Pedestrian and Bicyclist Safety and Comfort on Water Street
(Technical Topic)

Analyzing the Adverse Human Effects Experienced during Virtual Reality Testing
(STS Topic)

A Thesis Project Prospectus Submitted to the

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Introduction: *Pedestrian and Bicyclist Safety: A Global Concern*

People rely on roadway transportation networks to go to work, to go home, and to go anywhere and everywhere in between. Unfortunately, we face an extreme and very real danger every time we use our roads. The World Health Organization (WHO) has identified roadway deaths as the leading cause of unnatural death and ninth overall, with 1.25 million fatalities per year globally (WHO, 2015 p. ix). Over a quarter of these fatalities come from pedestrians and bicyclists, and this percentage is only growing (WHO, 2015 p. 9). Addressing this issue on a global scale is both difficult and costly, but one way to improve roadway safety is to build infrastructure to accommodate all forms of travel.

Infrastructure is at the core of the road safety problem. Pedestrians and bicyclists are often forced to use roadways that were only designed to accommodate automobiles. The United States has been particularly behind in this, with much of our infrastructure dating back to the middle of the 20th century when the automobile reigned supreme. We are now feeling the adverse effects, and will continue to unless change is enacted. These effects are not only displayed in the roadway fatalities statistic, but in many of the other top ten causes of death. The subpar pedestrian and bicycle infrastructure in the U.S. has led to an overreliance on automobiles, which has contributed to the country's obesity issues. While many people are willing to walk up to a mile and bike up to two miles, "Americans use their cars for 66% of all trips up to a mile long and for 89% of all trips between 1 and 2 miles long" (Pucher and Dijkstra, 2003 n.p). Only if we improve our infrastructure will we be able to improve these statistics.

To overcome these challenges and to implement new infrastructure ideas, my Capstone team proposes that transportation engineers must look to newly available modeling technology.

Specifically, we will use virtual reality (VR) software to test new design ideas for infrastructure. As a technical project, we will design a new roadway in VR for user testing since real-world testing is both unsafe and costly. Then, I will study the interactions between the technology and humans from an STS perspective to better understand the viability of VR for real-world applications.

Technical Topic: *Designing Pedestrian and Bicycle Infrastructure in VR for User Testing*

The recent advances in VR technology are gaining publicity for their gaming potential, yet other impressive applications are going unnoticed. While it has been around since the 1960's, only recently has VR gained wide-spread consumer and business use (Cipresso, Giglioli, Raya, and Riva, 2018 n.p.). The technology has permeated the educational and training portions of many fields as well as in aspects of the construction industry. Many construction companies use VR as a communication tool to better understand the complex 3D structures they are building. While construction is admittedly "one of the least automated industries in the world today," this application of VR is changing that (Dana, 2018 p.2). Construction companies also use VR to display their designs to the client so that they can more easily grasp what their structure will look like. This allows the client to ask for changes to the design so that the product would better suit their needs. Transportation engineers long for this ability when interacting with community members, as currently town hall meetings with poster displays are the only effective means of communication between the designer and future user of a transportation infrastructure project.

This is where the Omni-Reality and Cognition Lab at UVA comes in. Through the use of virtual reality, the lab looks to create an interface for testing transportation infrastructure in the virtual world. A much cheaper alternative to actually building large structures for testing, VR testing opens the door for a deeper understanding of how people will use a new piece of infrastructure (Chen, 2019). Specifically, the lab is developing pedestrian and bicycle testing in VR. Our team of undergraduate civil and systems engineers are hoping to get this lab up and running for user testing of new designs for the Water Street corridor in Downtown Charlottesville. Water Street, located adjacent to the Downtown Mall, was identified by the Virginia Department of Transportation (VDOT) as a priority corridor in their 2018 Pedestrian Safety Action Plan (VDOT p. 52). The plan was created due to the alarming number of pedestrian injuries occurring in Virginia (see Figure 1). The report revealed that 10 pedestrian crashes occurred on Water Street from 2012 to 2016. While bicycle data is not available, the corridor currently supports the bicycle TransAmerica Trail despite also having a lack of bike lanes. With an important site identified and the problem properly defined, the lab must be carefully set up to test new designs for Water Street using VR.

