones by pedestrians walking near traffic. Although this may appeal to scholars, such an objective may be unrealistic, even with legislative policy changes.

Bone conduction headsets offer a viable alternative to traditional headsets and may alleviate some of the problems associated with pedestrian use of earbuds/headphones. Instead of covering the ears completely or in part, bone conduction headsets transmit auditory stimuli, such as music and speech, to listeners without covering the ear canal, thus increasing the ability to perceive ambient noise. These devices use mild vibration to stimulate the bones of the skull, including the middle and inner ear structures that transmit auditory signals to the brain. These vibrations are not felt at normal listening levels nor are they hazardous to the listener. Previous research has shown that bone conducted signals can even be heard clearly within an environment of low to moderate background noise (McBride et al, 2008; McBride et al., 2015), such as those present in a typical pedestrian environment.

Based on the growing desire to increase pedestrian safety, the current study explored the effects of PLD usage and pedestrian street crossing behavior when vehicles are approaching. Specifically, this study investigated the impact of listening to music with bone conduction headsets and air conduction earbuds when performing a street crossing task. The purpose was to determine if the use of a bone conduction headset is a safer alternative for pedestrians when it comes to detecting and localizing the sounds of approaching automobiles since they do no obstruct the hearing pathway and allow ambient noises to be perceived even when the headset itself is transmitting sounds.

APPROACH AND METHODOLOGY

Participant Recruitment and Screening Process

Sixty students participated in this study. The ages of those involved ranged from 18 to 25 years old (mean age = 21.50, SD = 2.45). The sample included 25 males (41.7%) and 35 females (58.3%) and was moderately diverse racially (83.3% African American; 3.3% Latino/Hispanic; 1.7% Asian, Middle Eastern and Caucasian; and 8.3% mixed ethnicities). When the participant arrived at the test site, they were administered a consent form and participant information questionnaire (see Appendix A through C). All of the participants were required to read, sign and date the consent form prior to beginning the experiment. The participant information sheet captured the demographics of the participant in addition to questions regarding their day-to-day activities with PLDs. To ensure confidentiality, each participant was assigned an identification number that was used on all of their forms and data files. Once the forms were returned to the researcher, the participant was transferred to the adjacent room to perform the Snellen visual acuity test (Figure 1) and Ishihara Color Plate test (Figure 2) to ensure the vision criteria were met. The Snellen visual acuity test evaluated how well the participants could see printed characters presented from a 10-foot distance and the Ishihara Color Plate Test was used to determine if a person suffered from a color vision deficiency.

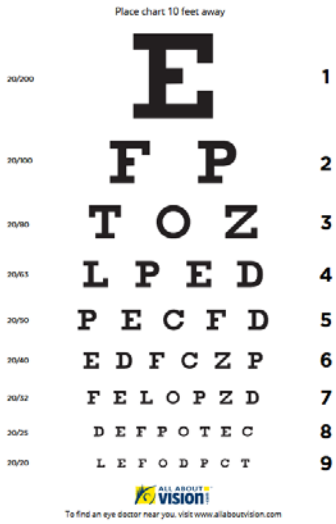

Figure 1: Snellen visual acuity test

(https://www.allaboutvision.com/eye-test/snellen-chart.pdf, Last accessed June 4, 2019)

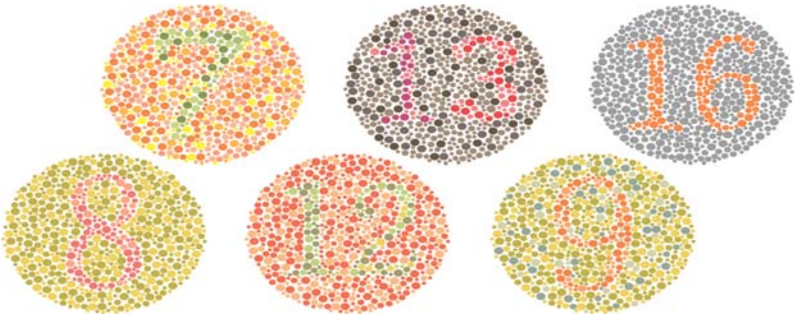

Figure 2: Ishihara color plate test

(https://www.allaboutvision.com/eye-exam/color-blind-tests.htm, Last accessed June 4, 2019).

Participants who met the criteria set for both vision tests were seated in a sound attenuating auditory chamber for the hearing threshold test. All participants had normal (20/20; full color vision) or corrected-to-normal vision. During the auditory test, pure tone auditory signals were transmitted by a clinical audiometer to headphones worn by the participant. The frequencies of the signals included 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz, and 8000 Hz. To pass this test, participants needed to hear all frequencies at 20 dB HL (hearing level) or lower and have a threshold difference between both ears of no more than 10dB HL for any frequency. Each participant was instructed to press down on a response button when s/he perceived the test signal. Participants who did not meet the vision and hearing criteria were dismissed from the study.

Procedure

This study was designed to evaluate the difference in street-crossing task performance when pedestrians use AC or BC listening devices under a variety of music conditions. The subsections below describe the various components of the study.

Music

The genres used in the experiment consisted of Rhythm and Blues (R&B) and popular music (Pop). Five widely known songs were identified for each genre by looking through credible music sources such as Billboard.com, BigTop40.com, Complex.com, Top10songnews.com, and Capitalxtra.com. Songs that contained explicit language were excluded from consideration. Some researchers suggest that music tempos may impact walking behavior (Franěk, van Noorden, & Režný, 2014); therefore, the tempo of the songs selected for the study were similar to ensure equivalency between the different genre conditions.

In order to reduce the number of variables that would have to be analyzed, it was decided that only one song from each genre would be chosen and both songs would have the same beats per minute (BPM). To determine the BPM, each song was submitted through songbpm.com. To choose the two songs that would be used in the study, the BPMs were reviewed initially to determine if any songs between the R&B and Pop lists shared the same BPM value. As it turned out, each list contained at least one song with a BPM of 96 (Table 1). The R&B list had two songs with a BPM of 96 and the Pop list had one song. One of the songs that had a BPM of 96 in the R&B list was sung by a female music artist while the other was sung by male music artists. The song in the Pop list that had a BPM of 96 was sung by a male music artist; therefore, to reduce the likelihood of music artist gender becoming a confounding variable in the study, the R&B song sung by the male artists was selected for the experiment. The yellow highlighted songs in Table 1 were the ones chosen for the study.

Table 1: Music list with BPM value

R&B	**BPM**
112 ft. Biggie & Mase - Only You	*96*
Mary J Blige - Real Love	96
Next - Too Close	100
GoldLink - Crew	130
Trey Songz- Nobody Else but You	140
POP	**BPM**
Ed Sheeran- Shape of You	*96*
Zedd and Alessia Cara- Stay	101
Justin Timberlake – Can't Stop the Feeling	113
Calvin Harris ft. Rihanna- This is What You Came For	123
Bruno Mars - That's what I Like	134

After the songs were selected, the music had to be adjusted to ensure the intensity level of the songs were similar. The two songs, along with a pink noise file set to the desired sound level, were downloaded onto a computer equipped with Sound Forge software. Pink noise is composed of a range of frequencies that can be perceived by humans presented at approximately the same perceived intensity. The pink noise recording was used in this study to calibrate the intensity of the two songs to ensure they were being presented at equivalent sound levels. To achieve this, each song was played in such a fashion that it alternated at a uniform pace with the pink noise. The sound level of the song was adjusted using an attenuator (Figure 3) and compared with the pink noise to ensure the average intensity of the song was approximately the same as the pink noise. Each song was adjusted to match the pink noise file at 55dbA and 65dbA. Once the sound levels of the songs were adjusted, the final song files and attenuator settings were saved for use in the experiment.

Figure 3: 839 Sound level attenuator

Wideband vs Narrowband Music

Music can be presented in either wideband or narrowband format. The terms wideband and narrowband refer to the number of times a signal is read or sampled during a second. In the case of wideband audio recordings, sampling occurs at a higher rate than narrowband audio recordings. The higher sampling rate creates a richer sound that most listeners find more pleasant. Wideband music is generally what is heard on FM radio stations or is download onto PLDs. These two formats were used in the study to analyze differences in pedestrian street crossing behavior when listening to a PLD to determine if the quality of sound influenced street crossing behaviors.

Simulation Software

PedSim VR software loaded onto a Samsung Galaxy S7 edge mobile phone was used for this study. This software has been used to simulate the street crossing environment in other studies pertaining to pedestrian safety (Schwebel et al., 2008; Schwebel et al., 2012; Stavrinos, Byington, & Schwebel, 2009). Similar to the previous studies, all crossings in the VR environment for the current study took place at the simulated intersection of a moderately busy 2-lane bidirectional suburban road. The VR headset environment is interactive and immersive, allowing the participant to incorporate head motions by looking both ways before crossing the street and button controls to initiate the street crossing action.

Figure 4 illustrates the setup screen for the software. At the top of the screen, the Subject ID box was used to input the text representing the participant and treatment condition before each street crossing trial. The program was set to its standard mode instead of the offline mode to allow the data to be collected and saved for each condition. The average traffic volume in the simulation was set to 8 vehicles per minute per lane at a speed of 35 mph, which correlates to a setting of 3 (i.e., SET 3). SET 3 is the hardest level out of the three settings provided by the software and was deemed the most appropriate given the age of the participants. This configuration was set at the beginning of each trial to ensure uniformity throughout the experiment.

SUBJECT ID

MODE standard

LEVEL hard

TRAFFIC SPEED 35 MPH

TRAFFIC DENSITY 8 V/L/M

Online Mode

v. 0.4.5.0

Figure 4: Main screen on the PedSim VR system

Experimental Task

After completing the visual and auditory screening tasks, participants remained inside the auditory chamber for the experimental task. All participants performed the virtual street-crossing task under seven treatment conditions:

A) without auditory distraction,

BN) with narrowband music played through AC earbuds at 55dBA,

BR) with wideband music played through AC earbuds at 55dBA,

CN) with narrowband music played through AC earbuds at 65dBA,

CR) with wideband music played through AC earbuds at 65dBA,

DN) with narrowband music played through a BC headset at 65dBA. and

DR) with wideband music played through a BC headset at 65dBA.

Images of participants completing conditions with AC or BC headsets can be seen in Figure 5. The order of the experimental conditions was counterbalanced across participants to minimize the impact of learning effects.

Figure 5: Participants wearing the BC (Images 1 and 4) and AC (Images 2 and 3) headsets

The experiment began with one of the seven treatment conditions – A, BN, BR, CN, CR, DN or DR. Before the first condition began, participants completed a practice set that consisted of five street crossings with no music to get them accustomed to the VR system and how to perform the experimental task. Prior to the start of each treatment condition, the participant was fitted with the appropriate listening device for the condition. The musical selection was played from a computer located outside of the auditory chamber during each of the six experimental conditions requiring music and was controlled by the experimenter. The experimenter completed the set up screen on the phone (see Figure 4), placed the phone inside the VR goggles, and handed the goggles to the participant.

