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IMPROVING YOUNG DRIVER PERCEPTIONS OF VULNERABLE ROAD USERS THROUGH A PERSUASIVE INTERVENTION

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IMPROVING YOUNG DRIVER PERCEPTIONS OF VULNERABLE ROAD USERS THROUGH A PERSUASIVE INTERVENTION

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ABSTRACT

IMPROVING YOUNG DRIVER PERCEPTIONS OF VULNERABLE ROAD USERS THROUGH A PERSUASIVE INTERVENTION

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Vulnerable road users (VRUs), including bicyclists, pedestrians, and road users of other modalities, are at a higher risk of collision with young drivers when a complex traffic situation presents itself. Past research has established the importance of young drivers' perceptions about VRUs that would encourage safe behavior. This research designed and evaluated a novel persuasive intervention that can help improve the perceptions of young drivers while they interact with VRUs. The study identified young drivers' perceptions towards VRUs who have been licensed in the past 12 to 18 months through structured interviews. Based on these findings, an interactive intervention was designed and evaluated that persuades young drivers to improve their interactions with VRUs. The results showed an improvement in self-reported violations among groups who received the intervention or the control. Additionally, participants who received a citation showed lower violations and lapses in the intervention and control groups compared to those who did not receive any treatment. The outcome of this research is a methodology that can help design future interventions for improving young driving behavior by understanding their perceptions, and continuously assess their performance during the intervention period.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

A significant focus of transportation research is addressing infrastructure and driver safety issues. The safety of vulnerable road users (VRUs) is emerging as a significant cause of concern. With an increased emphasis on repurposing and redesigning infrastructure for shared spaces for VRUs, an increase in fatalities is a challenge for the transportation safety community. A joint report by the World Health Organization and World Bank reported that 27% of all fatalities in the world involve vulnerable road users (VRUs), including pedestrians and cyclists (World Bank & World Health Organisation, 2013). The US Department of Transportation reported that 13% of all fatal crashes involved pedestrians (Balk, 2014). Stimpson et al. (2013) found a year-on-year increase in bicycle-related fatalities (31.5%) and pedestrians (45.12%) per 10 billion vehicle miles from 2005 to 2010. An ever-increasing number of conflicts between different road users cause crashes and injuries involving cars and VRUs (Bella, Natale, & Silvestri, 2017; Bieshaar et al., 2018a; Shinar, 2012). Research by Ni et al. (2017) found three significant factors that influence the state of conflicts between pedestrians and drivers: (1) individual demographic characteristics, (2) situational conditions, and (3) environmental factors. Additionally, a study monitored the risk of road users at intersections using survey-based methodologies to understand the perceptions of drivers (Borowsky, Oron-Gilad, Meir, & Parmet, 2012). However, no study has focused on understanding the causes that may lead to poor perceptions of VRUs from young drivers.

1.2 Vulnerabilities of the young driver group

Young drivers tend to perform poorly in complex traffic scenarios. Studies have attributed this to poor hazard anticipation and hazard mitigation skills (Fisher, Pollatsek, & Pradhan, 2006; McDonald, Goodwin, Pradhan, Romoser, & Williams, 2015; Pradhan, Fisher, & Pollatsek, 2006), as well as an inherent lack of

experience (Ābele, Haustein, & Møller, 2018) (Borowsky, Shinar, & Oron-Gilad, 2010a). Past studies have proposed methods to mitigate these limitations. Policy measures around injury prevention have been explored to increase the awareness of VRU's as potential hazards (Constant & Lagarde, 2010). Tripodi et al. (2012) documented countermeasures for VRUs, which are corrective and preventive policy directives aimed at improving the safety of VRUs. While these methods have benefits, they are limited to the overall design of roads and analyzing historical trends, rather than understanding problems from the driver's perspective. To improve hazard anticipation and mitigation of the young drivers' towards VRUs, interventions have focused on enhancing hazard anticipation (Fisher et al., 2006), informing drivers about VRUs through safer messaging (Rogé, El Zufari, Vienne, & Ndiaye, 2015), and encouraging young drivers to make safer choices while interacting with VRUs through instructional messages (Collins, Murphy, & Strecher, 2007). However, hazard anticipation and mitigation-focused interventions are not focused on interacting with VRUs on shared roads. Outside of policy changes, there are also methods involving technology-based solutions, such as through the use of onboard cameras that observe VRUs and evaluate the degree of interactions with VRUs (Aycard et al., 2006; Bieshaar et al., 2018b; Saleh, Hossny, & Nahavandi, 2017). However, these technology-based interventions do not consider individual traits of a young driver. This is important to consider because preventive methods can only find acceptability and compliance if they are designed while considering the perspective of the young driver.

1.3 Objectives and contributions of the research

This research aims to explore the perceptions of VRUs from a young drivers' perspective based on their interactions with VRUs. The research identifies prevalent themes, including young drivers' concerns when they interact with VRUs and their understanding of how they are expected to interact with VRUs. After theme identification, the research uses design elements to implement and evaluate a practical intervention that ensures safer road sharing between young drivers and VRUs. The outcome of this research is a novel methodology that supports safer driving behavior among young drivers when they interact with VRUs.

1.4 Summary of the dissertation

This dissertation looks to help introduce a novel method that can help improve the perceptions towards VRUs amongst young drivers. **Chapter 2** introduces the concepts around young drivers, their inherent risks, VRUs and their inherent risks, followed by exploring the applicability of training, interventions, and education towards changing perceptions. **Chapter 3** reports the results of an interview study which aimed towards understanding the perceptions of young drivers. **Chapter 4** utilizes the findings from the previous chapter, to design, implement, and assess the efficacy of the intervention which could improve perceptions of young drivers towards VRUs. **Chapter 5** discusses the wider implications of the study, the limitation of the studies, and how these findings can help inform the design of future interventions, which would serve the purpose of improving interactions between young drivers and VRUs.

CHAPTER 2

BACKGROUND

2.1. Young drivers

Young drivers are overrepresented in crash-related scenarios in the United States (Cooper, Pinili, & Chen, 1995). One of the primary reasons for this could be attributed to young driver inexperience. The lack of experience could potentially result in poor driving skills, poor hazard management, and increased odds of a crash (McCartt, Mayhew, Braitman, Ferguson, & Simpson, 2009). To this avail, the design and implementation of supplemental training and educational programs may reduce the crash risk of young drivers.

This chapter looks to discuss the risk factors associated with young drivers. A similar understanding of the risk factors associated with vulnerable road users (VRUs) is explored. Upon establishing the risk associated with young drivers and VRUs, the chapter explores driver training programs' efficacy. It discusses their applicability for improving interactions between young drivers and VRUs. Finally, the chapter proposes the applicability of persuasive design and exploring whether it has the potential efficacy. The chapter lays the foundation for designing the intervention program for young drivers towards VRUs and fulfills the objectives of this research. The following section is focused on the role of inexperience on crash risk, the impact on young driver performance, and the role of training in improving young driver behavior.

2.1.1 Role of inexperience on crash risk

Figure 1 shows the relationship between the total months of licensure and their relationship with the crashes observed per 10,000 novice drivers. The difference in crash rates is higher for age groups when the licensure is less than six months, which shows a higher risk associated with the lower driver experience than drivers who have driven longer. The results also suggest an interaction between age and experience.

At all ages, crash rates decrease with an increase in the driving experience. However, the drop is much sharper among drivers aged 20 years and older, particularly during the first year after licensing. Past researchers have explored and found a higher crash rate among young drivers (ages of 16 and 19 years old) than young drivers greater than 20 years old (McCartt et al., 2009). Studies have also shown that experienced and older drivers are more likely to identify and maneuver around potential hazards regardless of the measure used than young-inexperienced drivers (Borowsky, Shinar, & Oron-Gilad, 2010b).

A past study differentiates between drivers' propensity to engage in glance behavior that anticipates hazards, appropriately maintains speed, and maintains attendance (Chan, Pradhan, Pollatsek, Knodler, & Fisher, 2010a). The research also found that young drivers were less likely to detect potentially hazardous situations when they occurred after a planned (actual) event. In contrast, both older-experienced and experienced drivers continued to search for hazards that establish inexperienced drivers and their impact on potential risks.

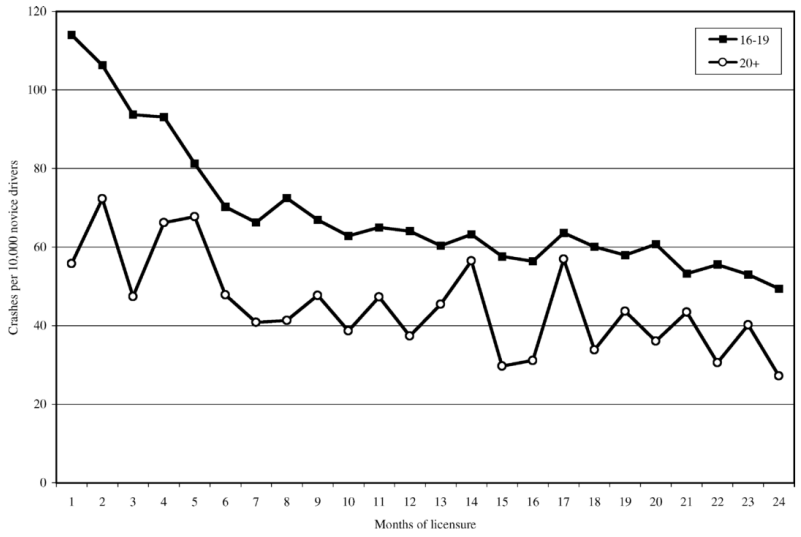


Figure 1 Relationship between crashes and licensure based on age groups (McCartt et al., 2009)

2.1.2 Young driver performance

Past research has helped understand the importance of better hazard anticipation, appropriate speed maintenance compared to experienced drivers, and why young drivers are more likely to have difficulty navigating complex traffic scenarios (Chan, Pradhan, Pollatsek, Knodler, & Fisher, 2010). To assess hazard anticipation, Pollatsek et al. (2013) established that the inexperience of young drivers results in them taking more time to complete in-vehicle glances than experienced drivers. They found that young drivers have a higher likelihood of a higher percentage of long in-vehicle glances. The longer than 1.5-second glances were associated with young inexperienced drivers, whereas glances shorter than 1.5 seconds were associated with older experienced drivers.