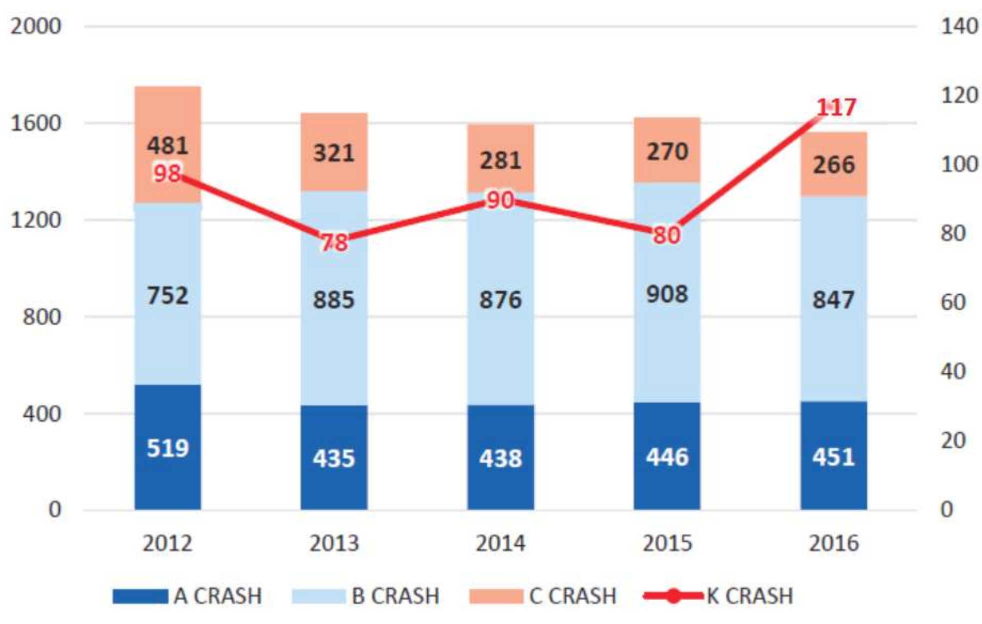

Figure 1: Virginia Pedestrian Crash Database Summary 2012-2016 from VDOT 2018 Pedestrian Safety Action Plan. K crashes resulted in fatalities, while A, B, and C crashes are organized in declining order of severity with A being the most severe (VDOT, 2018 p.1).

User testing relies on a quality and immersive VR experience. The lab is set up to accomplish this through a number of devices. First, the existing Water Street corridor has been created in a VR software called Unity. Next, the roadway improvements to be tested will be designed in the software for future user test-subjects to experience. The experience will be enhanced with a high-end graphics processing computer, a wireless headset, and a state-of-the-art stationary bike, which was originally designed to simulate the outdoors for training purposes. The bike comes complete with adaptive sensors to change the elevation angle and resistance of the bike with the conditions in the VR environment. There is even a fan in front of the bike to simulate air blowing in users faces as they advance in the simulation. Most importantly, as the user operates the bike in the lab, it makes corresponding movements in the VR environment to complete the experience as shown in Figure 2. After completing this advanced simulation, test users will be asked about their comfort level with each design, and any potential concerns they have about a design will be recorded. These responses will be accounted for in the design selection analysis, which will lead to the development of one of the deliverables of the project: planning-level designs for the improved roadway.