Once the VR environment was operating, each participant positioned the VR goggles in front of his/her eyes. The VR goggles displayed two different screens providing instructions on how to operate the VR display and software. After reading the instructions, the participant pressed a button and the street crossing scene shown in Figure 6 was presented through the VR goggles. When the participant indicated s/he was ready for the experiment to begin, the experimenter started the music (if applicable) and the participant pressed the button on the VR goggles to initiate the trial. Upon commencement of the trial, the participant was oriented on a sidewalk created within the virtual environment. In the VR environment, participants could do a 360-degree rotation allowing them to see a replicated suburban neighborhood. Turning their head left and right allowed the participants to look up and down the street. Participants were able to see vehicles approaching and passing and the sound of the vehicles could be heard once the vehicle was close to the intersection. By pressing the button on the VR goggles, a participant could begin walking across the virtual street. Participants were allowed to look left and right continuously to check for approaching vehicles.

Figure 6: Center view of participant within the virtual environment

Each treatment condition consisted of seven street crossing trials. Upon completion of a trial, the participants heard a pre-recorded voice summarizing the result of the crossing task, such as if they were hit, almost hit (i.e., near hit), or did a good job crossing the street safely (i.e., safe). The safe, near hit, and hit scores were displayed at the bottom of the screen during each of the seven trials. Once a condition was completed, the data were saved under the participant's identification code for further analysis. The participant handed the VR goggles back to the researcher after each treatment condition was completed so the system could be set up for the next condition.

The sound levels for the AC earbuds were calibrated before each participant arrived at the lab. However, since the perceived sound level of a signal transmitted through BC is dependent on the physical parameters of the skull and the force at which the BC transducer is held against the head, the sound level of the BC headset needed to be calibrated by each participant to ensure the music was perceived at the 65dBA level. Therefore, before performing the BC headset conditions (i.e., conditions DN and DR), each participant matched a 65dBA pink noise stream transmitted alternatingly through the BC headset worn by the participant and a small loud speaker located in front of the participant. The stream of the pink noise played through each device included a pause that allowed the noise to alternate between the speaker and BC headset, making it easier for the individual to adjust the level of the BC signal using an amplifier (Figure 7). After each participant completed the matching process, s/he was instructed not to touch the amplifier or the BC headset for the rest of the condition.

Figure 7: MicroAmp HA400 Stereo Amplifier

Upon completion of the condition with no music (condition A), participants were asked to fill out a realism questionnaire based on their perception of the virtual environment with no sound. Questions included “How realistic are the sounds of the vehicles?”, “How realistic is the presentation of the virtual environment?”, and “How realistic is the walking speed in the virtual environment?” These questions were answered using a five-point Likert scale ranging from “not realistic at all” [1] to “extremely realistic” [5]. The next set of questions included, “Is the speed of the vehicles similar to what you would expect in a school crossing zone?”, “Is the virtual environment similar to the walking environment you typically find yourself in?”, and “Did you encounter issues with placement or orientation within the VR system?” This set of questions was answered on a three-point scale: no [1], somewhat [2], or yes [3]. An image of these questions appears in Appendix C.

Data Collection and Analysis

After each trial was completed by a participant, the data were stored on the Samsung Galaxy S7 Edge as a file that was later downloaded onto a computer for analysis. Within each file, separate columns contained the results associated with each dependent variable (DV) per trial. The independent variables (IVs) for this study included the music genre (R&B and Pop), device (AC and BC), music type (narrowband and wideband), music levels (55dbA and 65dBA), and participant gender (male and female). The DVs provided by the software that were used in the study are shown in Table 2. Definitions of other variables collected by the software that were exempted from the study can be found in Appendix D.

Table 2: Dependent variables used in the study

VARIABLES	DEFINITION
Wait Time	The amount of time between the start of the trial and the moment when the participant starts crossing the street.
Number of Hits	Number of times the participant is hit while crossing the street in the virtual reality environment.
Close Calls	The number of instances when the estimated Time to Collision (TTC) between the pedestrian avatar and a vehicle is below a pre-determined threshold. The threshold is set to 1 second.
Missed Opportunities	The number of Missed Opportunities. Gaps that are greater than 1.5 times the participants average crossing time that the participant decides not to cross within.

In addition to the data collected by the simulation software, demographic and realism questionnaire responses were collected and evaluated based on the questions that closely examined the possible effects of pedestrian behavior while simultaneously crossing an intersection and listening to a PLD. The numeric data obtained from the software for *hits, close calls, missed opportunities*, and *wait time* were analyzed using the IBM Statistical Package for the Social Sciences (SPSS) version 24 software.

First, descriptive statistics were generated for the IVs and DVs. Half of the participants completed the study listening to R&B and the other half listened to Pop. This resulted in the descriptive tables being split into five groups: total, R&B, Pop, male, and female. The DVs were evaluated against each IV according to the groups. Second, because the data did not conform to normality assumptions based on the Shapiro-Wilk normality test ($\alpha > 0.05$), Chi-Square tests of independence were performed for the between subject IVs genre and gender against the dependent variables *hit, close calls, missed opportunities*, and *wait time*. Binary logistic regressions were used for the IVs device, song level, and song type to explore the probability of an observation falling into one of the two levels (i.e., yes or no) associated with each of the DVs *hits, close calls*, and *missed opportunities*. Lastly, since the DV *wait time* was collected as interval data, the Kruskal-Wallis H test was used to explore statistical differences between devices, song levels, song types, genders, and genres.

The IVs in the study and their levels included device (none, AC, BC), song level (0dBA, 55dBA, 65dBA), song level at 65dBA (AC, BC), song type (none, narrowband, wideband), gender (male, female), and genre (none, R&B, Pop). The DV *hits* (false/safe and true/hit) was originally collected as binary data; however, to be used in the Chi-Square independence test, this data had to be changed to frequency data or counts. *Missed opportunities* and c*lose calls* were recorded by the PedSim software as frequency data. Lastly, *wait time* was recorded as a scaled value whose minimum and maximum totals were 0 and 75, respectively. In the "none" condition, no music was present; therefore, neither the AC nor BC device was present.

FINDINGS

Demographic and PLD Questions

Table 3 displays the primary demographic data for the sample population. Participants involved in the study were between the ages of 18 and 25 years, inclusively; with 74% of the participants over the age of 21. The female and African American population had the highest participant involvement at 58% and 83%, respectively. Participants who grew up in a suburban environment made up the largest percentage of the sample population at 67%. When exploring pedestrian and PLD behaviors, most of the participants felt "somewhat unsafe" listening to their music while crossing the street. For the questions, "How well can you multitask?", "On average, how often do you listen to your music while crossing the street?", "While listening to music and crossing the street, I feel…", and "How loud do you listen to your PLD?", the highest responses received were, moderately (40%), almost always (28%), somewhat unsafe (32%), and loud (55%), respectively (see Table 4).

Table 3: Total participants demographic data

VARIABLES	RESPONSES	PERCENTAGES (n=60)
Age	18	5%
	19	10%
	20	12%
	21	15%
	22	20%
	23	***22%***
	24	7%
	25	10%
Gender	Male	42%
	Female	***58%***
Ethnicity	***Black/African American***	***83%***
	Latino/Hispanic	3%
	Asian	2%
	Middle Eastern	2%
	White/Caucasian	2%
	Other/Mixed	8%
Childhood Communities	Urban Area	25%
	Suburban Area	***67%***
	Rural Area	8%

Table 4: PLD related questions

PLD QUESTIONS	RESPONSES	PERCENTAGES (n=60)
How well can you multitask?	Not at all	2%
	Slight	8%
	Moderately	**40%**
	Very Well	38%
	Extremely Well	12%
On average, how often do you listen to music while crossing the street?	Never	7%
	Rarely	8%
	Sometimes	15%
	Often	23%
	Almost Always	**28%**
	Always	18%
While listening to music and crossing the street, I feel?	Very Unsafe	8%
	Somewhat Unsafe	**32%**
	Neither	27%
	Somewhat Safe	20%
	Very Safe	13%
How loud do you listen to your PLD?	Faint	0%
	Moderate	5%
	Comfortable	32%
	Loud	**55%**
	Very Loud	8%

Gender Simulator and PLD Questions

Table 5 summarizes the responses to the simulator realism questions and music-based questions presented to participants. In general, most of the participants felt that the sound of the vehicles in the simulation and the VR visual presentation were either very realistic or extremely realistic (53% and 68%, respectively). The largest percent of participants viewed the walking speed to be only slightly realistic (42%) and the speed of the cars only slightly representative of what would be seen at an actual school crossing (48%). Most participants viewed the VR environment to be similar to their typical walking environment (53%).

Table 5: Gender Responses for the Simulation Realism Questions

SIMULATOR REALISM QUESTIONS	RESPONSE	%
How realistic is the sound of the vehicles?	Extremely Realistic	8%
	Very Realistic	**45%**
	Moderately Realistic	30%
	Slightly Realistic	13%
	Not Realistic at All	3%
How realistic is the presentation of the VR?	Extremely Realistic	23%
	Very Realistic	**45%**
	Moderately Realistic	23%
	Slightly Realistic	8%
	Not Realistic at All	0%
How realistic is the walking speed in the VR?	Extremely Realistic	2%
	Very Realistic	8%
	Moderately Realistic	25%
	Slightly Realistic	**42%**
	Not Realistic at All	23%
Is the speed of the cars similar to what you would expect in a school crossing zone?	Yes	42%
	Somewhat	**48%**
	No	10%
Is the VR environment similar to the walking environment you typically find yourself in?	**Yes**	**53%**
	Somewhat	40%
	No	7%

Experimental Descriptive Statistics

In SPSS, descriptive data (i.e., medians and standard deviations) and Shapiro-Wilk normality tests were explored to identify potential relationships between the independent and dependent variables. Tables 6 through 10 display the aggregate descriptive data for all participants. The variables were assessed by evaluating one IV at a time against each DV. Median values were recorded instead of the mean values for all of the dependent variables due to the skewed nature of the data that resulted in extreme values within the *hits, close calls*, and *missed opportunities* variables. Standard deviations are shown within the parentheses beside the median values. The Shapiro-Wilk tests detected that the values observed within the dataset were not normally distributed for any of the IVs and DVs tested ($p < 0.001$ across all tested variables); therefore, nonparametric statistics were used to perform additional analyses of the data.