In addition to hazard perception, inexperienced and young drivers have poor speed management and directional control (lateral and longitudinal) (Isler, Starkey, & Sheppard, 2011a). They reported elevated g-force events derived from kinematic data (Simons-Morton et al., 2015). Another study found that elevated g-force event rate was a great predictor in accurately determining a crash/near-crash (Simons-Morton et al., 2012). Young drivers with higher rates of hard stops and sharp turns were more likely to crash. In comparison, young drivers with fewer hard stops and then teenagers' low rates of risky driving, those whose driving style included few such events. Therefore, drivers have a slower reaction time to respond to traffic scenarios, indicating a poor driving response. Hatfield et al. (2009) found that young drivers had a lower aversion to risky driving and a higher propensity to take risks than older drivers. Additionally, in comparison with older drivers, young drivers reported higher infractions due to speeding, not stopping entirely at stop signs, and following lead vehicles too closely (Porter & Whitton, 2002). Young drivers often indulge in risky driving behavior. In the next section, risky driving behavior among young drivers is explored.

2.1.3 Young drivers and risky behavior

It is essential to consider whether young driver behavior is affected by rewards associated with risky behavior. It is essential to understand the reasons behind risk-taking young drivers' higher propensity and

whether risky behavior rewards them. For young driver road safety, reward sensitivity is significant to study since psychological characteristics are strongly associated with propensity to risk rewards. Rewards may be motivating, external (obtaining from outside sources), or internal (feeling good about oneself). Punishments may also be encouraging when they are external (such as a traffic infringement, in preparation, or internal (e.g., the anxiety experienced in response to risky driving behavior or the negative feeling that they are breaching their trust passengers). Behaviors which are perceived to be punishing are less likely to be repeated. In contrast, behaviors which are perceived to be rewarding – of particular interest for this literature review – are more likely to be repeated. This may be partly because of the teenager's' developing prefrontal cortex, which may explain why young drivers may have a proclivity to take risks (Steinberg, 2008).

Additionally, it is normatively typical for teen drivers to undertake risky behavior (Scott-Parker & Weston, 2017). There are other factors like propensity to drive under the influence of alcohol (Hasselberg & Laflamme, 2009), lack of compliance with speeding (Ferguson, 2013), seatbelt (Shults, Haegerich, Bhat, & Zhang, 2016). Additionally, these factors may confound with underdeveloped hazard perception skills (Borowsky et al., 2010b). In addition to these factors, the social environment also influences the risky behavior among drivers (Guggenheim & Taubman – Ben-Ari, 2018). The purpose for understanding young drivers and the risk associated with them is critical not only for their safety but also for the safety of vulnerable road users (VRUs). The risk associated with other road users and the inherent risks is explored in the next section.

2.2 Vulnerable road users

2.2.1 Crash risk

Motor vehicle crashes related to pedestrians, bicyclists, and other road users constitute a small percentage of crashes. The fatality rates of Vulnerable road users (VRUs) increased to 34% in 2018 from 20% in 1996 (National Center for Statistics and Analysis., 2019). Researchers have found systematic underreporting of accidents, with pedestrian accidents not involving a motorized vehicle. Road incidents

are often excluded in the official police accident database (Turner, Roozenburg, & Francis, 2006). Shinar et al. (2017) addressed the problem suggesting new data recording methods to combine reports from hospitals, police sources, and other medical sources.

While capturing the crash risk is essential, many factors cause risky interactions between drivers and VRUs. Several research papers have reviewed the risk associated with different VRUs. States with mandatory helmet laws had 5.6% fewer motorcycle fatalities per 10,000 motorcycle registrations and 7.85% fewer motorcycle fatalities for every 100,000 in each population. Maneuvers such as overtaking, motorcyclists being older than 40 years, not using motorcycle helmets, daytime riding, crashes occurring on roadside shoulders. The influence of alcohol among the riders during crashes increased the risk of crash fatalities (Dissanayake & Shaheed Saad, 2012).

Crash risks associated with pedestrians have been explored in the past (Rifaat, Tay, & De Barros, 2011). The primary factor explored in the study was regarding the street patterns and their impacts on the risk associated with the crash. The results found that pedestrians and bicyclists involved crashes on divided roads with a barrier noticeably increasing the probability of fatality. The crash severity of events on private driveways or parking lots experienced a lower non-fatal injury risk. A potential reason for the severity could be associated with hit objects (non-injury) or minor children (tend to be fatal although the very low probability of occurrence).

Several factors have helped explore the factors that reduce the potential crash risk of VRUs. Traffic signals reduced the probability of a fatal injury. The efficacy of traffic signals could be attributed to quicker response times among drivers, resulting in reduced vehicle speed, resulting in lower crash severity. Environmental factors found a seasonal variation in crash severity, particularly during the winter season. The study reported that "unfavorable driving conditions" caused slow down, reducing the likelihood of a fatal crash. However, the road surface is covered by snow or ice, increasing skidding and braking distance, leading to more injury crashes. Another dominant factor with regards to VRU associated crash risk was

with regards to visibility. When examined, lighting conditions (daylight, sun glare, darkness, and unknown) influenced crash fatality. Drivers could detect pedestrians/cyclists during daylight, which enabled better detection of VRUs, providing them the time needed to take evasive actions and reduce speed(Rogé et al., 2015; Wegman, Zhang, & Dijkstra, 2012). Wegman et al. (2012) found that countermeasures including fluorescent reflective material and safe lighting reduce drivers' chances of detecting pedestrians and cyclists. Additionally, visibility issues (time of day or climate) (Rogé, El Zufari, Vienne, & Ndiaye, 2015) are a significant factor in drivers' inability to detect VRUs.

VRUs do not always observe traffic laws. VRUs may exhibit crash risk when they do not adhere to the road rules, even when drivers are observant. With the disregard for VRUs by drivers, or VRU's inability to observe traffic rules combine, there are potential conflicts regarding drivers and pedestrians (Hagel et al., 2007). The crash risk increases when we consider individual factors that are related to pedestrians and bicyclists. Henary et al. (2006) explored how demographic factors like older age and frailty are directly demonstrable to increase crash risk. The following section focuses on laying out the basis for interactions between drivers and VRUs, and how safer interactions occur between all road users.

2.2.2 Interactions between drivers and VRUs

To avoid a collision, all road users must be aware of each other and communicate for safety. Before exploring the importance of how safe interactions may potentially prevent future crashes, it is critical to understand the different types of interactions. Snyder and Knoblauch (1971) described the approach of driver and pedestrian as a series of six sequential processes described as.-

(1) Select the path of movement

(2) A visual scan of the relevant scene for the potential or actual presence of the other

(3) Detect the other and assess their relative location

(4) Evaluate the intention of the other

(5) Decide on the proper course of action

(6) Take the measure to avoid a collision

According to their research, if either road user missed out on the steps, the odds of crashes increased, resulting in fatal outcomes. While this helps structure the interaction, it is challenging to qualify factors like intent, context, and relative path selection. Markkula et al. (2020) addressed these challenges by defining concepts of "space-sharing" from a collision avoidance point of view rather than the traffic conflict perspective. Different types of movements between the pedestrian and drivers could help define whether the movement path could be constrained or lead to conflict. An additional contribution of this research helps define the intention as appreciation, perception, or movement. The different types of interactions include signaling, requesting, and achievement, which would help address potential conflicts related to a "space-sharing" paradigm. The research provides a unique perspective on defining interaction types. These interactions can help understand the potential crash risk associated with performing or missing out on these different definitions of intention. Similar intent detection was explored in the context of Automated Vehicles (Bieshaar et al., 2018b).

2.2.3 Factors that influence interactions between drivers and VRUs

The risk associated with the interaction between different types of road users has been explored extensively in previous literature. Dozza et al. (2016) found that critical events identified pedestrians, light vehicles, and other bicycles as primary threats to a safe ride. The study helped quantify the concept of drivers' comfort zone boundaries (CZB). The research investigated the combination of factors that affect the CZBs while drivers overtake cyclists in a naturalistic setting. The results found that a higher car speed resulted in larger CZBs while approaching and passing. However, the presence of an oncoming vehicle significantly decreased the CZB during passing. This study's results lacked generalizability as the study was conducted exclusively in Sweden and may require replication in different locations.

Similarly, a past study addressed the challenge of protected bike lanes; bicyclists must merge or interact with turning traffic at intersections unless all movements are signalized (Foster & Mcneil, 2015). The

research compared five designs for protected bike lanes at intersections without bicycle signals. The designs were representative of how bicycles and motor vehicles would interact and mix on the road, and the design communication was related to the normative behavior of all VRUs. The designs conveyed interactions between road users when observing the lane striping, green pavement markings, shared lane-use markings (Sharrow), and vertical flex post delineators. For evaluation purposes, the designs were compared between "mixing zones" and "turning zones with a through bike lane" groups. For this purpose, user behavior was observed around the different designs (from 78 h of video analyzed, 6,082 bicyclists, and 7,574 turning vehicles). In addition to video data, self-reported behaviors and comprehension from 1,245 nearby residents and 690 intercepted bicyclists were considered. The results found the benefits to clear demarcation of the entry to the merge zone for bicycles and cars and to creating a semi-protected through the bicycle lane. In terms of defining a clear space, demarcation of the entry to the merge zone for bicycles and cars created a semi-protected bicycle lane for safer interactions between drivers and cyclists.

Self-explaining road (SER) design helps inform and demarcate the zones allocated towards different road users. SER design may help understand the nature of interactions between different road users (MacKie, Charlton, Baas, & Villasenor, 2013). Such interventions can help other road users have better freedom of road usage while overcoming constraints. The findings from this study were that pedestrian and motorist movements were constrained and non-uniform within the local roads following SER construction. There was a shift to less through traffic and more turning traffic at local intersections, less indicating when turning, and a more significant proportion of severe lane deviations. There appeared to be a shift to proportionately less through traffic and more traffic leaving residences at mid-block locations. The explanation could be attributed to the assumption of motorists entering the same residence before or after the data collection times). There was also a change in lane-keeping behavior following SER construction with a much more significant proportion of severe lane-keeping deviations. The results found pedestrian movements to be less constrained within the SER local road environment. Also, pedestrians are more willing to interact with traffic, presumably due to the lower traffic speeds. A limitation of this research was

that there was no control to compare the performance to establish the efficacy of SER constructions and enable interactions between different road users.