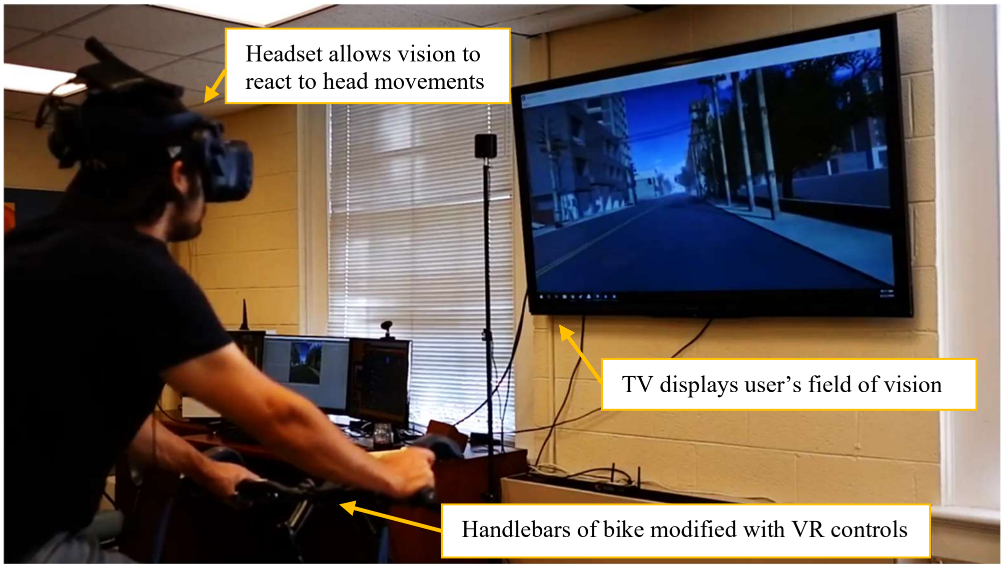

Figure 2: Graduate student Austin Angulo operates the modified bike in the lab. Photo credits are to Erin Robartes of the lab (labels created by author).

STS Topic: *Analyzing the Adverse Human Effects Experienced during Virtual Reality Testing*

Beyond a technical understanding of how to develop an effective simulation in VR, my STS research will study how VR environments and individuals interact. As stated earlier, the project hinges on the software's ability to accurately portray the real world to human test subjects. It is important to remember that all technology has a direct impact on human action, as Bruno Latour explains in his description of a door in "Where Are the Missing Masses?" (p.153). Just as a mechanical door decides who can enter a building, the VR simulation can change people's opinion of a new road, hopefully revealing whether they perceive it as safe. While the door is what causes the separation of people, it is the engineer of the door that incites this action. As Latour states in the ending soliloquy of *Aramis, or the Love of Technology*: "The finest project in the world can't give more than it has, and what it has is what you give it" (p. 294). That quote comes from a piece of technology itself: the personified Parisian transportation network. Aramis maintains that the engineers were at fault for his ultimate failure. Furthermore, Gary Downey writes that engineers maintain control over technology through problem definition in his 2005 article "Are Engineers Losing Control of Technology?" (p.1). These pieces of literature serve as the basis for the project's STS perspective, and they emphasize how we as engineers need to consider and control the human interactions with our VR environment.

As important as setting up the lab to provide the most realistic VR experience is, the simulation is useless if the test is administered in the wrong way. In order to conduct proper testing, the common pitfalls of VR testing must be first researched. I will describe a few of these failures that derail tests. One is the possibility of motion-sickness. Young, Adelstein, and Ellis proved in a 2006 study that motion sickness reports, "are generally based upon survey and self-reported measures rather than controlled experiments" (Young et al., 2006 n.p.). They go on to prove that many reports of motion sickness arise from a demand bias instituted from a pre-test questionnaire. By introducing the idea of motion sickness in a questionnaire to subjects prior to testing, researchers are left with subjects who report motion sickness due to a self-fulfilling prophecy. Knowing this, the project team will be sure to leave all questions of motion sickness until after the VR testing.