Table 6: Descriptive statistics for each independent variable per level

SONG LEVEL	**Dependent Variables**	**55dBA AC**	**65dBA AC**	**65dBA BC**
	Hits	.00(.22)	.00(.20)	.00(.21)
	Close Calls	.00(.38)	.00(.40)	.00(.36)
	Missed Opportunities	.00(.38)	.00(.39)	.00(.39)
	Wait Time	5.58(7.38)	5.74(7.71)	5.62(8.65)
DEVICE	**Dependent Variables**	**AC**	**BC**	
	Hits	.00(.21)	.00(.21)	
	Close Calls	.00(.39)	.00(.36)	
	Missed Opportunities	.00(.38)	.00(.39)	
	Wait Time	5.66(7.55)	5.62(8.65)	
SONG TYPE	**Dependent Variables**	**NARROWBAND**	**WIDEBAND**	
	Hits	.00(.20)	.00(.22)	
	Close Calls	.00(.38)	.00(.38)	
	Missed Opportunities	.00(.38)	.00(.39)	
	Wait Time	5.61(7.91)	5.66(7.95)	
GENDER	**Dependent Variables**	**MALE**	**FEMALE**	
	Hits	.00(.19)	.00(.23)	
	Close Calls	.00(.37)	.00(.39)	
	Missed Opportunities	.00(.37)	.00(.39)	
	Wait Time	5.40(7.39)	5.77(8.27)	
GENRE	**Dependent Variables**	**R&B**	**POP**	
	Hits	.00(.22)	.00(.20)	
	Close Calls	.00(.38)	.00(.38)	
	Missed Opportunities	.00(.36)	.00(.41)	
	Wait Time	5.49(6.50)	5.84(9.03)	
CONTROL	**Dependent Variables**	**NONE**		
	Hits	.00(.25)		
	Close Calls	.00(.40)		
	Missed Opportunities	.00(.38)		
	Wait Time	5.56(7.93)		

Table 7: R&B descriptive statistics for each independent variable per level

SONG LEVEL	**Dependent Variables**	**55dBA AC**	**65dBA AC**	**65dBA BC**
	Hits	.00(.25)	.00(.21)	.00(.20)
	Close Calls	.00(.40)	.00(.40)	.00(.33)
	Missed Opportunities	.00(.34)	.00(.36)	.00(.37)
	Wait Time	5.45(5.98)	5.57(6.40)	5.44(7.07)
DEVICE	**Dependent Variables**	**AC**	**BC**	
	Hits	.00(.23)	.00(.20)	
	Close Calls	.00(.40)	.00(.33)	
	Missed Opportunities	.00(.35)	.00(.37)	
	Wait Time	5.51(6.19)	5.44(7.07)	
SONG TYPE	**Dependent Variables**	**NARROWBAND**	**WIDEBAND**	
	Hits	.00(.20)	.00(.24)	
	Close Calls	.00(.38)	.00(.37)	
	Missed Opportunities	.00(.34)	.00(.37)	
	Wait Time	5.52(6.95)	5.45(6.00)	
GENDER	**Dependent Variables**	**MALE**	**FEMALE**	
	Hits	.00(.20)	.00(.24)	
	Close Calls	.00(.37)	.00(.39)	
	Missed Opportunities	.00(.34)	.00(.36)	
	Wait Time	5.24(7.18)	5.71(5.85)	
CONTROL	Hits	.00(.27)		
	Close Calls	.00(.40)		
	Missed Opportunities	.00(.33)		
	Wait Time	5.57(6.56)		

Table 8: Pop descriptive statistics for each independent variable per level

SONG LEVEL	**Dependent Variables**	**55dBA AC**	**65dBA AC**	**65dBA BC**
	Hits	.00(.20)	.00(.19)	.00(.22)
	Close Calls	.00(.38)	.00(.39)	.00(.38)
	Missed Opportunities	.00(.41)	.00(.41)	.00(.40)
	Wait Time	5.74(8.45)	5.93(8.73)	5.89(9.87)
DEVICE	**DVs**	**AC**	**BC**	
	Hits	.00(.19)	.00(.22)	
	Close Calls	.00(.39)	.00(.38)	
	Missed Opportunities	.00(.41)	.00(.40)	
	Wait Time	5.82(8.59)	5.89(9.87)	
SONG TYPE	**DVs**	**NARROWBAND**	**WIDEBAND**	
	Hits	.00(.20)	.00(.20)	
	Close Calls	.00(.38)	.00(.39)	
	Missed Opportunities	.00(.41)	.00(.41)	
	Wait Time	5.78(8.69)	5.89(9.37)	
GENDER	**DVs**	**MALE**	**FEMALE**	
	Hits	.00(.17)	.00(.22)	
	Close Calls	.00(.38)	.00(.39)	
	Missed Opportunities	.00(.39)	.00(.42)	
	Wait Time	5.73(7.59)	5.86(9.75)	
CONTROL	Hits	.00(.21)		
	Close Calls	.00(.39)		
	Missed Opportunities	.00(.41)		
	Wait Time	5.55(9.06)		

Table 9: Male descriptive statistics for each independent variable per level

SONG LEVEL	**Dependent Variables**	**55dBA AC**	**65dBA AC**	**65dBA BC**
	Hits	.00(.19)	.00(.17)	.00(.17)
	Close Calls	.00(.38)	.00(.41)	.00(.33)
	Missed Opportunities	.00(.34)	.00(.39)	.00(.37)
	Wait Time	5.34(6.32)	5.47(7.92)	5.52(7.85)
DEVICE	**Dependent Variables**	**AC**	**BC**	
	Hits	.00(.18)	.00(.17)	
	Close Calls	.00(.40)	.00(.33)	
	Missed Opportunities	.00(.37)	.00(.37)	
	Wait Time	5.38(7.19)	5.52(7.85)	
SONG TYPE	**Dependent Variables**	**NARROWBAND**	**WIDEBAND**	
	Hits	.00(.17)	.00(.18)	
	Close Calls	.00(.39)	.00(.36)	
	Missed Opportunities	.00(.37)	.00(.37)	
	Wait Time	5.39(7.85)	5.48(6.96)	
GENRE	**Dependent Variables**	**R&B**	**Pop**	
	Hits	.00(.19)	.00(.16)	
	Close Calls	.00(.37)	.00(.39)	
	Missed Opportunities	.00(.34)	.00(.40)	
	Wait Time	5.26(7.13)	5.77(7.70)	
CONTROL	Hits	.00(.26)		
	Close Calls	.00(.35)		
	Missed Opportunities	.00(.35)		
	Wait Time	5.23(7.23)		

Table 10: Female descriptive statistics for each independent variable per level

SONG LEVEL	**Dependent Variables**	**55dBA AC**	**65dBA AC**	**65dBA BC**
	Hits	.00(.24)	.00(.22)	.00(.23)
	Close Calls	.00(.38)	.00(.39)	.00(.38)
	Missed Opportunities	.00(.40)	.00(.38)	.00(.40)
	Wait Time	5.77(7.97)	5.85(7.57)	5.67(9.16)
DEVICE	**Dependent Variables**	**AC**	**BC**	
	Hits	.00(.23)	.00(.23)	
	Close Calls	.00(.39)	.00(.38)	
	Missed Opportunities	.00(.39)	.00(.40)	
	Wait Time	5.82(7.77)	5.67(9.16)	
SONG TYPE	**Dependent Variables**	**NARROWBAND**	**WIDEBAND**	
	Hits	.00(.22)	.00(.24)	
	Close Calls	.00(.37)	.00(.39)	
	Missed Opportunities	.00(.39)	.00(.40)	
	Wait Time	5.77(7.95)	5.75(8.55)	
GENRE	**Dependent Variables**	**R&B**	**Pop**	
	Hits	.00(.24)	.00(.22)	
	Close Calls	.00(.38)	.00(.38)	
	Missed Opportunities	.00(.37)	.00(.41)	
	Wait Time	5.70(5.89)	5.91(9.70)	
CONTROL	Hits	.00(.23)		
	Close Calls	.00(.42)		
	Missed Opportunities	.00(.39)		
	Wait Time	5.86(8.37)		

Chi-Square Inferential Statistics

Chi-Square tests of independence were considered to examine the categorical data for song level, song level at 65dBA, device, song type, gender, and genre separately. Because the song level factor consisted of AC at 55dBA and 65dBA as well as BC at 65dBA, song level at 65 dBA was analyzed separately to compare AC and BC differences at the same song level. Chi-Square assumptions pertaining to the following IVs were violated because they were within-subject conditions: device, song level, song level at 65dBA, and song type. Therefore, the Chi-Square test of independence was only used to analyze genre and gender.

<u>Hits</u>

Based on the Chi-Square test for *hits*, there was a significant relationship between gender and *hits* $X^2\,(1) = 4.79$, $p < .05$. This indicated that gender was not independent of the number of *hits* observed. However, the test indicated no significant relationships between genre and *hits* X^2 (1) = .904, p = .34; therefore, the number of *hits* was not influenced by the genre of music heard while crossing the simulated street. Table 11 shows the count (the observed number of observations for a given condition), the expected count (the number of observations expected for the condition) and the residual (computed as observed minus expected value) for each gender. Sixty people participated in the study; therefore, there were 1,225 crossings analyzed for the male participants (25 males x 7 conditions x 7 street crossing trials = 1,225) and 1,715 crossings for the female participants (35 females x 7 conditions x 7 street crossing trials = 1,715). The evaluation assessed whether the proportion of *hits* that occurred for male participants (males = 47 hits) differed significantly from the proportion of *hits* for female participants (females = 96 hits). The number of *hits* was found not to be independent of gender, suggesting the number of observed *hits* for females was significantly higher than expected based on the number of female participants in the sample. In contrast, the number of observed *hits* for males was significantly lower than expected. Figure 8 graphically illustrates the differences in observed and expected *hits* between both genders. The female participants were expected to have 23 more *hits* than the male participants; however, they had 49 more *hits* than the males.

Table 11: Hits x Gender crosstabulation

			Gender		
			Male	Female	Total
Hits	Not Hit	Count	1178.0	1619.0	2797.0
		Expected Count	1165.4	1631.6	2797.0
		Residual	12.6	-12.6	
	Hit	Count	47.0	96.0	143.0
		Expected Count	59.6	83.4	143.0
		Residual	-12.6	12.6	
Total		Count	1225.0	1715.0	2940.0
		Expected Count	1225.0	1715.0	2940.0

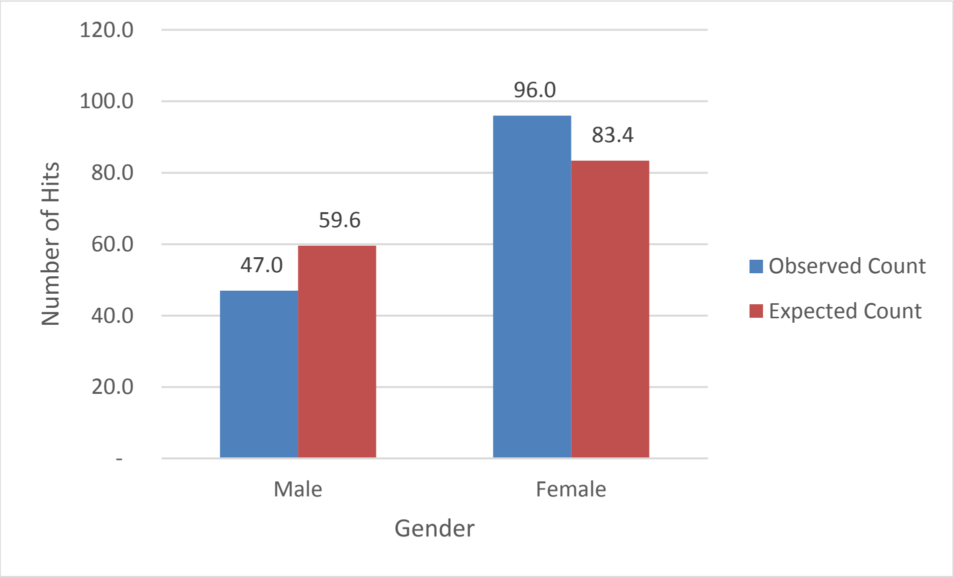

Figure 8: Observed versus expected hits per gender

Close Calls

The results of the Chi-Square test for gender and *close calls* indicated no significant relationship between the variables $X^2\,(1) = 1.60$, $p = .21$. The same is true for the Chi-Square test for genre and *close calls* $X^2\,(1) = .27$, $p = .60$. This means the number of *close calls* was independent of both gender and genre, thus neither the gender of the participant nor the genre of the music influenced the number of *close calls*.