An assessment of the perceived control of the interaction between drivers and VRUs showed how drivers are likely to yield to pedestrians. Pedestrians and vehicles are equally likely to yield to one another outside the marked crosswalk (Balk, 2014). The assessment found that drivers are likely to yield to pedestrians. However, while drivers are more likely to yield to pedestrians in the marked crosswalk, pedestrians and vehicles are equally likely to yield to one another outside. The findings suggest that measures that reduce the perceived affordances to cross the roadway reduce the proportion of crossings outside the marked crosswalks. It also appears that pedestrians cross when perceived control of the crossing is greatest. Measures to increase perceived control can increase (e.g., visible countdown clocks) or decrease (e.g., large medians) crossings in the marked crosswalk. A model to predict pedestrian crossing location is provided. The model uses various environmental variables as predicting factors and successfully predicts an average of 90 percent of the crossings. Several changes to the infrastructure have been tested in past research that may improve traffic flow efficiency, enabling right-turning drivers to bypass traffic lights at signalized intersections (for right-hand drive countries) (van Haperen et al., 2018).

Another factor that impacts interactions between different road users is driver maneuvering. Driver maneuvering had a significant impact on the degree of interaction between bicyclists and drivers. Drivers were influenced by car speed, pedestrian speed, pedestrian size, crossing angle, crossing presence, crossing entry, and lane width while approaching pedestrians (Jaber & Thalya, 2016). In this study, the participants were compared between two groups of frequent and occasional drivers. The research found that the car speed and crossing entry had a significant relationship with the TTC at brake onset for both groups. TTC decreases with the pedestrian size and the lane width on the brake onset for both groups. However, a limitation of this study was the lack of accounting for pedestrians changing their comfort boundaries with the crossing. Another limitation was the lack of replicability of the environment in a simulated environment.

In some studies, the mere presence of VRUs helped explore the differences in interactions. A study exploring the impact of protected intersection and driver behavior found that a bicyclist crossing a protected intersection significantly reduced the driver's speed while performing a right turn (Deliali, Campbell, Knodler, & Christofa, 2020). The study found that a bicyclist crossing a protected intersection significantly reduced the speed of the drivers who were performing a right turn. A corner refuge island with larger width also reduced speed at the curve as they were accompanied by more significant curb extensions, which reduced the space for the automobiles. At the intersection where the bicycle and crossing pavement markings merged, only approach speeds before the actual turn were slower since that is the location where they were the most visible. Additional factors like age, gender, and bicycling frequency were observed to affect turning speeds. The findings of this study can guide the implementation of protected intersections of protected design elements for facilitating road sharing and driver-VRU interactions. While considering the safety of VRUs, it is essential to consider how the infrastructure designed for the VRUs may not address the safety concerns. A past study reviewed evidence from 23 articles (eight that examined intersections and 15 that examined straightaways) that suggested how infrastructure influenced crash risk (Reynolds, Harris, Teschke, Cripton, & Winters, 2009). The study reviewed the existing literature on transportation infrastructure and cyclist safety, focusing on the range of facilities and difficulties in controlling for risk exposure. The evidence from the articles (8 that examined intersections and 15 that examined straightaways) found that infrastructure influenced the risk of injury and crash. Intersection studies found that multi-lane roundabouts can significantly increase the risk to bicyclists unless a separated protected bike lane is designed.

Additionally, the presence of sidewalks and multi-use trails posed the highest risk, major roads were found to be more hazardous than minor roads, and the presence of bicycle facilities (e.g., on-road bike routes, on-road marked bike lanes, and off-road bike paths) was associated with the lowest risk. Evidence suggests that purpose-built bicycle-specific facilities reduce crashes and injuries among cyclists, providing the basis for initial transportation engineering guidelines for cyclist safety. Additionally, proper street

lighting, paved surfaces, and low-angled grades are additional factors that appear to improve cyclist safety. In a similar vein, street patterns with loops and lollipops design increase the probability of an injury but reduce the probability of fatality and property damage only in the event of a crash (Rifaat et al., 2011). This study investigated and found that motorists willingly gave the right-of-way as a possible courtesy or fear of injuring vulnerable road users. Dozza et al. (2014) found that cyclists near an intersection were observed to have an increased crash risk. Furthermore, the risk increased by twelve times when the intersection presented some form of visual occlusion (e.g., buildings and hedges). Additionally, lack of road maintenance also led to an increase in risk.

While infrastructure has a significant role in crash risk, illumination may also influence the crash risk. Several research papers have found how cyclists who carried fluorescent cycling garments on 77% of their cycle trips reported a 38% lower incident rate (Lahrmann, Kidholm, Madsen, & Olesen, 2018; Lahrmann, Kidholm, Madsen, Olesen, et al., 2018). Wood et al. (2005) studied how driver age, clothing configuration, headlamp beam, and glare significantly affect performance in detecting a pedestrian. The study showed that only 5% of pedestrians were detected in the most challenging condition (low beams, black clothing, glare). In contrast, drivers recognized 100% of the pedestrians who wore retroreflective clothing configured to depict biological motion (no glare). Another research found that the number of lanes per link and the pedestrian flow was associated with an increase in nighttime accident frequency.

In contrast, vehicle flow was associated with decreasing pedestrian accidents (Nabavi Niaki et al., 2016). Crash patterns analysis using GIS systems has found that pedestrian nighttime has negatively impacted the pedestrian crash risk (Dai, 2012). While infrastructure and illumination are critical towards arresting the risk associated with VRU crashes, the most critical factor is the interactions between drivers and VRUs. Buch et.al., (2017) found cyclists to have a higher relative risk when they engaged in risky behavior or wore inconspicuous clothing.

Regarding pedestrians, the crash risk is associated with the infrastructure, and the potential of collision is associated with signalized/unsignalized signals. Results from a past study that involved pedestrians who self-reported their crossing found driving and walking experiences, self-reported crossing difficulties and falls in the street) were also essential factors in safety-related crossing behaviors (Dommes et al., 2015) when associated with red-light violations. Gap acceptance was another significant factor that has been found to impact pedestrians. Sufficient gap acceptance includes vehicular gap size, movement of pedestrian from the curb or median, rolling gap (pedestrian rolling over available small gaps), type of gap, pedestrian speed change condition, and pedestrian waiting time (Kadali & Vedagiri, 2013).

For this study, 12 behavioral indicators were observed before and while crossing. The results found that the gender of a pedestrian had no significant impact, and older pedestrians tend to have more cautious behaviors. The three contextual variables related to the traffic (group size, parked vehicles, and traffic density) and four mobility-associated variables (driving and walking experiences, self-reported crossing difficulties, and falls in the street) were also essential factors in safety-related crossing behaviors. Regarding the red-light violations, situational factors (group size, parked vehicles) and particularly associated with some behavioral patterns (looking toward the traffic, the ground, the light, running, and crossing diagonally) were impacted.

Vehicle attributes, including origin, vehicle type, stopping at upstream traffic, and variability in speeding and headways, impacted pedestrian crossing behavior (Figliozzi & Tipagornwong, 2016). Similar findings were reported in a study where the vehicle characteristics are key factors to predict pedestrian crosswalk law compliance and stopping behavior. Additionally, variability in speeding and vehicle headway tends to have a high explanatory power regarding gap acceptance regarding pedestrian crossing behavior.

Distraction among pedestrians has been associated with collision risk. Pedestrians who use cell phones were found to have a higher risk of being associated with a collision (Zhang, Zhang, Wei, & Chen, 2017).

The study found that additional factors like pedestrians, vehicle lane, traffic speed, driver yielding rate explored crash risk among distracted pedestrians. The results found that age, gender, the usage of mobile phones, traffic volume is related to pedestrian crossing safety.

2.3 Training, education, and feedback to improve young driver performance

Young drivers can acquire specific skill sets relevant to safely conducting the tasks associated with driving through training (Beanland, Goode, Salmon, & Lenné, 2013), education programs, or feedback. Most driver training and education programs help mitigate risky behaviors, particularly among young drivers in crash-related fatalities. Driver training' is often used interchangeably with driver education, although the two terms have distinct definitions. Driver training focuses on developing specific skill sets relevant to safely conducting the tasks associated with driving (Beanland et al., 2013). The focus of driver training is primarily procedural, such as vehicle maneuvering, training to ensure practical higher-order cognitive skills, including hazard perception (Isler et al., 2011a). In short, it would be safe to say that training associated with driving could be the process of reinforcing "knowledge in the head." Driver education is focused on knowledge acquisition about driving and road safety (Christie, 2001). Similarly, driver feedback informs drivers about their performance and establishes expectations about future behavior. Most feedback leverages elements of driver training, traffic safety efforts, and research on driver behavior (B. G. Simons-Morton, Zhang, Jackson, & Albert, 2012).

2.3.1 Driver training

There have been successfully training programs developed to address these issues, had varying degrees of success on the targeted population. In this response, we understand the details of the training programs and their details. We will consider risk training programs that would control issues around the tactical and vehicle control measures. While personality, social, and environmental factors have a bearing on driving behavior, the focus of most driving education is improving higher-order skills (Hazard Anticipation, Hazard Mitigation, and Perceptual Training). Several driver education and training programs have improved hazard

perception, anticipation, and mitigation to reduce risky driving behavior (Masten, 2004; McDonald et al., 2015; Obregón-Biosca, Betanzo-Quezada, Romero-Navarrete, & Ríos-Nuñez, 2018). This training has shown promise in several contexts and has been utilized by many researchers in driving and safety sciences.