Additionally, the right test subjects need to be brought in for the testing to be significant. If the type of people brought in to test the design alternatives are not similar to the type of people who will end up using the infrastructure, then the VR testing would be meaningless. To carefully select test subjects, we will consider a number of factors. Residents of Charlottesville will be asked for testing since they are the most likely to go to Water Street. A variety of citizens of different ages and abilities will be selected for compete testing. The most notable consideration must be bicyclist ability. The American Association of State Highway and Transportation Official's (AASHTO) 2019 Guide for the Development of Bicycle Facilities emphasizes the need for new bicycle infrastructure to appeal to people of all abilities (Toole Design, 2019). Figure 3 describes the different levels of bicycle users and what forms of infrastructure they are typically comfortable with. If the simulation only tests highly confident riders who are already comfortable in most situations, then bicycle activity will not be expanded and the health dangers we want to solve will continue. Another way the testing could go wrong is if volunteer bias takes over. The type of people who are more willing to come in for testing may not share the same characteristics of the entire population. To counteract this the team will need to devise methods of getting an appropriate group of subjects, and we will need to conduct the experiments appropriately as well.

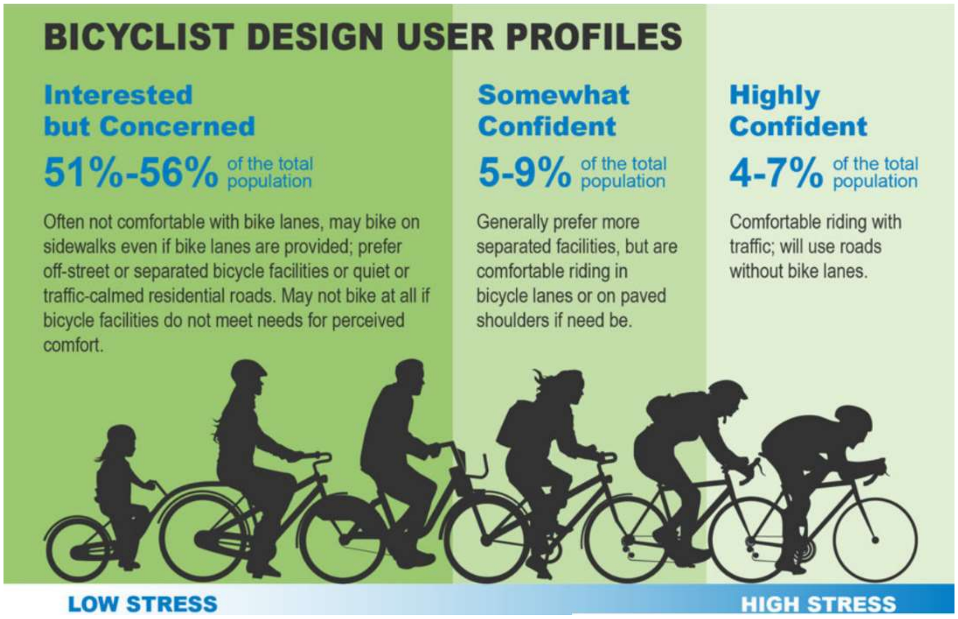

Figure 3: Different types of users of bicycle infrastructure as described in Toole Design's update to the AASHTO Guide for the Development of Bike Facilities. It was created with funding and direction from the National Highway Cooperative Research Program (Toole Design, 2019).

Conclusion: *For a Safer and Healthier Future*

Many of the safety and health issues afflicting our country stem from failed transportation infrastructure, particularly a lack of appropriate bicycle and pedestrian facilities. Through a redesign of Water Street and research on proper virtual reality testing, these critical problems our nation faces can be alleviated. The deliverables of the Water Street redesign will be planning-level CAD designs of a new roadway layout with documentation of the design alternative selection process included. For VR research, a deliverable will come in the form of an extensive STS essay addressing the concerns of human interaction in a VR environment. The research in turn will help the design team better test designs in VR and, furthermore, the proper implementation of user input from the testing will improve the final designs. In the future, this design process could be implemented in industry, enabling engineers to better understand biker skill levels and human reactions to new roadway designs. All of this hopes to increase bicycle and pedestrian travel, making us all healthier.

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