Missed Opportunities

The results of the Chi-Square test evaluated for *missed opportunities* indicated that there was a significant relationship between gender and *missed opportunities* $X^2\,(1) = 5.66$, $p < .05$ and genre and *missed opportunities* $X^2\,(1) = 15.96$, $p < .05$. This signified that neither the gender of the participant nor genre of the music were independent of the number of *missed opportunities* observed.

Table 12 displays the m*issed opportunities* by gender crosstabulation and Chi-Square test output provided by SPSS. The expected number of *missed opportunities* for the male and female participants was 218.3 and 305.7, respectively, indicating the number of observed *missed opportunities* was significantly lower for the male participants than expected, while the number of *missed opportunities* was significantly higher than expected for the female participants. As seen in Figure 9, the males' expected count was higher than the observed count; however, the females' expected count was lower than the observed count.

Table 12: Missed Opportunities x Gender Crosstabulation

			Gender		
			Male	Female	Total
Missed Opportunities	No Missed Opportunities	Count	1031.0	1385.0	2416.0
		Expected Count	1006.7	1409.3	2416.0
		Residual	24.3	-24.3	
	Missed Opportunities	Count	194.0	330.0	524.0
		Expected Count	218.3	305.7	524.0
		Residual	-24.3	24.3	
Total		Count	1225.0	1715.0	2940.0
		Expected Count	1225.0	1715.0	2940.0

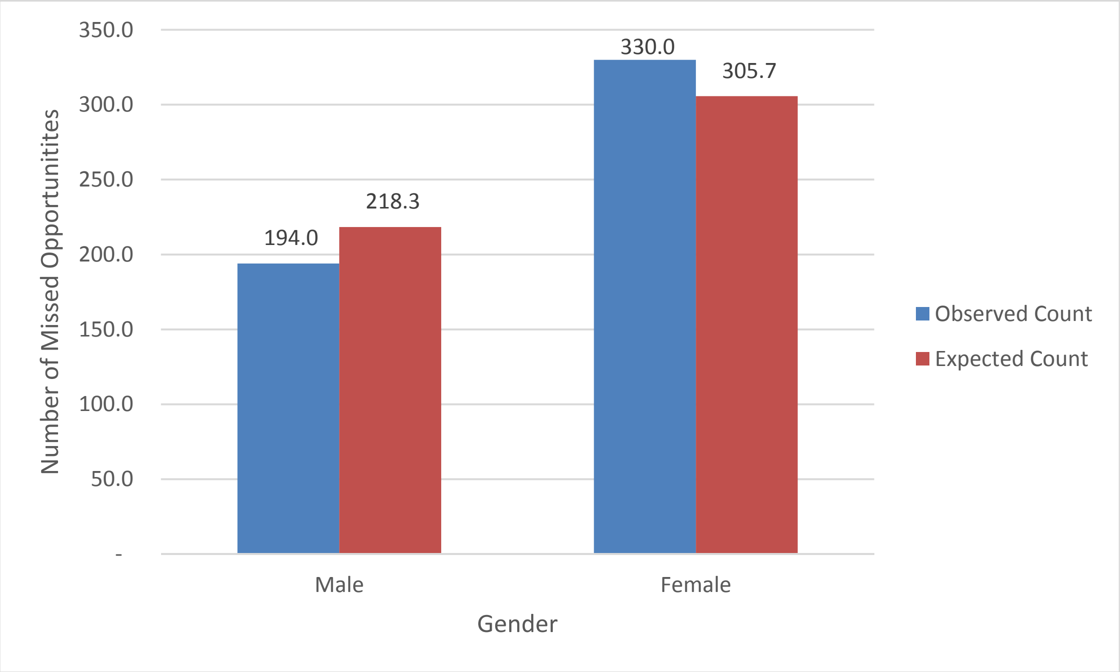

Figure 9: Observed versus expected missed opportunities per gender

Table 13 displays the crosstabulation results for the *missed opportunities* by genre. There were 1,260 crossings analyzed for both R&B and Pop (30 participants in each genre x 6 conditions [one without music] x 7 street crossing trials = 1,260). The number of *missed opportunities* while listening to R&B was 188 while the number of *missed opportunities* while listening to Pop was 265. The expected number of *missed opportunities* for both R&B and Pop was 226.5; therefore, the observed number was significantly lower than expected for the R&B genre and higher than expected for the Pop genre (Figure 10). Overall, there were more *missed opportunities* while the participants listened to Pop music than R&B.

Table 13: Missed Opportunities x Genre Crosstabulation

			Genre		
			R&B	Pop	Total
Missed Opportunities	No Missed Opportunities	Count	1072.0	995.0	2067.0
		Expected Count	1033.5	1033.5	2067.0
		Residual	38.5	-38.5	
	Missed Opportunities	Count	188.0	265.0	453.0
		Expected Count	226.5	226.5	453.0
		Residual	-38.5	38.5	
Total		Count	1260.0	1260.0	2520.0
		Expected Count	1260.0	1260.0	2520.0

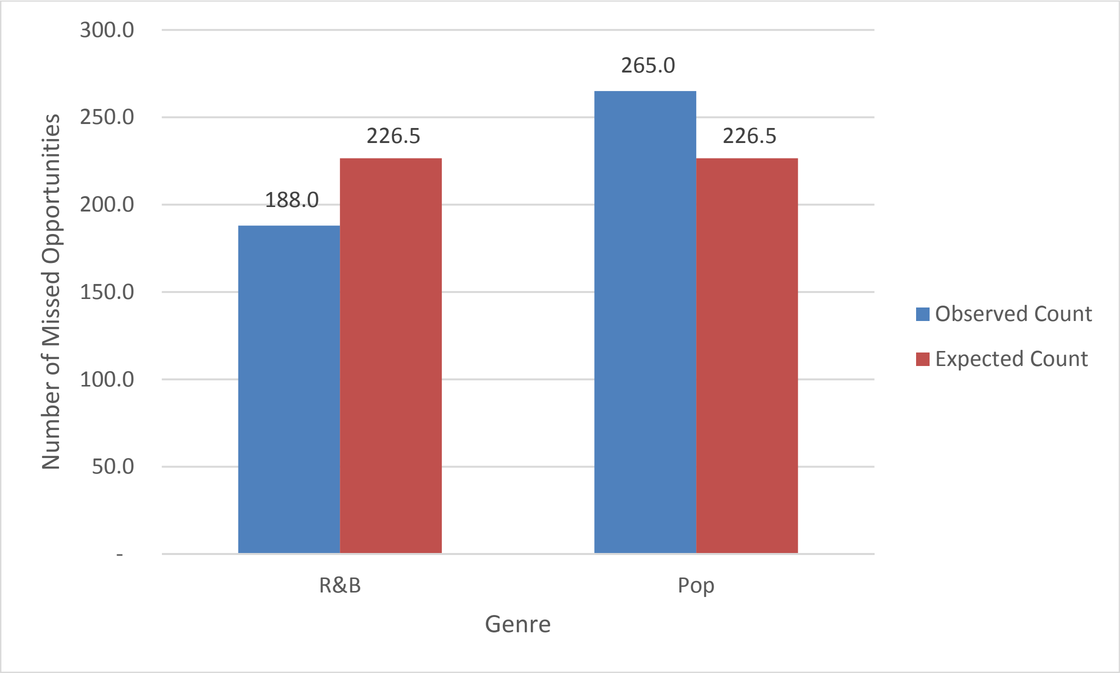

Figure 10: Observed versus expected missed opportunities per genre

Genre Chi-Square Statistics per Gender

Table 14 displays the summary from the Chi-Square statistical tests for *hits, close calls*, and *missed opportunities* based on the participants' gender. The tests displayed that a significant relationship existed between genre and *missed opportunities* for males $X^2(1) = 7.00$, $p < .05$, and genre and *missed opportunities* for females $X^2(1) = 7.63$, $p < .05$. This signified that the genre of the music was not independent of the number of *missed opportunities* observed for either gender. However, no significant relationships existed between *hits* or *close calls* and genre for either the male or female participants. This indicated that both the number of *hits* and *close calls* were independent of the music genre, meaning the number of *hits* and *close calls* were not influenced by the type of music.

Table 14: Chi-Square test of independence relationship for genre on gender

Dependent Variable	Gender	χ^2 Statistic	df	*p*-value
Hits	Male	1.08	1	.30
Close Calls	Male	.63	1	.43
Missed Opportunities	***Male***	***7.00***	***1***	***< .05***
Hits	Female	.64	1	.42
Close Calls	Female	.00	1	.98
Missed Opportunities	***Female***	***7.63***	***1***	***< .05***

(bold font = a significant association)

Table 15 and Table 16 display the *missed opportunities* per genre crosstabulation for male and female participants, respectively. Twenty-five males participated in the study, resulting in 1,050 crossings analyzed for the male participants (25 males x 6 conditions x 7 street crossing trials = 1,050). This number is lower than the total number of crossings analyzed because the without music condition was removed from the data set since no genre was associated with this condition. The genre of the music presented to each participant was predetermined based on the participants' odd or even ordinal position in the experiment (i.e., odd positions received R&B music while even positions received Pop). Based on the analysis results, male participants had 79 *missed opportunities* while listening to R&B and 90 *missed opportunities* while listening to Pop. The expected numbers of *missed opportunities* for R&B and Pop were 94.6 and 74.4, respectively, exhibiting that there were more *missed opportunities* for Pop than anticipated and fewer *missed opportunities* for R&B.

Table 15: Missed Opportunities x Genre crosstabulation - male

			Genre		
			R&B	Pop	Total
Missed Opportunities	No Missed Opportunities	Count	509.0	372.0	881.0
		Expected Count	493.4	387.6	881.0
		Residual	15.6	-15.6	
	Missed Opportunities	Count	79.0	90.0	169.0
		Expected Count	94.6	74.4	169.0
		Residual	-15.6	15.6	
Total		Count	588.0	462.0	1050.0
		Expected Count	588.0	462.0	1050.0

Thirty-five females participated in the study, resulting in 1,470 crossings analyzed for the female participants (35 females x 6 conditions x 7 street crossing trials = 1,470). Similar to the males, those who listened to R&B or Pop varied based on their odd or even ordinal position in the experiment. The results for the female participants showed there were 109 *missed opportunities* for the R&B condition and 175 *missed opportunities* for the Pop condition. The expected numbers of *missed opportunities* were 129.8 and 154.2 for R&B and Pop, respectively. The observed number of *missed opportunities* was lower for the R&B genre than expected and higher than expected for the Pop genre.