Studies have been done in the past to improve hazard anticipation, hazard mitigation, and attention maintenance skills to lower the potential risks associated with driving-related crashes. It was found that novice drivers are more likely to perform worse than experienced drivers in the context of poor performance in the higher-order skills. Research has helped create an accelerated learning curriculum to address these issues with the help of a concise, ubiquitous curriculum that looks to improve the performance of these drivers (Fisher, Knodler, & Samuel, 2017). This training program, known as ACCEL, was developed by providing feedback about complex traffic scenarios conducted by hazard-based training. This training program was evaluated on 100 participants in two phases. In the first phase, 100 participants were recruited: 50 young novice drivers trained on ACCEL, 25 young novice drivers received a placebo training program (a video about vehicle maintenance), and 25 experienced adult drivers received no treatment. Two experiments evaluated the program. In Experiment 1, participants' performance was evaluated immediately after training on a driving simulator. Evaluation of the program showed improvement in each type of crash. The program showed that the same participant's performance was evaluated between three and six months later. The findings confirm that while the interventions effectively improve the higher-order skills of the driver, recurrent training is essential to improving the overall driving performance of drivers. Similarly, multiple pieces of training have been designed in the context of mitigating driver risks (McDonald et al., 2015). Several pieces of training have been designed (Crundall, Howard, & Young, 2017; Fisher et al., 2006; Isler, Starkey, & Sheppard, 2011b; Peck, 2011a) to design different training methodologies.

Several training programs have been designed to improve young drivers' skills. Computer-based training programs have been used to train young newly licensed drivers with basic vehicle handling skills to hazards they may or may not have encountered. An example of such a training program is Risk Awareness and Perception Training (RAPT) (Fisher et al., 2006). RAPT is a PC- based training program

for novice drivers that tends to be educating them about various types of risks encountered while driving. RAPT specifically focused on emergent as well as latent risks. A commentary-based approach towards educating novice drivers describes what they are observing, thinking, and planning to do using the commentary driving wither provided by participants or experts (Isler et al., 2011). Training using a simulated environment where finite training sessions were conducted on a low-fidelity desktop simulator was used to train young drivers. These sessions describe the hazardous situations and risky driving practices, followed by a simulated drive to ascertain whether the training was practical.

2.3.2 Driver feedback

Driving feedback provides information about performance, anomalies in driving behavior, detects driving uncertainty, and establishes and reinforces expectations for behavior. Feedback is available in a wide range of vehicle devices essential to driver performance and a common element of driver training, traffic safety efforts, and research on driver behavior (B. G. Simons-Morton, Zhang, et al., 2012). Although personalized feedback is essential to behavioral self-regulation, it approximates the standards of a driver's task and its effect on their behavior. This may be complicated and may impact individual motivation (Van Houten & Nau, 1983). Effective in-vehicle monitoring has enabled better monitoring of driving behavior. Such monitoring resulted in better seatbelt usage and an improved reduction in speeding (Farmer, Kirley, & McCartt, 2010). An additional component to such feedback included the performance shared with the parents in reports. However, the system helped improved teen driver performance. Past studies have also found that real-time feedback to drivers may improve their performance and make them more attentive to their driving task at hand (Donmez, Boyle, & Lee, 2007).

While technology provides real-time feedback to teen drivers, several feedback systems in conjunction with parental, peer, social, and parental influence improve overall driving performance. Providing provisional feedback to both parents and teens ensures a reduced risk in driving compared to when the feedback is shared with teens (Simons-Morton et al., 2013). Similar findings from other research found that

mothers played a more significant role in lowering the event rate of risky driving. However, the target population here was from Israel (Farah et al., 2014). While there have been studies that have found the effectiveness of such feedback systems, there are findings that suggest that feedback may have varying implications. Ever-present concerns around privacy, parent-young driver relationship, self-esteem and confidence, constructive use of the feedback data, and the limitations of the documentation about the feedback technology concerned the dyads of parents and teens. Apart from the parental inputs, peer influence also influences the feedback of driving behavior.

2.3.3 Driver education

In addition to training and feedback methods, driver education programs are designed and implemented to improve young driver behavior over a sustained period. Two informative driver education frameworks elicit behavior changes among young drivers. Hatakka et al., (2002) proposed guidelines for formulating any future guidelines for developing driver education programs to be based on active learning and self-reflection from the driver. Another approach involved the health action process, which looked to understand the motivations behind risky behavior while driving were explored (Dale, Scott, & Ozakinci, 2017). In addition to these frameworks, a popular approach for designing driver education programs leverages the theory of planned behavior (Ajzen, 1991), focusing on behavioral outcomes. Several teen driver training programs are designed to improve the distraction behavior among teen drivers (McDonald & Sommers, 2015; Roberts & Lee, 2012), grounded in the theory of planned behavior. While this is a fundamental approach towards reducing risky behavior among drivers, it is essential to consider how changes in the perception can be affected.

While several considerations have been taken into designing these programs in the future, while many of these programs are effective, there are limitations and methodological issues which must be considered. Firstly, future studies should be done on larger sample sizes to ensure that the results may be more generalizable. Additionally, these sample sizes should consider the differences in demographics to

ensure the results have applicability with the overall population. These demographics would include differences around age and experience when designing programs for young drivers. Secondly, studies should consider the previous driver education that has been done in terms of the extent and the content which may influence their results. Many drivers begin by taking compulsory driver education to young drivers with informal training. This would enable more targeted training and feedback programs, ensuring the training is designed for the appropriate group. Based on this fact, studies evaluating hazard anticipation and other higher-order skills should examine effects on drivers that may need it most or may need them in varying degrees. This enables a more dynamic intervention strategy that would enable better efficacy of the training and education programs. Fourthly, evaluating the long-term effects of training is essential to understand whether targeted following up can enable a more sustained effect of these training. Evaluation at multiple time points would help understand whether training may contribute to crash reduction during the early period of high-risk driving. Future studies should consider heart rate, respiratory response, pupil dilation, and other physiological measures that capture more automatic or involuntary behavior, in addition to evaluating the driving performance and glance behaviors. This data would help, which may be a valuable indicator of the implicit understanding of the underlying processes related to hazard anticipation. Risky driving behavior can be mitigated for young and inexperienced drivers. It is vital to consider the motivation for young drivers' risk. In the context of young driver road safety, reward sensitivity is significant to study since psychological characteristics are strongly associated with a propensity to risk rewards. In the next section, we explore how leveraging persuasion-based solutions has shown promise in developing the requisite skillsets towards making young drivers a safer driving population group.

2.3.4 Role of persuasion to influence safer driving

In addition to training and feedback to improve young drivers' skills, a novel approach towards improving young driver behavior is by introducing a set of values that could potentially modify the driver's behavior towards safer driving. This concept is grounded in the philosophy of affecting change through

different means. The behavioral change can be influenced through self-efficacy and self-regulation (Bandura, 1994; Cerezo et al., 2019; Cristea & Gheorghiu, 2016), societal influence (Bandura, 2004a), and peer/parental influence (Beck, Hartos, & Simons-Morton, 2002; Jewett, Shults, & Bhat, 2016; McDonald & Sommers, 2016; B. Simons-Morton, Chen, Abroms, & Haynie, 2004). These studies have helped put forward a case for various methods to influence driver behavior. While they have their own merits and advantages, persuasion is a popular emerging methodology for affecting behavior change.

The philosophy of persuasion comprises how behavior change can be affected when the end-user is motivated for change when they are enabled for change and provided motivation for such change (B. J. Fogg, 2009). When a system is designed to enable behavior change, persuasion will affect such change when the end-user is motivated for change, resulting in a higher change outcome. In the context of driver safety, persuasive interventions aim to intuitively influence attitudes and behavior (i.e., without forcing them) (van Gent, Farah, van Nes, & van Arem, 2019). Designing such systems is challenging to maximize the persuasive effect without infringing upon the driver's safety. Van Gent et al., (2019) described a conceptual model that helps describe the process of utilizing persuasive systems and leverage them to affect behavior change among drivers. The details of the model are beyond the scope of this research.

It is essential to understand the applicability of persuasive interventions in affecting driver performance in the context of young drivers. To affect change, it is essential to consider whether the performance outcome requires persuasion that may affect the driver through the parental/social/psychological effects. Additionally, it is essential to consider whether the intervention requires information that may hinder the drivers functioning at a tactical driving level due to information insufficiency or over-representation. Finally, it is essential to consider whether the driver can comply with the outcome where well-defined stated rules provide coherent feedback. Through these questions, we can ascertain the possibility of outcomes that can be affected by persuasion.

Several studies have found that driver's attitude having a bearing on the risky behavior of drivers. For example, in controlling speeding behavior, psychosocial influence on driving performance can be influenced. Factors including peer influence, preferences towards speeds, and influence of social factors, and parental influence were explored in the past (Farah et al., 2014; Gheorghiu, Delhomme, & Felonneau, 2015; Møller & Haustein, 2014; Schroeder, Kostynuik, & Mack, 2011; B. G. Simons-Morton, Ouimet, et al., 2012).

While social and psychological factors can influence speeding, there is no definite way of knowing the influence on the driver due to the output of the intervention. Existing interventions leverage specific systems, which display the status of the speed limit. Finally, compliance to speeding through the intervention is feasible as it allows for the definitive definition of the speed limit and can be complied with based on the driver's location. Speed cameras and radar-based intervention leveraged persuasive technology for this purpose (Goldenbeld & van Schagen, 2005; Wilson, Willis, Hendrikz, Le Brocque, & Bellamy, 2010).

Similarly, compliance with seatbelts is impacted through persuasion. It has been found that seatbelt compliance is strongly related to the region, demographics, and social factors. (Adanu, Smith, Powell, & Jones, 2017; Shults, Haegerich, Bhat, & Zhang, 2016). The information on seatbelts is ubiquitously available in the current driving, which shows the state of seatbelts worn by drivers and passengers alike. While the type of feedback might be debatable, it is still present in almost all vehicles. With regards to compliance, the current feedback systems may feel that the compliance should be higher. However, there are substantial regional disparities in wearing seat belts, which can be affected by designing persuasive interventions.

This novel approach holds the promise of improving the perceptions of young drivers. A study found that persuasive systems were leveraged for ensuring self-efficacy (Wiafe, 2010). The messaging for better efficacy through binding communication can help towards compliance, as explored through the argument proposed by the theory of commitment, which is beyond the scope of this research (Joule, Girandola, &

Bernard, 2007). The approach has been explored in several studies that look to leverage the ubiquitous nature of technology to elicit desired behavior. Studies in the past have explored the merits of affective computing mechanisms that consider the socio-emotional nature of the end-user (Ho & Jung, 2013).