Table 16: Missed Opportunities x Genre crosstabulation – female

			Genre		
			R&B	Pop	Total
Missed Opportunities	No Missed Opportunities	Count	563.0	623.0	1186.0
		Expected Count	542.2	643.8	1186.0
		Residual	20.8	-20.8	
	Missed Opportunities	Count	109.0	175.0	284.0
		Expected Count	129.8	154.2	284.0
		Residual	-20.8	20.8	
Total		Count	672.0	798.0	1470.0
		Expected Count	672.0	798.0	1470.0

Figure 11 and Figure 12 show the differences in observed and expected *missed opportunities* for both genders. As seen in Figure 11, the male participants' observed count for *missed opportunities* was lower for the R&B genre but higher for the Pop genre. Similarly, the female participants' observed count for *missed opportunities* was also lower for the R&B genre and higher for the Pop genre (Figure 12). The comparison of the genders' observed counts for R&B revealed that they both fell behind their expected counts by an average of 18.2 *missed opportunities*. In contrast, the comparison of the observed counts for the Pop genre revealed that both genders exceeded their expected counts by an average of 18.2 *missed opportunities*.

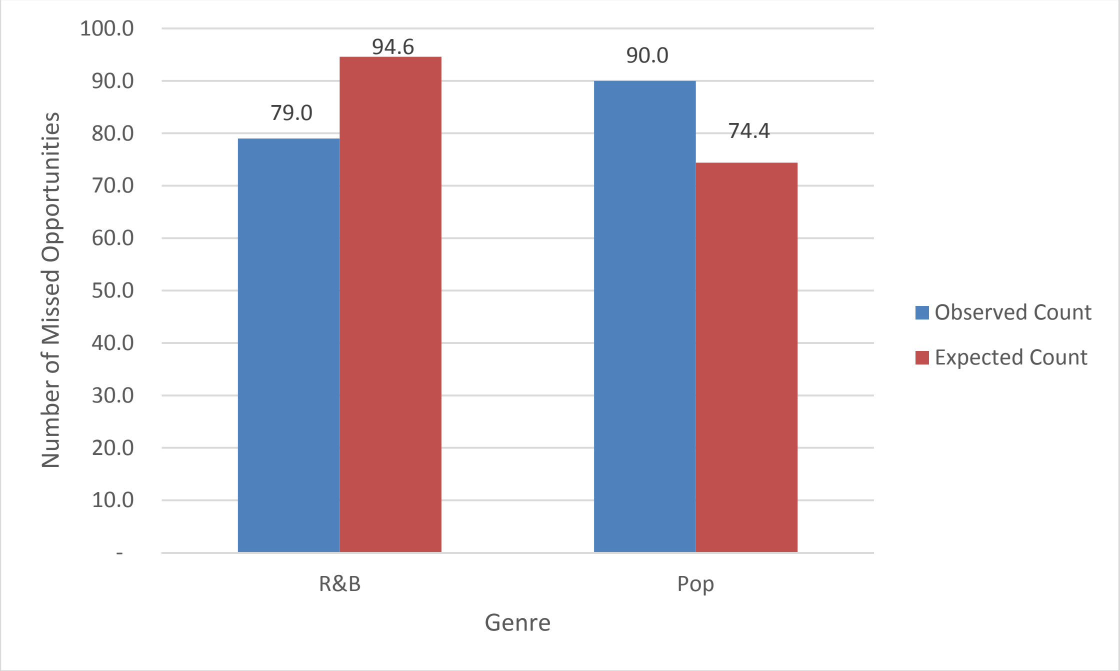

Figure 11: Observed versus expected missed opportunities per genre - male

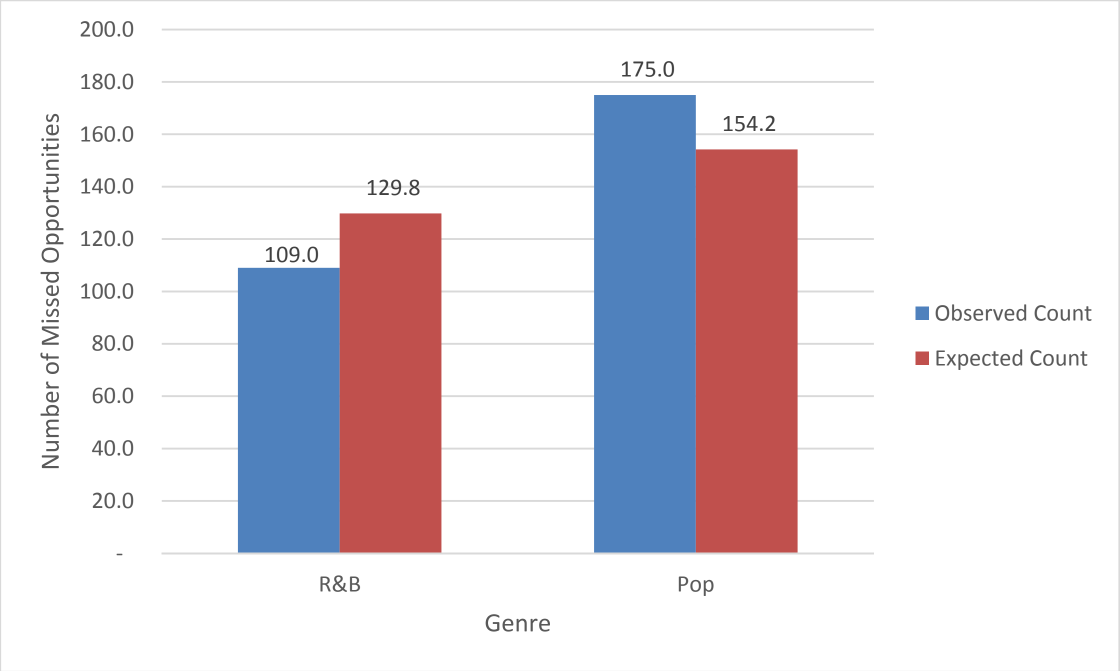

Figure 12: Observed versus expected missed opportunities per genre - female

Binomial Logistic Regression

Device, song level, song level at 65dBA, and song type violated the Chi-Square test of independence assumptions because they were within subject conditions. Therefore, binomial logistic regressions were used to analyze the data for the full data set as well as for the R&B and Pop categories separately. Each IV tested the comparison of different elements. Device tested AC vs BC headsets; song level tested AC earbuds at 55dBA and 65dBA and BC headset at 65dBA; song type tested narrowband and wideband music frequencies; and song level at 65dBA tested both AC and BC headsets at 65dBA. Based on the Cox-Snell R^2 values shown in Table 17, the results of the binomial logistic regressions for each IV indicated a lack-of-fit for the model ($p <$ .05). This is believed to be caused by a lack of variation due to multicollinearity (Table 18). Also known as collinearity, this occurs whenever two or more of the independent variables in a regression are moderately or highly correlated (Pardoe, Simon, & Young, 2018). Due to this characteristic, the variables tested were deemed unreliable for predicting the probability of the occurrence of *hits, close calls*, and *missed opportunities*. This, in turn, resulted in the inability to detect a concrete relationship for the IVs because the model was unable to describe adequately a functional relationship between any of the IVs per DV.

Table 17: Binomial logistic regression on hits, close calls, and missed opportunities

Dependent Variable	Independent Variable	Cox & Snell R Square
Hits	Device, Song Level, Song Type, Song Level at 65dBA	< .05
Close Calls	Device, Song Level, Song Type, Song Level at 65dBA	< .05
Missed Opportunities	Device, Song Level, Song Type, Song Level at 65dBA	< .05

Table 18: Pearson correlation statistics for device, song level, and song type

Independent Variable	Device	Song Level	Song Type
Device		0.79	0.55
Song Level			0.60
Song Type			

Kruskal-Wallis H Test

The dependent variable *wait time* was explored using the Kruskal-Wallis H test because the wait time data was interval in nature and this rank-based nonparametric test can be used to determine if there are statistically significant differences between two or more independent variable groups on an interval dependent variable. As opposed to a one-way ANOVA, the Kruskal-Wallis H test does not assume the dependent variable is normally distributed or that there are equal variances across the independent groups; therefore, the test can be used for interval dependent variables. As seen in Table 19, the Kruskal-Wallis H test was used to determine if there was a significant difference between any of the six independent variables (device, song level, song level at 65dBA, song type, genre, and gender) on the dependent variable *wait time*. This test indicated that there was a significant difference in the *wait time* per genre X^2 (1) = 26.84, $p < .05$, with a mean rank score of 1,185.41 for R&B and 1,335.59 for Pop. There was also a significant difference in the *wait time* for gender X^2 (1) = 33.76, $p < .05$, with a mean rank score of 1,362.88 for the males and 1,547.37 for the females. Based on the mean ranks, the female participants and those participants who listened to the Pop genre waited longer to cross the virtual street. Therefore, the Kruskal-Wallis test implied that genre and gender were not independent of the amount of time it takes a pedestrian to cross a street.

Table 19: Kruskal-Wallis H test for independent variable effects with wait time

Independent Variable	χ^2 Statistic	df	p-value	Mean Rank
Device	.807	2	.69	None (1445.83), AC (1467.11), BC (1489.61)
Song Level	3.16	2	.21	None (1445.83), 55dBA (1434.98), 65dBA (1494.43)
Song Level at 65dBA	.06	1	.80	AC 65dBA (843.43) and BC 65dBA (837.57)
Song Type	.44	2	.80	None (1445.83), Narrowband (1471.66), Regular (1477.56)
Genre	***26.84***	***1***	***< .05***	***R&B (1185.41) and Pop (1335.59)***
Gender	***33.76***	***1***	***< .05***	***Male (1362.88) and Female (1547.37)***

A Kruskal-Wallis H test was also used to analyze both genders independently to establish if there was a significant difference between any of the six independent variables (device, song level, song level with AC and BC at 65dBA, song type, genre and gender) and *wait time* within each gender group. As shown in Table 20, this test indicated a significant difference between genre and *wait time* X^2 (1) = 16.40, $p < .05$ for the male participants with a mean rank score of 491.91 for R&B and 568.25 for Pop. In addition, there was a significant difference in wait time for the female participants based on the genre of the music X^2 (1) = 7.18, $p < .05$ where the mean rank score was 703.18 for R&B and 762.71 for Pop. Based on the mean ranks, the male and female participants both had longer *wait times* when listening to the Pop genre. Therefore, the Kruskal-Wallis test indicated that genre is not independent of the amount of time it takes a pedestrian to cross a street while listening to Pop music for either genre.

Table 20: Kruskal-Wallis H test for genre on gender effects with wait time

Independent Variable	Gender	χ^2 Statistics	df	p-value	Mean Rank
Device	Male	1.72	2	.41	None (593.48), AC (607.97), BC (632.81)
Song Level	Male	5.36	2	.07	None (593.48), 55dBA (582.65), 65dBA (633.05)
Song Level at 65dBA	Male	< .05	1	.97	AC 65dBA (350.78) and BC 65dBA (350.22)
Song Type	Male	.64	2	.73	None (593.48), Narrowband (614.79), Regular (617.72)
Genre	***Male***	***16.40***	***1***	***< .05***	***R&B (491.91) and Pop (568.25)***
Device	Female	.04	2	.98	None (854.29), AC (860.07), BC (855.71)
Song Level	Female	.05	2	.98	None (854.29), 55dBA (855.50), 65dBA (860.18)
Song Level at 65dBA	Female	.10	1	.75	AC 65dBA (493.34) and BC 65dBA (487.66)
Song Type	Female	< .05	2	.98	None (854.29), Narrowband (856.78), Regular (860.45)
Genre	***Female***	***7.18***	***1***	***< .05***	***R&B (703.18) and Pop (762.71)***

CONCLUSIONS AND RECOMMENDATIONS

The primary purpose of this study was to determine if pedestrians were able to complete a street crossing task more safely when using a BC headset than when using an AC headset to listen to music on a PLD. While the results did not reveal any statistical differences between the two types of devices, the results of the Chi-Square tests for gender and genre conveyed that the females experienced more *hits and missed opportunities* in comparison to males. When incorporating the distraction of music, a higher number of *missed opportunities* was discovered when the participants listened to Pop in a genre-to-genre comparison against R&B. This corresponded with both male and female participants obtaining more *missed opportunities* while listening to Pop over R&B when the genders were analyzed independently.

Female participants in this study were struck more often than males in the gender-to-gender comparison for *hits*. One reason for this occurrence could be because the VR system in this study replicated a video game console. According to Paaßen, Morgenroth, and Stratemeyer, multiple studies have shown that on average women spend less time playing video games than males (Paaßen, Morgenroth, & Stratemeyer, 2017). By interpreting information from a graph representing the statistics of computer and video game gamers from 2016 to 2018, 55% of males ranked higher in video game activity, while females made up 45% of the gamer population (Entertainment Software Association, 2018). Based on previous research pertaining to video game affects, researchers Sungar and Boduroglu believe that video game users show improvements in cognitive tasks related to video games that involve sensory processing, reaction times, and visual processing (Sungur & Boduroglu, 2012). In reference to this study, the females' higher *wait time* averages may have correlated to their lower involvement with video games, therefore, resulting in a higher number of *hits*.

The Kruskal-Wallis H tests analyzing the *wait time* variable against device, song level, song level at 65dBA, song type, genre, and gender resulted in only the gender and genre variables demonstrating significant differences. Based on these tests, female participants had a greater *wait times* than male participants and the *wait time* for participants listening to the R&B song was shorter than for those listening to the Pop song. Furthermore, a connection was detected between the average *wait time* and number of *missed opportunities* observed while listening to Pop. When the participants listened to Pop music, they experienced more *missed opportunities* while deciding on an optimal point at which it was safe to cross the intersection. Observations of how each of the genders performed suggest both had an increased *wait time* when listening to Pop music.

As discussed, based on the results of the inferential statistics, it was observed that the participants who listened to the song *Only You* by 112 featuring The Notorious B.I.G (R&B) experienced shorter *wait time* ranges compared to those who listened to the *Shape of You* by Ed Sheeran (Pop). Similarly, the number of *missed opportunities* was lower for participants listening to *Only You* in comparison to those listening to *Shape of You*. In post-experiment interviews, participants reported being pleased with the R&B song *Only You*. At least 10 participants were observed humming or singing along in the auditory chamber. One participant even stated, "I can honestly say, this is the first experiment I've participated in that involved The Notorious B.I.G. I definitely enjoyed this." However, a participant who was assigned the Pop genre mentioned that they did not like the song and asked if there was another song they could listen to. When comparing these two statements, it is possible that those who enjoyed the song *Only You* were already familiar with the song which allowed them to focus more on the street crossing task. This would also allow them to multitask more efficiently while using a PLD, thereby, crossing the street in a relatively short amount of time. While the participants reported not being distracted when crossing the street and listening to *Only You*, the song *Shape of You* appeared to have had an impact on their attentiveness and ability to detect an opening in the passing of vehicles. It is possible that participants were distracted by the actual song because they were not as familiar with it, thereby, forgetting to detect the oncoming vehicles. Pertaining to the participants who listened to the *Shape of You*, such as the individual who did not like the song, both genders may have felt that the song was an additional distraction which may have contributed to more *missed opportunities* and longer *wait times.*

While this study provided some interesting results, additional research is required to make concrete recommendations. Future researchers who have a desire to explore pedestrian safety with personal listening devices should carefully analyze the variables and results obtained from this experiment to determine in which direction to proceed. A replication of this study could be conducted to determine whether the same results occur for a different sample population. Additionally, while the conditions selected for this study were important for exploring street crossing behaviors, expanding the selection of genres and song options available for the participants could conceivably open an array of discoveries. However, this analysis could help determine how other songs, whether sung by a male or female music artist, impact pedestrian walking behaviors. Assigning a playlist specific to a genre can create a more realistic experience since it would allow participants to listen to multiple songs rather than one song played repeatedly throughout the trials.

Aside from the impact a genre selection can have on the way a pedestrian crosses a street, it is important to confirm that the demographics of the study correlate with the variables when different genres are present. For instance, the majority of the participants in this experiment were African American. An article focusing solely on this group's preference in music indicated that they demonstrate a stronger connection with a genre of music they have helped to create and with which they have been closely associated (Nielsen, 2014). This information relates to the results of this study in that both genders performed better when they completed the VR conditions while listening to R&B rather than Pop music. When music is involved in a study with various ethnic participants, it is important to offer a culturally responsive study, meaning that all cultures of the experiment are exposed to a suitable music genre that leans towards their preferences and/or traditions. With modifications to this experiment, hypotheses can be tested to further investigate the association between PLDs and pedestrian safety, therefore, enabling a better understanding of the strategies pedestrians use to decide whether or not they feel it is safe to cross a street while distracted.

Analyzing the results of this study revealed that female participants acquired more hits, missed opportunities, and experienced longer wait times while using the VR system. Gender difference studies pertaining to human computer interaction (HCI) have proclaimed that females exhibit lower confidence than males in computer related abilities (Beckwith, Burnett, Grigoreanu, & Wiedenbeck, 2006). HCI and end-user development studies have concluded that the gender of a video gamer has a significant impact on an end-user's computer interaction behavior, perception, acceptance and overall gaming experience (Tzafilkou, Protogeros, Karagiannidis, & Koumpis, 2017). Various research has confirmed that the difference in genders is a determining factor to a users' gaming performance (Beckwith et al., 2005; Beckwith et al., 2006). Future research dealing with the dissimilarities between males and females as it pertains to pedestrian crossing behaviors should be conducted. Exploring this behavioral attribute can determine if a different experimental method should be used in studies such as this one to decrease the variability seen amongst gender results due to the VR interface.

While the initial intent of this study was to test for street crossing performance differences when AC and BC headsets are utilized, the music that is played can have an effect on how the participant performs. By researching references to confirm the effects of music and behavioral differences between genders, unexpected or additional discoveries could be helpful in the science community. Research questions that can be developed in reference to this study include, “Did the participant experience more hits while listening to a specific genre?” or “Did the participant execute safe crossing behaviors while listening to this genre?”. An additional factor to consider when using a VR system is if the participant is regularly involved with video games. As the notes conveyed, some males believed the simulation to be a learning process, a game that they could win with practice. However, while a specific female participant acquired the same stimulating involvement as her male counterparts, she did find the task to be difficult which could be associated with her lack of prior involvement with video game consoles. Including a question that asks participants about their video game usage could provide data that can be used to determine if performance differences exist between video game users and non-users while using a VR system for a street crossing study.

Pedestrian safety is a concern that continues to escalate with the use of PLDs. In an era where technology is enhancing, new ways to listen to music will be designed, likely resulting in more pedestrians attending to their PLD instead of their surroundings. While BC was the initial focus of this experiment, finding ways to prove the device’s efficacy could result in influencing a pedestrian’s choice of headsets. In a study exploring the effects of distractions during pedestrian crossings, between listening to music (n = 11.3%), making phone calls (n = 5.6%), and surfing the web (n = 6.0%), listening to music resulted in the highest percentage of distractions (Li & Ming, 2016). Listening to music is a means by which many pedestrians block out undesired external noises. However, by blocking out the environmental sounds, pedestrians are also increasing the likelihood of potential fatal incidents. In order to decrease the number of pedestrian safety-related incidents associated with the use of PLDs, it is vital to continue exploring ways to mitigate this growing concern.

REFERENCES

Barton, B. K., Heath, G. E., & Lew, R. (2016). Detection and Direction Determination of Approaching Vehicle Noises Among Older Adults. *The International Journal of Aging and Human Development, 82*(2-3), 229-250.

Barton, B.K., Lew, R., Kovesdi, C., Cottrell, N. D., & Ulrich, T. (2013). Developmental differences in auditory detection and localization of approaching vehicles. *Accident Analysis & Prevention*, *53*, 1-8.

Barton, B. K., Ulrich, T. A., & Lew, R. (2012). Auditory detection and localization of approaching vehicles. *Accident Analysis & Prevention*, *49*, 347-353.

Beckwith, L., Burnett, M., Grigoreanu, V., & Wiedenbeck, S. (2006). Gender HCI: What About the Software? *Computer, 39*(11), 97-101.

Beckwith, L., Sorte, S., Burnett, M., Wiedenbeck, S., Chintakovid, T., & Cook, C. (2005). Designing Features for Both Genders in End-User Programming Environments. Paper presented at the Proceedings of the 2005 IEEE Symposium on Visual Languages and Human-Centric Computing.

Byington, K. W., & Schwebel, D. C. (2013). Effects of mobile Internet use on college student pedestrian injury risk. *Accident Analysis & Prevention, 51*(Supplement C), 78-83.

Duncan, J. (1980). The Demonstration of Capacity Limitation. Cognitive Psychology, 12(1), 75-96.

Entertainment Software Association. (2018). Essential Facts About the Computer and Video Game Industry. Retrieved from http://www.theesa.com/wp-content/uploads/2018/05/EF2018_FINAL.pdf (Last accessed 07/05/2019).

Eysenck, M. W., & Keane, M. T. (2005). *Cognitive Psychology: A Student's Handbook, 5th ed.* New York, NY, US: Psychology Press.

Franěk, M., van Noorden, L., & Režný, L. (2014). Tempo and walking speed with music in the urban context. *Frontiers in Psychology, 5*(1361), 1-14.