For inducing self-efficacy among users, persuasive technology has been leveraged, particularly in driving. Fogg et al. (2009) proposed how technology-based interventions help direct drivers towards safer speed selection choices. The specific purpose of promoting good driving behavior through a persuasive message may result in the desired safer behavior. Implementing a persuasive technology solution can help improve drivers' attitudes and helps them reduce their risk (van Gent et al., 2019).

2.3.5 Designing training programs for safer interactions

This research aims to create an intervention that can be used to improve the perceptions of young drivers towards VRUs. Therefore, it is essential to understand the interactions between young drivers and VRUs. While the different contexts of interactions, risks associated with crashes, and their outcomes have been illustrated, this section looks explicitly towards addressing the potential issues related to young drivers, pedestrians, and their interactions. Additionally, the utility of interventions and leveraging persuasive and dynamic intervention is presented to explore whether a potential solution may address the gaps.

While the implementation and evaluation of persuasive intervention in the context of driving are few, past work done by Van Gent et.al., (2019) explores how Persuasive in-vehicle systems aim to intuitively influence attitudes and behavior of a driver (i.e., without forcing them). This approach persuades drivers to change their behavior without compromising their safety. The approach was tested in advising drivers with a lane-specific advice system that aims to reduce travel time delay and traffic congestion by advising some drivers to change lanes to achieve a better distribution of traffic. Schepers et.al., (2014) proposed a conceptual road safety framework that looked to model the crash and injury risks in terms of infrastructure, road users and their mode of vehicles. Through the determination of the exposure risk, future interventions can help quantify perceived risk and the exposure may impact the way road user interactions may occur,

mainly how infrastructure may be designed using the risk exposure, where the infrastructure may persuade different road users to interact in different ways.

The review found a new vulnerable road user driver license competency called for the greater inclusion of cyclists in the driver licensing system. Such lack of explicit training has been addressed through supplemental training programs through expert training in improving hazard perception towards motorcyclists (Di Stasi, Contreras, Cándido, Cañas, & Catena, 2011). Other methods found that the visual training programs help improve drivers' perceptions towards pedestrians among older drivers as well (Rogé, Ndiaye, & Vienne, 2014). Similar training that helps improve the perception of novice drivers that helps improve the interaction between drivers and VRUs at intersections has been designed and has been found to have promising results in improving the hazard perception of the drivers (Borowsky et al., 2012).

While these use-cases help us understand the different types of interactions, it is critical to evaluate whether our target driver population may be skilled enough to handle these different types of interactions. The clarity on how drivers should interact with vulnerable road users is further supplemented by the lack of clear information. A review of graduate driving licensing systems in Australia found that cyclists are rarely mentioned in the GDLS, and references often constructed cyclists as problematic or were based on instructors' personal opinions (rather than scripted responses) (Bonham & Johnson, 2018). Cyclists are discussed across various components of the graduated driver licensing system. However, cyclist-related information is not comprehensive or systematic. It is rarely included in materials directly targeting pre-learner or novice drivers. Novice drivers are not equipped, as a matter of routine, with the knowledge required to understand or interact safely with cyclists.

Further, the views of supervising drivers, teachers, facilitators, and driving instructors will significantly impact the nature and extent of cyclist-related information received by any in- dividual pre-learner or novice driver. A novice driver can go through the entire licensing process without instruction on interacting with cyclists. Equally, or perhaps more, important is the way road users are represented throughout the driver

licensing process. The problematic behaviors and adverse circumstances in which cyclists have discussed contrast with the positive representations of drivers and driving. Together, the lack of advice on cyclists and the contrasting representations of drivers and cyclists' risk producing the very cyclist-motorist tensions that road safety authorities are seeking to address. It may also undermine government efforts to increase participation in cycling.

Another factor that interventions that may cause behavior change are through self-reported behavior (McDonald & Sommers, 2015) by the peer groups. An interesting study looked towards exploring the identity of how both self-described car drivers and cyclists reported having more in common, which impacted their self-reported outcomes (Hoekstra, Twisk, & Hagenzieker, 2018). The interest in exploring identity as a road user is essential as it can impact perceptions since the road users may have better empathy and understanding towards different complex traffic scenarios. The issues for such types of interventions could be around a lack of ground truth for such an intervention. However, it is difficult to capture all the self-reported measures using ground-truth measures. While such problems may exist, the advantage of self-reporting measures post-intervention can help establish how different road users feel towards road sharing, which could help researchers further understand what specific treatment approaches may help improve the perceptions of different road users.

2.4 Summary

This chapter looked to explore the risk factors associated with young drivers, with a primary focus on the lack of experience and proclivity towards indulging in risky driving behavior. Upon establishing the importance of those factors, the implications on driving performance were explored. Additionally, the risk associated with VRUs regarding infrastructure constraints and gaps in incorrect interactions with drivers were explored. Finally, the chapter explored a case for designing a training intervention that can help improve interactions between different road users. Thus, the chapter lays the foundation for the design of the intervention program for young drivers towards VRUs and is the basis for the different studies that

helped understand the perceptions and utilize those findings for proposing a new intervention approach for the objective.

CHAPTER 3

UNDERSTANDING YOUNG DRIVERS' PERCEPTIONS TOWARDS VRUs THROUGH QUALITATIVE METHODS

To create a well-defined intervention, it is important to understand the current perceptions of young drivers about VRUs. To achieve this objective, young drivers were interviewed, and their responses were analyzed to understand prevailing perceptions. In this chapter, we discuss the interview study that found the perceptions of young drivers about VRUs. We start by describing the benefits of qualitative research, the methodology of the interviews, and discuss the findings from the interviews.

3.1 Qualitative research

To understand the perceptions of young drivers on VRUs, the research relied on qualitative methods (Creswell, 2013) to understand how young drivers receive training, how they perceive VRUs, and how VRUs impact them. While there are different methods to accomplish this objective, qualitative interviews were chosen as the instrument of data collection because they allow the researchers to compile historical information, elicit views and opinions, and allow for open-ended responses from the participants on relevant questions. The line of questioning allows for contextual inquiries to better understand the perceptions of VRUs by young drivers, who have different experiences themselves. The focus was to uncover interesting insights about their attitudes, norms that may have adopted, or their intended behavior towards VRUs in different environments. This allows the researchers a unique opportunity to comprehensively understand these differences.

3.2 Participant recruitment

To conduct qualitative interviews around understanding perceptions of VRUs from young drivers, approval was sought from the IRB. Upon approval, participants were recruited (all aged 18 years) using email advertisements within the Mechanical and Industrial Engineering department on the University of Massachusetts campus. In terms of gender distribution, there were five males and one female. All

participants received their driver's license at the age of 18 and had completed the GDL program in the state of Massachusetts. Upon completing an informed consent form that explained the details of the study, a semi-structured interview was recorded using Zoom meeting software. The interview lasted between 45 to 60 minutes. Each participant was compensated $20 for their time.

3.3 Design of the qualitative interview

As explained earlier, the focus of this research was to understand the attitudes of young drivers towards VRUs. Questions were constructed to guide exploring several themes around young drivers and their perceptions of VRUs. Specific contextual follow-up questions were asked based on the information provided by the participant. These questions were designed to drill down to certain vital opinions, views, and information critical to fully understanding their perceptions. The questions and the objectives for the line of questions have been described in Table 1.

Table 1 Questions for the qualitative interviews

The objective of the line of questioning	Questions
Understanding the driving motivations and transitioning to full licensure	Who taught you how to drive and what were your motivations for getting a drivers' license? What were the modes of transportation you took before you started driving? What are the different modes of transportation (cycling, skateboard, public transportation, walking) you take now and what are the circumstances for each of the modes?
Identification of change in approach towards driving while approaching a pedestrian sign/zone or sharing the road with pedestrians	How do you approach the pedestrian crossing while driving? Have you encountered occasions when you missed a pedestrian and kept driving? What are your thoughts on pedestrian contact with the drivers?

Identifying approach towards road sharing with bicyclists	How do you position yourself when you observe a bicyclist and how does it affect your driving behavior? Do you think it is positive if the common roads are shared with bicyclists or do you think there should be separate sections on the road?
Considering safety issues for drivers who are VRUs themselves	Do you use a bicycle? If yes, what are your safety concerns when riding with other drivers?
Understanding the current efficacy of programs and methods to improve VRU safety	Do you think the risk for VRU related crashes is related to the number of pedestrians and bicyclists (e.g., a larger number of pedestrians and bicyclists may result in more safety)?
Considering differences in urbanicity on understanding risk for VRUs	Do you think the risk for VRU related crashes is also related to a geographic area (e.g., downtown vs trails vs rural areas)?

3.4 Data Collection and analysis

Upon completion of the interviews, the transcripts of each interview were generated and reviewed. The transcripts were generated by the cloud recording feature provided by Zoom, which was further reviewed on the Microsoft Office Word 2020 software. The transcripts were analyzed and information pertaining to each question was coded based on the response that was elicited from the participant. The information was coded along the same line of objective questioning that was conducted from the end user. In other words, for each question, the corresponding responses from the participants were documented, compiled, and analyzed as responses to the questions. This methodology has been followed in several research studies and has been documented in qualitative research methods literature (Creswell, 2013). The emergent themes were combined and finalized. The coding was done by the author, and the validation of the themes was conducted by the dissertation chair. Since the sample size was small, and the themes were one-to-one responses, interrater reliability of response was not conducted. The description of the coding mechanism is explained in the next section.

3.4.1 Mechanism of transcript coding

As mentioned earlier, the interview included open-ended questions as well as follow up probes that helped establish the perceptions of young drivers towards VRUs. With the purpose of establishing the perceptions, and how that enabled the behavior of the young drivers, it was essential that the response of the questions was analyzed not only for the direct questions that were asked, but also to account for the response to the follow up questions. Since the interview format was semi-structured, most responses were one-to-one answers to the questions that were posed by the interviewer. However, it was important to deduce the relevant information that was required. The questions were based on the literature review, the objectives of the research, and exploring the potential outcomes of the possible interactions between the different road users. Therefore, the coding relied on the framing of the research objectives, as well as the themes emergent from the responses from the participants.