Guo, H., Wang, W., Guo, W., Jiang, X., & Bubb, H. (2012). Reliability analysis of pedestrian safety crossing in urban traffic environment. *Safety Science, 50*(4), 968-973.

Hatfield, J., & Murphy, S. (2007). The effects of mobile phone use on pedestrian crossing behaviour at signalised and unsignalised intersections, *Accident Analysis & Prevention, 39*(1), 197-205.

Lenhart, A., Purcell, K., Smith, A., & Zickuhr, K. (2010). *Social Media and Mobile Internet Use Among Teens and Young Adults*. Pew Internet & American Life Project. Retrieved from https://www.pewinternet.org/2010/02/03/social-media-and-young-adults/ (Last accessed 07/05/2019).

McBride, M., Letowski, T., & Tran, P. (2008). Bone conduction reception: Head sensitivity mapping. *Ergonomics, 51*(5), 702-718.

McBride, M., Tran, P., Pollard, K. A., Letowski, T., & McMillan, G. P. (2015). Effects of bone vibrator position on auditory spatial perception tasks. *Human Factors*, *57*(8), 1443-1458.

McComas, J., MacKay, M., & Pivik, J. (2002). Effectiveness of virtual reality for teaching pedestrian safety. *CyberPsychology & Behavior, 5*(3), 185-190.

Nasar, J., Hecht, P., & Wener, R. (2008). Mobile telephones, distracted attention, and pedestrian safety. *Accident Analysis & Prevention*, *40*(1), 69-75.

Nasar, J. L., & Troyer, D. (2013). Pedestrian injuries due to mobile phone use in public places. *Accident Analysis & Prevention, 57*, 91-95.

National Highway Traffic Safety Administration. (2004). *Traffic Safety Facts 2004*. (DOT 809 919). Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/Publication/809919 (Last accessed 07/05/2019).

National Highway Traffic Safety Administration. (2009). *Traffic Safety Facts: 2009 Data*. Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811394 (Last accessed 07/05/2019).

National Highway Traffic Safety Administration. (2012). *Traffic Safety Facts: 2010 Data*. Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811625 (Last accessed 07/05/2019).

Nielsen. (2014). *Listen Up: African-American Consumers and Music*. Retrieved from https://www.nielsen.com/us/en/insights/report/2014/listen-up-african-american-consumers-and-music/ (Last accessed 07/05/2019).

Paaßen, B., Morgenroth, T., & Stratemeyer, M. (2017). What is a true gamer? The male gamer stereotype and the marginalization of women in video game culture. *Sex Roles, 76*(7-8), 421-435.

Pardoe, I., Simon, L., & Young, D. (2018). *STAT 501 Regression Methods*. Retrieved from https://newonlinecourses.science.psu.edu/stat501/ (Last accessed 07/05/2019).

Pfeffer, K., & Barnecutt, P. (1996). Children's auditory perception of movement of traffic sounds. *Child: Care, Health and Development*, *22*(2), 129-137.

Retting, R., & Schwartz, S. (2016). *Pedestrian Traffic Fatalities by State: 2016 Preliminary Data*. Governors Highway Safety Association. Retrieved from https://www.ghsa.org/resources/spotlight-peds17 (Last accessed 07/05/2019).

Roberts, I., Norton, R., Jackson, R., Dunn, R., & Hassall, I. (1995). Effect of environmental factors on risk of injury of child pedestrians by motor vehicles: a case-control study. *British Medical Journal*, *310*(6972), 91-94.

Schaper, D. (2017). *Distraction, on Street and Sidewalk, Helps Cause Record Pedestrian Deaths. Retrieved from National Public Radio, Inc.* Retrieved from https://www.npr.org/2017/03/30/522085503/2016-saw-a-record-increase-in-pedestrian-deaths (Last accessed 07/05/2019).

Schwebel, D. C. (2013). Do our ears help us cross streets safely?. *Injury Prevention, 19*(1), 75-76.

Schwebel, D. C., Gaines, J., & Severson, J. (2008). Validation of virtual reality as a tool to understand and prevent child pedestrian injury. *Accident Analysis & Prevention, 40*(4), 1394-1400.

Schwebel, D. C., Stavrinos, D., Byington, K. W., Davis, T., O'Neal, E. E., & de Jong, D. (2012). Distraction and pedestrian safety: How talking on the phone, texting, and listening to music impact crossing the street. *Accident Analysis & Prevention, 45*, 266-271.

Stavrinos, D., Byington, K. W., & Schwebel, D. C. (2009). Effect of cell phone distraction on pediatric pedestrian injury risk. *Pediatrics, 123*(2), e179-e185.

Stavrinos, D., Byington, K. W., & Schwebel, D. C. (2011). Distracted walking: cell phones increase injury risk for college pedestrians. *Journal of Safety Research, 42*(2), 101-107.

Sungur, H., & Boduroglu, A. (2012). Action video game players form more detailed representation of objects. *Acta Psychologica, 139*(2), 327-334.

Tzafilkou, K., Protogeros, N., Karagiannidis, C., & Koumpis, A. (2017). Gender-based behavioral analysis for end-user development and the 'RULES' attributes. *Education and Information Technologies, 22*(4), 1853-1894.

Ulfarsson, G.F., Kim, S., Booth, K.M., 2010. Analyzing fault in pedestrian-motorvehicle crashes in North Carolina. *Accident Analysis and Prevention, 42* (6), 1805–1813.

Wells, H. L., McClure, L. A., Porter, B. E., & Schwebel, D. C. (2018). Distracted pedestrian behavior on two urban college campuses. *Journal of Community Health, 43*, 96-102.

Wickens, C. D. (2002). Multiple resources and performance prediction. *Theoretical Issues in Ergonomics Science, 3*(2), 159-177.

Wickens, C. D. (2008). Multiple Resources and Mental Workload. *Human Factors, 50*(3), 449-455.

APPENDIX A: Consent Form

NORTH CAROLINA AGRICULTURAL AND TECHNICAL STATE UNIVERSITY
INFORMED CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Personal Listening Devices and Pedestrian Safety
Principal Investigators: Dr. Maranda McBride and Janelle Horton

Purpose of the Study

You have been asked to participate in a research study about the impact of personal listening devices and pedestrian safety. The purpose of this research is to determine whether the use of a bone conduction listening device can improve safety for pedestrians by increasing situation awareness when compared to standard listening devices such as ear buds. You have been asked to participate in this study because you are between the ages of 18 and 25, inclusively, have normal hearing and vision.

This research is sponsored by the Southeastern Transportation Center.

Procedures

If you choose to participate in this project, you must take and pass visual and hearing screenings. If you meet the criteria for the study, you will be asked to listen to music from a headset while navigating a virtual street environment. Your task will be to safely cross a virtual street under four different conditions: 1) with no music, 2) while using earbuds to listen to music presented at a sound level equivalent to normal conversation, 3) while wearing earbuds to listen to music presented at a sound level equivalent to a loud conversation, and 4) while wearing a bone conduction headset to listen to music at a sound level equivalent to a loud conversation. The virtual street will be presented through a virtual reality viewer. It is expected to take about 2.5 hours to complete the experiment.

Risks and Discomforts

This experiment presents no greater than minimal risks to your health. The most common discomforts and risks are typical of those encountered during daily office work. Some individuals may find the auditory headset or virtual reality viewer uncomfortable. You will be permitted to make slight adjustments to the devices to ensure a comfortable fit. If you become fatigued or experience virtual reality sickness (similar to nausea experienced during motion sickness) during the experiment, you are encouraged to inform the experimenter that you require a short break. Some people may find the auditory signals used in the study to be too loud for them to tolerate. If you are presented with a sound level that causes you discomfort, please notify the experimenter so the signal can be adjusted to a comfortable level.

Benefits

There are no personal benefits to you for taking part in this study; however, your participation in this experiment can provide you with the satisfaction of knowing that you have helped increase the body of knowledge concerning pedestrian safety. Finally, you will have the opportunity to learn about the various cues that humans use to avoid hazards.

Compensation or Costs to Study Participants

Participants who complete the entire study will receive a $40 Walmart gift card or extra credit from a designated class for their time. Compensation for participants who complete only a portion of the study will be prorated according to the percentage of the study completed. Once the study has finished, you will pick up the gift card from Dr. Maranda McBride's office located in the School of Business and Economics, Craig Hall, room 402. You will be required to bring your Aggie One card or driver's license for proof of identity. You must sign, date, and provide your banner ID or driver's license number on a form before receiving the Walmart gift card. There are no costs associated with participating in the study.

Revised

08/2013

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This box must remain for office use. Do not remove or reposition.

Confidentiality

Your participation in this research is confidential; therefore, all data and information obtained about you will be considered privileged and held in confidence. All data will be recorded using a volunteer identifier code. All hardcopies of data will be stored and secured in a locked file cabinet. Electronic data will be saved in password protected files and will be transferred to a password-protected computer for data analysis.

If the results of the experiment are published or presented to anyone, no personally identifiable information will be shared. Publication of the results of this study in a journal or technical report, or presentation at a meeting, will not reveal personally identifiable information.

All information collected in this study will be kept completely confidential to the extent permitted by law. The research staff will protect your data from disclosure to people not connected with the study. However, complete confidentiality cannot be guaranteed because officials of North Carolina A&T State University's Institutional Review Board are permitted by law to inspect the records obtained in this study to insure compliance with laws and regulations covering experiments using human subjects.

Still photos may be taken throughout the study; however, your personal data will not be directly connected to any of the photos acquired. The photos will be used in presentations, newsletters, and funding agency reports. If you **do not** want us to take photos of you during the study, please place your initials in this box

Questions about the Study

If you have any questions about your involvement in this project, you may contact the Principal Investigator, Dr. Maranda McBride, at 336-285-3359 or by email at mcbride@ncat.edu. If you have any study-related concerns or any questions about your rights as a research study participant, you may contact the Office of Research Compliance and Ethics at North Carolina A&T State University at 336 285-2961.

Voluntary Participation/Withdrawal

Your participation in this study is voluntary and you may end your participation at any time. Refusing to participate or leaving the study at a later time will not result in any penalty or loss of benefits to which you are entitled. If you are a student, your grade, record, academic standing, or relationship with the University will not be affected if you choose not to participate in or withdraw from the study.