The coding scheme for the analysis explored two steps of exploring the responses and themes from the participants. In the first step, the direct responses to the questions were captured and documented. Questions that focused on the background, opinions, perceptions of different types of road users were captured and documented. In the second step, a conventional content analysis was done which explored the observations from the participants within the direct questions that were asked (Hsieh & Shannon, 2005). Hsieh and Shannon (2005) describe conventional content analysis as a methodology where the researcher derives the knowledge and categories from the transcribed data. The purpose of this methodology is to develop a richer understanding of a phenomenon, particularly in circumstances where existing theoretical constructs or existing themes do not exist. By this methodology, researchers analyze the data, wherein the transcribed text is often approached to a particular context. Transcripts were reviewed by the researcher in Microsoft Word 2020, and the categories were assigned to the section of the transcript for the sections of the text where it was applicable. Themes were developed based on the participants' data that illustrated the coding categories.

The methodology helped with uncovering emergent themes from the compiled transcripts. The methodology was particularly useful for uncovering themes when the responses were obtained through a series of probe. One example of such an interaction was with regards to experiences in driving school. When asked about what was covered in the driving school curriculum, the participant responded by discussing the curriculum covered. Statements like that below was coded around the experience of how drivers transition to licensure.

"[In driving school], I attended a few sessions where I had an hour of driving time in [the school's] observation. [After] I had just two hours of driving time, I was told to [perform] 12 hours of driving, and six hours of [driving under] observation. Those were just on the roads around here."

When further probed on whether the education covered information about VRUs, the participant explained the gaps in their knowledge around VRUs. The participant spoke about how their parent was the one who spoke to them about VRU interactions and provided them education from her experience.

"My mother would talk about a lot [about sharing roads]. She was a bigger cyclist [enthusiast] than I am. She shared an experience where, she went on a long bike ride and there was a driver who would blow past fast [driving fast around a bicyclist]. She mentioned that to us all the time. So, I was always conscious of cyclists, especially pedestrians on the side of the road, in the small town where I grew up."

The above information is then coded as informing perceptions towards VRUS (from parenting) and how participants approach VRUs.

Another example involves talking about their process of road sharing with bicyclists. A participant described their opinion of how they share the road.

"Most recently we've [The University] has added bike lanes, which kind of scares me because it's near the busiest intersection where cars are coming off the highway. Similarly, near the mass pike[Highway], they have added a bike lane which is kind of worrying, It is because there's a lot of traffic going on, especially

kids. When kids get out of school around rush hour, and they are biking [around] there, so I haven't driven around during that time. So, I wonder [if it's safe to have bike lanes]. I'm not sure."

When probed on how they deal with situations about sharing with bicyclists, the participant just presented their process and talked in detail about leaving more spaces.

"I actually give them more space than they need. I always come out alive [around bicyclists]. I always look at the curve and automatically give them [bicyclists] more space. I just need to [make a] shift in my lane to see oncoming traffic. That is my only focus, [which is to] just give them more space."

As described in the previous sections, the transcripts from the interview responses were coded to understand the emergent themes.

3.5 Results from the interview study

3.5.1 Background of the young drivers as VRUs

All participants went through formal driving school training between the age of 16 to 16.5 years old at a driving school in the state of Massachusetts. The participants obtained their junior operator's license, and they got their full license at the age of 18. Most participants started by driving along with their parents in circumstances like backing up the vehicle in a vacant parking lot or driving with parents around their neighborhood. On one occasion, the participant was not allowed to drive until they signed up for a driving school course and were authorized to drive under adult supervision, which was found to be consistent across all our participants as they had to abide by the 2007 Graduate Driving License (Williams, Tefft, & Grabowski, 2012).

3.5.1.1 Usage of alternate modes of transportation

There were certain differences between the opinions of the participants with regards to their journeys as VRUs. Two participants did not use the bicycle or any other forms of transportation before they received their GDL license. They were primarily driven around by their parents to school or other places. The rest

of the participants enjoyed biking (four participants actively bicycled during their time before they got fully licensed) and used alternate modes (two participants used longboards).

3.5.1.2 Experiences on training

While all drivers confirmed that the driving schools covered specific topics around vulnerable road users like bicyclists and pedestrians, by their admission, they felt that it wasn't focused enough during their training. They felt that the school covered those topics the same as any other topic. However, all participants confirmed that their parents specifically directed them on how to interact with VRUs. Two participants confirmed their parents nudging them to slow down the vehicle anytime they are anywhere near a pedestrian crosswalk, with emphasis on stopping much earlier to allow the pedestrian to walk through. For bicyclists, there were only two participants who were given specific instructions as to how to navigate around them. One participant detailed how their mother suggested a heuristic around: "leaving enough space so that a cyclist can fall towards the vehicle and still be safe from the vehicle". The other participant confirmed that they slow down around bicycles and leave a complete lane around them. It is important to consider that those (2) participants and their parents were avid bicyclists.

3.5.2 Perceptions of interactions with pedestrians

All participants confirmed that they felt a heightened sense of caution around approaching crosswalks as young drivers (e.g., yield). However, five participants reported instances where they missed out on spotting a pedestrian due to different issues.

3.5.2.1 Reasons for missing the pedestrian

Four participants noted that they were especially scared of missing out on pedestrians when they least expect it. Occasions like driving at night when no classes are going on (on campus), inability to detect the pedestrian when they are wearing dark clothes and slips in recognizing pedestrians were major concerns. One participant even noted that approaching crosswalks makes him nervous. Causes of this nervousness were attributed more to his fear of not knowing when a pedestrian may try to cross without establishing contact with the driver. Two participants reported that as drivers, they specifically missed out on the

pedestrians due to the drivers being distracted while approaching the crosswalk and missing out on detecting the pedestrian altogether.

3.5.2.2. General issues with interacting with pedestrians

All six participants reported that their biggest fear while interacting with pedestrians was the fear of "missing out on cues" of how the pedestrian is likely to move. While drivers were more comfortable when pedestrians turned the lights on the crosswalk signal whenever available, it was difficult to ascertain the intent of certain pedestrians on occasions where the drivers and pedestrians were expected to have an interaction. Under these circumstances, there have been issues where it is difficult for the driver to decide whether they need to go forward or stay stopped/yield. While all pedestrians are treated equally while negotiating, two drivers reported more caution whenever they saw older pedestrians. Another concern that all participants had was with dealing with pedestrians who did not make eye contact with the driver even though they knew they needed to yield. It was very difficult for them to ascertain the next step the driver is supposed to take (e.g., move or yield). For three drivers, we found that they would much rather drive through a longer route without a crosswalk than a shorter route with a crosswalk, which was due to the uncertainties in timing and behavior to be observed at pedestrian crosswalks.

3.5.3 Perceptions of interactions with bicyclists

While there were consistent findings around the perceptions of interactions with the pedestrians, there was a lack of information around the correct method of interacting with bicyclists, the type of roads determining the interaction, and a lack of clarity on whether to treat a bicyclist as a car driver or someone different. Finally, there were divided opinions around road sharing between drivers and bicyclists.

3.5.3.1 Interactions with bicyclists

All participants expressed that they intended to exhibit safe passing behavior while passing bicyclists, however, they also expressed an inherent lack of clarity on what is the "right" way to ensure safety. As pointed earlier, two drivers interviewed relied on the heuristics they discovered either through parental norms or through being observant on what would be the best possible way to ensure safety. The other

drivers mentioned that they just made sure they left “sufficient” distance between themselves, however, the distance varied based on the type of road they are driving on.

3.5.3.2 Road type in determining the interaction behavior with bicyclists

All participants suggested that the lack of clarity on road sharing impeded understanding of how to ensure safe behavior while interacting with bicyclists. When asked about explaining what they meant by the type of roads, they were more comfortable sharing space with bicyclists on roads that had a marked solid line where the participants know where they are expected to share the roads. Additionally, it was interesting to observe that there were differences between the opinions of young drivers when sharing the roads based on the degree of urbanicity. Three participants suggested that they were more comfortable sharing roads in more urban areas where there is marked infrastructure and signage for road sharing. However, one participant reported that it was very difficult to share the roads in more urban areas because of traffic: it is difficult to negotiate heavy traffic and share the road with bicyclists due to limited space. Two drivers were agnostic to the type of road and suggested that road sharing is the same for whether the roads are marked, unmarked, urban, or rural. In terms of the road signage, all participants appreciated road signs in prompting where the road sharing zones start or end. However, they felt that the signs themselves were not informative in understanding what they should be doing differently since most road sharing signs only contain a bicycle with no text.

3.5.4 Opinions on road sharing

As mentioned earlier, all participants expressed positive opinions about road sharing as a concept but were skeptical about the roles of drivers and cyclists with road sharing in different contexts. One concern was around adherence to the law by bicyclists in terms of stopping, showing hand signals, using their dedicated lanes whenever appropriate, and their utilization of the crosswalks to negotiate traffic. Participants suggested that it was difficult for them to ascertain the correct norms with variability in bicyclists’ behavior in urban areas in terms of observing laws. Two participants spoke about their need to ensure that the cyclists are better off riding in dedicated bike lanes in areas where there is less traffic as it

is sometimes difficult for drivers to anticipate bicyclists in rural areas and missing out could be catastrophic. In areas where roads were narrower, participants suggested that road sharing may not be advisable. Finally, all participants suggested that road sharing laws need to be better explained in driving schools, and there needs to be further training to explain how the road sharing laws need to be adhered to.

3.6 Conclusion

The objective of the interview study was to examine young drivers to understand their perceptions towards VRUs. The results indicate that most young drivers tend to have a positive perception towards VRUs in terms of negotiating shared spaces, stopping for pedestrians, and leaving spaces between themselves and bicyclists. However, it is interesting to observe that young drivers are not clear on how to share spaces, and mostly rely on heuristics and observing how other drivers interact with VRUs. Additionally, young drivers are more comfortable with sharing spaces in an urban environment, as compared to a rural setting. These findings confirm that a lack of clarity on laws, and a lack of understanding of what spaces are to be shared with VRUs are important factors that need to be addressed. We consider these findings in the next chapter where we discuss the creation, delivery, and assessment of the intervention.

CHAPTER 4

DESIGNING AND EVALUATING AN INTERACTIVE INTERVENTION FOR IMPROVING PERCEPTIONS OF VRUs AMONG YOUNG DRIVERS

The purpose of this chapter is to design and evaluate an interactive intervention that can help improve young driver perceptions. The intervention assessed in this chapter was designed based on the results of the previous chapter, and the themes helped identify the perceptions of VRUs among the young driver population. A critical emergent theme from the interviews was a lack of clarity on what constitutes a shared space regarding VRUs. While participants showed enthusiasm and clarity on the importance of sharing roads, they expressed a lack of clarity regarding their expectations as drivers in certain situations. This theme is critical for informing the intervention's design, content, and delivery to provide relevant information to the driver. In this chapter, an intervention is proposed, which shares critical ideas around the vulnerability of different road users. The results from a pilot study evaluated the efficacy of the intervention.

4.1 Methods

4.1.1 Description of the intervention

4.1.1.1 Process of finalizing content based on the emergent themes

The findings from the previous chapter established a need for creating a program that would educate young drivers about how they are expected to interact with VRUs. There were four key concepts that were required to be communicated to the participants.

Figure 2 Themes emergent from the interview study and how they can be addressed in the intervention

Figure 2 shows the emergent themes from the interviews and the corresponding themes for the intervention. For the theme where young drivers reported missing out on detecting pedestrians due to distraction, the intervention focused on information about what put drivers and VRUs at risk when interacting with each other. Regarding a lack of clarity on the laws around road sharing, the intervention focused on educating young drivers on the laws of road sharing with pedestrians and bicyclists. Third, the intervention discussed the expectations from road users, and the laws that protect VRUs in different contexts. Finally, the content of the intervention focused on educating young drivers about how road sharing and the importance of dedicated infrastructure, which is emergent in cities. More specifically, the purpose was to introduce these new designs to young drivers and educate them on expectations when interacting with these different infrastructures that yield separate spaces for the different road users.

The interactive intervention contained necessary information to improve perceptions of road sharing among young drivers. The interactive nature helped participants improve their engagement and explore

different facets of the weekly content. As established in section 2.3.5, the persuasive systems can help improve the behavioral outcomes of the driver (B. Fogg, 2009; Gent, Farah, Nes, & Arem, 2019), whenever there is low effort involved and interactive behavioral can help impress upon the importance of interactions between different road users in an easier manner. The intervention introduces the complexities of interacting with VRUs, understanding the changing landscape of road sharing, and how to improve perceptions of VRUs. The overarching topics included road sharing, interacting with pedestrians, bicyclists, and how cities look to create shared spaces for all road users. The content is shared for four weeks continuously, with the content broken into smaller components. The intervention requires 10 minutes of reading followed by a short assessment of current perceptions around VRUs. This assessment gauges understanding of VRUs. The types of questions were around the participants, recalling if they had a negative experience while interacting with a VRU while driving, exploring their knowledge of the laws around road sharing, and their interpretation of road sharing in different traffic scenarios.

4.1.1.2 Description of the interactive intervention

The structure of each week's intervention starts with declaring instructions for each week, the interactive content, and finally, questions that ask the participant to reflect on their learnings and provide qualitative responses to their understanding of the content. The purpose of eliciting qualitative responses ensures participants reflect and develop a deeper understanding of the issues discussed each week. The key points covered in each week's content involved the themes discussed for each week's content, the interaction components covered in each week's content, the visualizations included in each week's content (an example is shown in Figure 3), and the questions based on each week's content. Table 2 summarizes this information by week. Table 3 shows the snapshots of the intervention presented to participants.

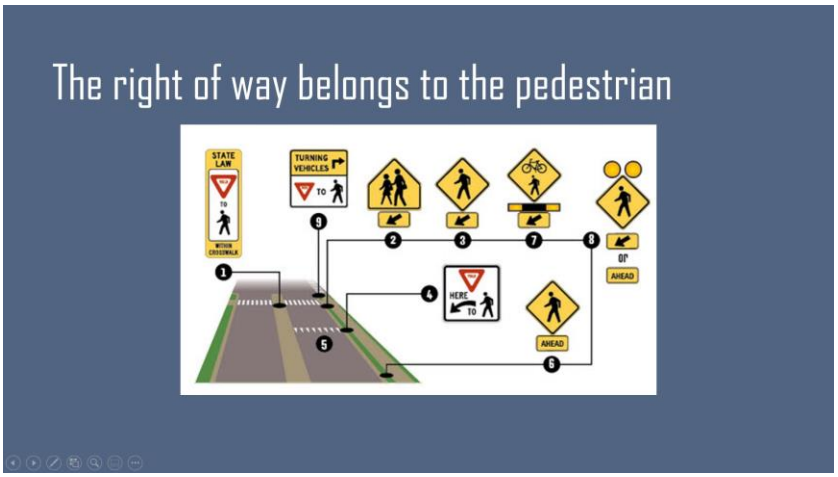


Figure 3 An example image of the visualization conveying information about the right of way

The intervention focused on the visualization and interactions, which are critical aspects to gauge interests of the participant and ensure they are engaged with the content. To accomplish this, each week has introduced a dedicated visualization component, and interaction component which can cause better interpretability of the content presented in the intervention. The visualization component in each week's content explains the weekly content to explain the concepts visually. The purpose of the visualization component is to communicate the ideas with the purpose of understanding the risks and normative behavior that is expected around VRUs.

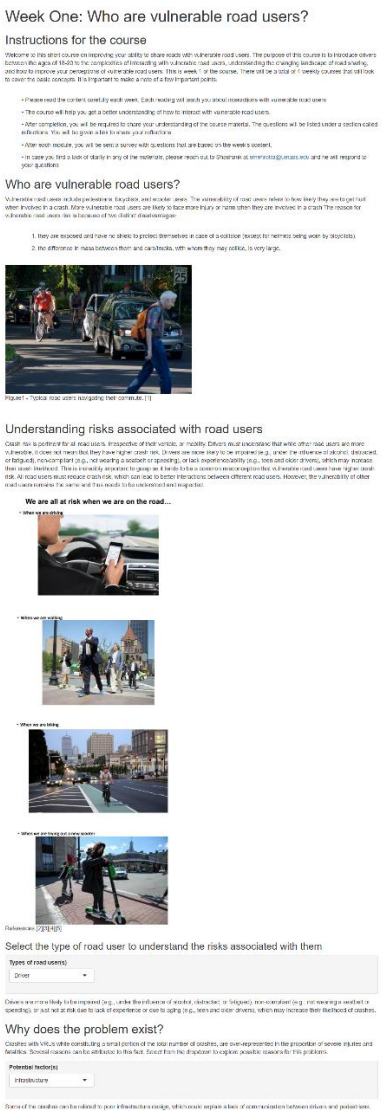
Table 2 Summary of each weeks' content

Week	Themes	Visualization	Interactive component	Subjective Questions
1	Introduction to Vulnerable Road users	Understanding risks associated with road users	Factors that describe the problem of interactions between drivers and VRUs	• "Think about times when as a driver, you may have missed out on a VRU which may have resulted in you getting nervous. Describe that scenario and think of what you felt you could have done better in your driving?" • "Do you think your community does enough or should do enough for the safety of VRUs? If yes, do mention what do you think they do consider. If not, what would be your suggestions?" • "Do you think roads should be designed for sharing, or should we only have dedicated spaces for pedestrians, drivers, and other mobility users for safety?"
2	Drivers' interaction with pedestrians	How to understand if a pedestrian is at risk and how to interact with pedestrians	Select potential conflict scenarios with pedestrians	• "Could you think of a few methods of communication that would maybe help reduce the risk of children and older pedestrians when crossing the road?" • "As a driver, what would you do differently now to improve your approach to a crossing, now that you know which pedestrians are at a higher risk?" • "After discussing the role of communication between pedestrians and drivers, do you think trust between the driver and pedestrian plays a role when

				crossing the road? If so, in what way? If not, why not?"
3	Drivers' interaction with bicyclists	How to understand risks associated with bicyclists	How to understand risks associated with bicyclists	• "Do you think cyclists and drivers should share roads considering all the risks described in this week's discussion?" • "As a driver, are you nervous when there is a bicycle on the road?" • "Do you think it helps if the drivers are themselves bicyclists who can better understand the risks associated with interactions between drivers and cyclists?"
4	Driving on shared roads	Interpreting the dedicated infrastructure for road sharing	Discussion about how different road features can enable road sharing between different road users	• "Do you think you can add other mobilities to your travel? If not, can you think of reasons why that may not be realistic?" • "Which of the dedicated infrastructures are unsafe for VRUs, and what can you do as a driver to make sure how to make them safer for VRUs when driving?" • "What do you think are challenges for drivers to acknowledge the growing shared streets in cities?" • "How can VRUs make sure that they can be safer on the shared streets when sharing spaces with drivers?"

Table 3 Weekly intervention content

Week 1



Week One: Who are vulnerable road users?

Instructions for the course

Welcome to this short course on improving your ability to share roads with vulnerable road users. The purpose of this course is to introduce drivers between the ages of 18-20 to the complexities of interacting with vulnerable road users, understanding the changing landscape of road sharing, and how to improve your perceptions of vulnerable road users. This is week 1 of the course. There will be a total of 4 weekly courses that will look to cover the basic concepts. It is important to make a note of a few important points.

- Please read the content carefully each week. Each reading will teach you about interactions with vulnerable road users
- The course will help you get a better understanding of how to interact with vulnerable road users.
- After completion, you will be required to share your understanding of the course material. The questions will be listed under a section called reflections. You will be given a link to share your reflections.
- After each module, you will be sent a survey with questions that are based on the week's content.
- In case you find a lack of clarity in any of the materials, please reach out to Shashank at smehrotra@umass.edu and he will respond to your questions

Who are vulnerable road users?

Vulnerable road users include pedestrians, bicyclists, and scooter users. The vulnerability of road users refers to how likely they are to get hurt when involved in a crash. More vulnerable road users are likely to face more injury or harm when they are involved in a crash.The reason for vulnerable road users risk is because of two distinct disadvantages:

1. they are exposed and have no shield to protect themselves in case of a collision (except for helmets being worn by bicyclists).
2. the difference in mass between them and cars/trucks, with whom they may collide, is very large.