Statement of Consent

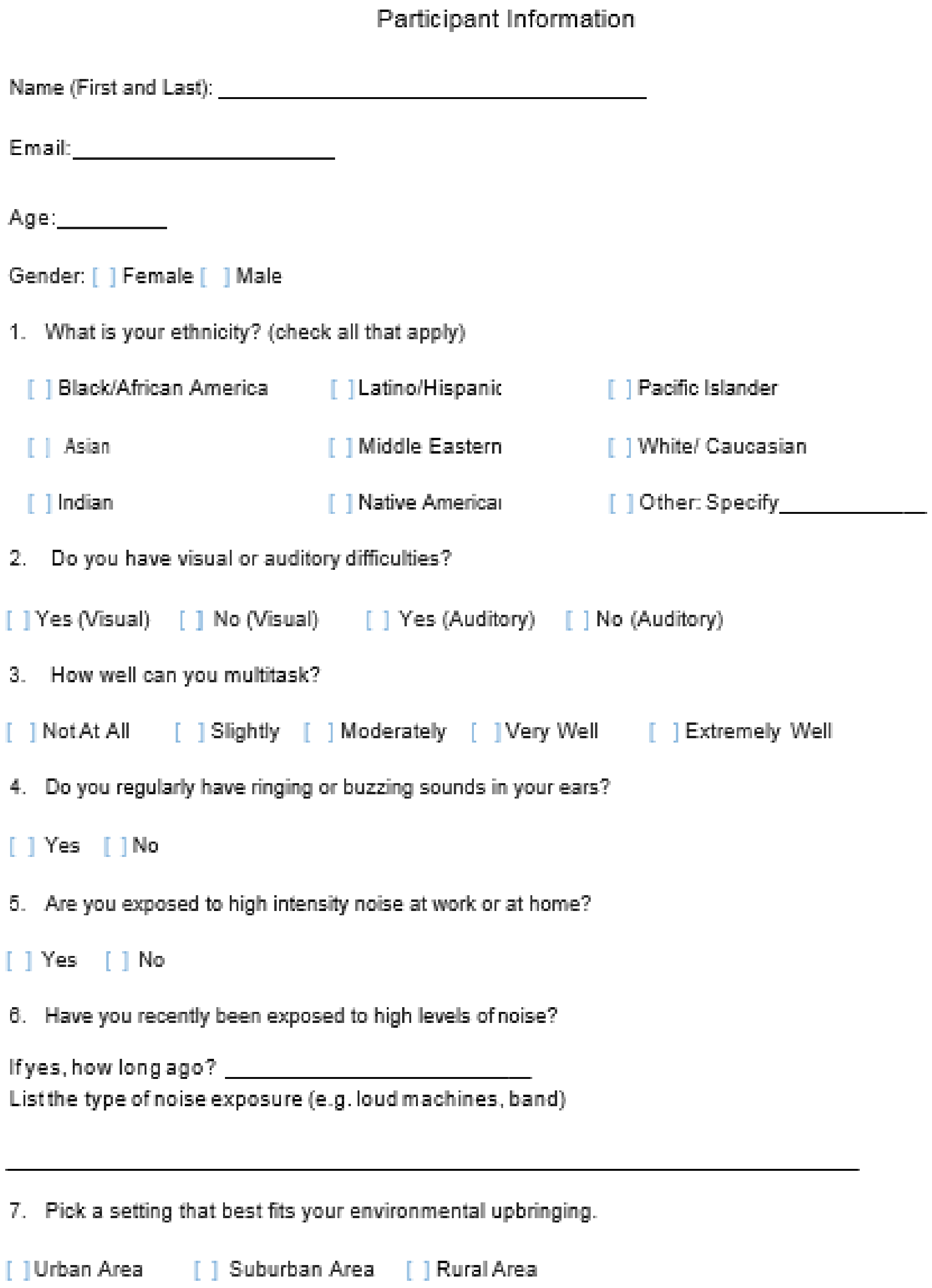
I have read the above information and have received answers to any questions I had. I am at least 18 years of age or older and voluntarily consent to take part in this research study.

Participant's Name (Printed): ____________________________

Participant's Signature:____________________________Date: _______

Researcher's Signature:____________________________Date: _______

APPENDIX B. Participant Information Form



Participant Information

Name (First and Last): ______________________________

Email: ____________________

Age: ________

Gender: [ ] Female [ ] Male

1. What is your ethnicity? (check all that apply)

[ ] Black/African America
[ ] Asian
[ ] Indian
[ ] Latino/Hispanic
[ ] Middle Eastern
[ ] Native America
[ ] Pacific Islander
[ ] White/ Caucasian
[ ] Other: Specify___________

2. Do you have visual or auditory difficulties?

[ ] Yes (Visual) [ ] No (Visual) [ ] Yes (Auditory) [ ] No (Auditory)

3. How well can you multitask?

[ ] Not At All [ ] Slightly [ ] Moderately [ ] Very Well [ ] Extremely Well

4. Do you regularly have ringing or buzzing sounds in your ears?

[ ] Yes [ ] No

5. Are you exposed to high intensity noise at work or at home?

[ ] Yes [ ] No

6. Have you recently been exposed to high levels of noise?

If yes, how long ago? ______________________
List the type of noise exposure (e.g. loud machines, band)

____

7. Pick a setting that best fits your environmental upbringing.

[ ] Urban Area [ ] Suburban Area [ ] Rural Area

Please use the following scale to answer the questions relating to walking while using a mobile device:

1	2	3	4	5	6
Never	Rarely	Sometimes	Often	Almost Always	Always

1. On average, how often do you **talk** on your cell phone while crossing streets? _________
2. On average, how often do you **text message** while crossing streets? _________
3. On average, how often do you **use the mobile internet** while crossing streets? _________
4. On average, how often do you **listen to music** while crossing streets? _________
5. How often do you **walk half a mile** in a given day (roughly 3 blocks)? ___________

Please use the following scale to rate the statements below:

1	2	3	4	5
Very Unsafe	Somewhat Unsafe	Neither Safe/Nor Unsafe	Somewhat Safe	Very Safe

6. While talking on a cell phone and crossing a street, I feel ________
7. While listening to music and crossing a street, I feel ______

Please use the following scale to answer the question below:

40dB	50dB	60dB	70dB	80dB
Faint	*Moderate*	*Comfortable*	*Loud*	*Very Loud*
Refrigerator	Moderate Rainfall	Conversation/Dishwasher	Alarm Clock/City Traffic	Vacuum

8. How loud do you listen to your music device? ___________

APPENDIX C: Realism Questionnaire

Realism Questionnaire

1. How realistic are the sounds of the vehicles?

[ ] Extremely realistic [ ] Very realistic [ ] Moderately realistic [ ] Slightly realistic [ ] Not realistic at all

2. How realistic is the presentation of the virtual environment?

[ ] Extremely realistic [ ] Very realistic [ ] Moderately realistic [ ] Slightly realistic [ ] Not realistic at all

3. How realistic is the walking speed in the virtual reality (VR)?

[ ] Extremely realistic [ ] Very realistic [ ] Moderately realistic [ ] Slightly realistic [ ] Not realistic at all

4. Is the speed of the cars similar to what you would expect in a school crossing zone?

[ ] Yes [ ] Somewhat [ ] No

5. Is the VR environment similar to the walking environment you typically find yourself in?

[ ] Yes [ ] Somewhat [ ] No

6. Did you encounter issues with placement orientation within the VR system?

[ ] Yes [ ] Somewhat [ ] No

APPENDIX D: Additional Data Collected by PedSim Software

VARIABLES	DEFINITIONS
Looks Left	The number of times the participants look to the left in the virtual environment.
Looks Right	The number of times the participants look to the right in the virtual. environment
Time Crossing	The amount of time between the moment the participant starts crossing and the end of the crossing, when the pedestrian avatar either reaches the other side of the street or is hit by a vehicle. If the pedestrian avatar successfully crosses the street, the time crossing value should be consistent with the walk speed, with slight variations due to undeterministic factors in the simulation. This value is a good indicator of on which side of the street the pedestrian avatar is hit in case of collision.
Time Crossing Safely	The amount of time during the pedestrian crossing when the avatar is safe, in other words, when there are no vehicles passing the crosswalk on either side of the street.
Close Calls Oncoming Only	The number of occasions when the estimated Time to Collision (TTC) between the pedestrian avatar and a vehicle is below a pre-determined threshold, only counting vehicles that are still approaching when the pedestrian crosses the collision zone. The threshold is set to 1 second.
Time to Contact (TTC) Oncoming Only	The smallest value among all the estimated TTCs between the pedestrian avatar and a vehicle during the crossing without collision. The oncoming only TTC is calculated only after the avatar passes a point of potential collision on the crosswalk. Therefore, if the pedestrian avatar never passes such a point during the crossing (e.g. a collision takes place, ending the trial before any such occasion can happen), time to contact oncoming only will be undefined and set to -1.
TTC Lane 1	Minimum time-to-collision value from oncoming vehicles to pedestrian avatar on the near lane. It should be noted that the collision zone for a specific vehicle matches the width of that vehicle and is always narrower than the full width of the lane. The moment when the pedestrian is crossing the lane but outside an approaching vehicle's collision zone, the vehicle is not considered a collision hazard (yet) and its time-to-collision is not tallied. The value is -1 if no vehicle ever became a collision hazard in the near lane during the crossing.

TTC Lane 2	Minimum time-to-collision value from oncoming vehicles to pedestrian avatar on the far lane. The value is -1 if no vehicle ever became a collision hazard in the far lane during the crossing. This is always true if the pedestrian was hit in the near lane, thus never entering the far lane.
Distance Lane 1	Distance between closest approaching vehicle and the pedestrian avatar on the near lane at the moment when the pedestrian enters the near lane. -1 if there is no vehicle in that lane at the moment.
Distance Lane 2	Distance between closest approaching vehicle and the pedestrian avatar on the far lane at the moment when the pedestrian enters the near lane. -1 if there is no vehicle in that lane at the moment.
Distance Lane 1 at Start:	The distance between closest approaching vehicle and the pedestrian avatar on the near lane at the moment when the pedestrian starts crossing. -1 if there is no vehicle in that lane at the moment.
Distance Lane 2 at Start	Distance between closest approaching vehicle and the pedestrian avatar on the far lane at the moment when the pedestrian starts crossing. -1 if there is no vehicle in that lane at the moment
Walking Speed	Walking speed of the pedestrian avatar in the simulation during the trial set. 0 – slow; 1 – medium speed; 2 – fast.
Traffic Speed	Speed of vehicles in the simulation during the trial set. 0 – slow; 1 – medium speed; 2 – fast.
Beginning Time Stamp	Time when the researcher clicks the “start” button on the simulator control page.
Ending Time Stamp:	Time when the last trial of the trial set is completed or when the researcher clicks the “stop” button on the simulator control page. Some trial sets do not have a valid end time. In those cases, no trials are recorded for the trial sets. It is also possible for trial sets with valid end time to have no trials recorded.
Starting Gap	The amount of time between the last vehicle passing and the participant starting crossing. If the participant starts crossing when there are still vehicles passing the crosswalk on either side of the street, the start gap is set to 0.

APPENDIX E: Publications, Presentations, Posters Resulting from this Project

Horton, J. (2017). Pedestrian Safety with Personal Listening Devices, 5th Annual UTC Conference of the Southeastern Region, November 16-17, 2017, Gainesville, Florida (poster presentation).

Horton, J. (2018). Pedestrian Safety with Personal Listening Devices, Institute of Industrial and Systems Engineering (IISE) Annual Conference and Exposition, May 19-22, 2018, Orlando, Florida (lecture presentation).

Horton, J. (2018). Pedestrian Safety with Personal Listening Devices, Thesis defense, September 21, 2018.