Figure1 - Typical road users navigating their commute. [1]

Understanding risks associated with road users

Crash risk is pertinent for all road users. Irrespective of their vehicle, or mobility. Drivers must understand that while other road users are more vulnerable, it does not mean that they have higher crash risk. Drivers are more likely to be impaired (e.g., under the influence of alcohol, distracted, or fatigued), non-compliant (e.g., not wearing a seatbelt or speeding), or lack experience/ability (e.g., teen and older drivers), which may increase their crash likelihood. This is incredibly important to grasp as it tends to be a common misconception that vulnerable road users have higher crash risk. All road users must reduce crash risk, which can lead to better interactions between different road users. However, the vulnerability of other road users remains the same and this needs to be understood and respected.

We are all at risk when we are on the road...

- When we are driving

- When we are walking

- When we are biking

- When we are trying out a new scooter!

References [2][3][4][5]

Select the type of road user to understand the risks associated with them

Types of road user(s)

Driver

Drivers are more likely to be impaired (e.g., under the influence of alcohol, distracted, or fatigued), non-compliant (e.g., not wearing a seatbelt or speeding), or just not at risk due to lack of experience or due to aging (e.g., teen and older drivers), which may increase their likelihood of crashes.

Why does the problem exist?

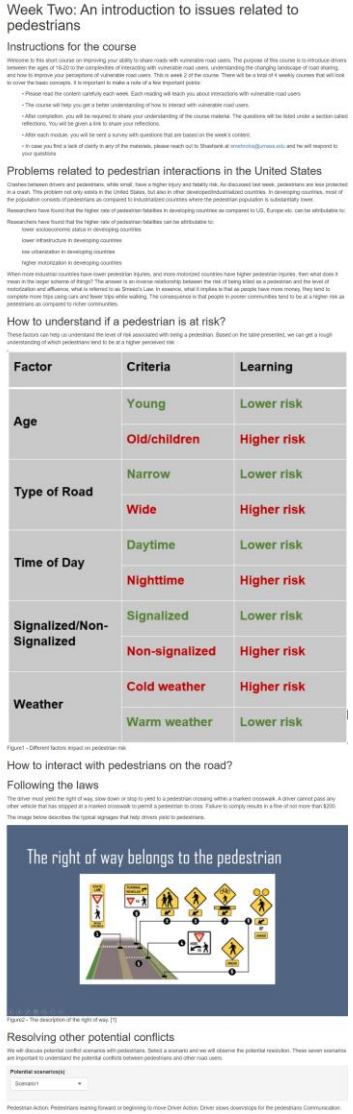
Crashes with VRUs while constituting a small portion of the total number of crashes, are over-represented in the proportion of severe injuries and fatalities. Societal reasons can be attributed to this fact. Scout from the dropdown to explore possible reasons for this problem.

Potential factor(s)

Infrastructure

Some of the crashes can be referred to poor infrastructure design, which could explain a lack of communication between drivers and pedestrians.

Week 2



Week Two: An introduction to issues related to pedestrians

Instructions for the course

Welcome to this short course on improving your ability to share roads with vulnerable road users. The purpose of this course is to introduce drivers between the ages of 18-20 to the complexities of interacting with vulnerable road users, understanding the changing landscape of road sharing, and how to improve your perceptions of vulnerable road users. This is week 2 of the course. There will be a total of 4 weekly courses that will look to cover the basic concepts. It is important to make a note of a few important points.

- Please read the content carefully each week. Each reading will teach you about interactions with vulnerable road users
- The course will help you get a better understanding of how to interact with vulnerable road users.
- After completion, you will be required to share your understanding of the course material. The questions will be listed under a section called reflections. You will be given a link to share your reflections.
- After each module, you will be sent a survey with questions that are based on the week's content.
- In case you find a lack of clarity in any of the materials, please reach out to Shashank at smehrotra@umass.edu and he will respond to your questions

Problems related to pedestrian interactions in the United States

Crashes between drivers and pedestrians, while small, have a higher injury and fatality risk. As discussed last week, pedestrians are less protected in a crash. This problem not only exists in the United States, but also in other developed/industrialized countries. In developing countries, most of the population consists of pedestrians as compared to industrialized countries where the pedestrian population is substantially lower.

Researchers have found that the higher rate of pedestrian fatalities in developing countries as compared to US, Europe etc. can be attributable to:

Researchers have found that the higher rate of pedestrian fatalities can be attributable to:

- lower socioeconomic status in developing countries
- lower infrastructure in developing countries
- low urbanization in developing countries
- higher motorization in developing countries

When more industrial countries have lower pedestrian injuries, and more motorized countries have higher pedestrian injuries, then what does it mean in the larger scheme of things? The answer is an inverse relationship between the risk of being killed as a pedestrian and the level of motorization and affluence, what is referred to as Smeed's Law. In essence, what it implies is that as people have more money, they tend to complete more trips using cars and fewer trips while walking. The consequence is that people in poorer communities tend to be at a higher risk as pedestrians as compared to richer communities.

How to understand if a pedestrian is at risk?

These factors can help us understand the level of risk associated with being a pedestrian. Based on the table presented, we can get a rough understanding of which pedestrians tend to be at a higher perceived risk.

Factor	Criteria	Learning
Age	Young	Lower risk
	Old/children	Higher risk
Type of Road	Narrow	Lower risk
	Wide	Higher risk
Time of Day	Daytime	Lower risk
	Nighttime	Higher risk
Signalized/Non-Signalized	Signalized	Lower risk
	Non-signalized	Higher risk
Weather	Cold weather	Higher risk
	Warm weather	Lower risk

Figure1 - Different factors impact on pedestrian risk

How to interact with pedestrians on the road?

Following the laws

The driver must yield the right of way, slow down or stop to yield to a pedestrian crossing within a marked crosswalk. A driver cannot pass any other vehicle that has stopped at a marked crosswalk to permit a pedestrian to cross. Failure to comply results in a fine of not more than $200.

The image below describes the typical signages that help drivers yield to pedestrians.

Figure2 - The description of the right of way. [1]

Resolving other potential conflicts

We will discuss potential conflict scenarios with pedestrians. Select a scenario and we will observe the potential resolution. These seven scenarios are important to understand the potential conflicts between pedestrians and other road users.

Potential scenarios(s)

Scenario1

Pedestrian Action: Pedestrians leaning forward or beginning to move Driver Action: Driver slows down/stops for the pedestrians Communication:

Week Three: Drivers interaction with bicyclists

Instructions for the course

Welcome to this short course on improving your understanding of sharing roads with vulnerable road users. This week is focused on looking at issues related to interactions between bicyclists and drivers. It is important to make a note of a few important things before this week

- Please read the content carefully each week. Each reading will teach you about interactions with vulnerable road users
- The course will help you get a better understanding of how to interact with vulnerable road users.
- After completion, you will be required to share your understanding of the course material. The questions will be listed under a section called reflections. You will be given a link to share your reflections.
- After each module, you will be sent a survey with questions that are based on the week's content.
- In case you find a lack of clarity in any of the materials, please reach out to Shashank at smehrotra@umass.edu and he will respond to your questions

The dilemma of bicycle use with regards to safety

Bicycles as a medium for transportation are an anomaly. You do not have to register them or take a test to ride a bike. You can use them on the road, you can travel through dense traffic, and you are perhaps the only vehicle that is good for the environment. The only reason they are discouraged is because they are unsafe, in comparison to using public transit or driving. This leads us to certain questions with regards to bicycle use.

Why are bicycles considered unsafe compared to cars or public transit?

Even though we know it's good for your health to bicycle, the safety of bicycle riders has been a cause for concern. To address these concerns, it is important to consider what makes bicycling unsafe. Researchers attribute certain risks with bicyclists such as:

a. Vulnerable in crash
b. Unpredictable in behavior
c. Inconspicuous at night
d. Unstable i.e., easy to fall
e. Differing abilities i.e., all people cannot bike at the same skill level

By exploring these factors, we understand that bicyclists have higher variability in their behavior. Since they must rely on their physical abilities and skills, it can be difficult to have the same expectations from each bicyclist. Also, unlike pedestrians, there are fewer instances of dedicated bicycle infrastructure, and most roads are shared with bicyclists. With the current pandemic and an increase in awareness and usage of bicycles, they are more vulnerable than ever before.

How to understand the risks associated with bicyclists?

These factors can help us understand the risk associated with different factors. Based on the table presented, we can get a rough understanding of which bicyclists tend to be at a higher risk.

Factors	Risk attributed to:	Relationship
Helmet usage	Wore helmet	Lower risk
	Did not wear a helmet	Higher risk
Age	Older Riders	Higher risk
	Younger Riders	Lower risk
	Preadolescent (Particularly males)	Higher risk
Alcohol	BAC > 0.8 mg/ml	Higher risk
	BAC < 0.8 mg/ml	Lower risk
Climate	Summer	Lower risk
	Winter	Higher risk
Illumination and Visibility	Wearing night reflective gear	Lower risk
	Well-lit roads	Lower risk
	No lighting on the road	Higher risk
	Not wearing night reflective gear	Higher risk
Cell phone	Using cell phones	Higher risk
	Do not use cell phones	Lower risk

Figure1 - Factors that may influence the interactions with bicyclists.

How to interact with bicyclists on the road?

A common observation in road sharing is when bicyclists and drivers share the same lane, with most drivers looking to leave a gap between themselves and bicyclists. Drivers who observe bicyclists wearing reflective cycling gear, wearing a helmet, and looking like "biking pros", are more comfortable overtaking them. In comparison, if drivers saw bicyclists who were wearing common clothes, and did not appear to be like typical bicyclists make them nervous when overtaking them. Additionally, drivers tend to not keep a sufficient distance of 1.5 m between themselves and the bicyclists while overtaking.

Another interesting observation has been that bicyclists tend to adapt their behavior according to expediency rather than based on rules. Bicyclists utilize pedestrian crossings, use regular traffic and pedestrian traffic regulations interchangeably whenever requisite infrastructure is absent, which makes it difficult to interact with them.

With regards to interacting with bicycles, while passing a bicycle traveling in the same direction, a right turn is not allowed. Similarly, no abrupt turns are allowed right after passing a bicycle. Sufficient distance – 3 feet – must be maintained, as bicyclists cannot be squeezed into a narrow lane. When drivers are turning left, they must yield the right of way to the bike from the opposite direction like they would to any other vehicle. These interactions are based on Massachusetts state laws.

Resolving potential conflicts

We will discuss potential conflict scenarios with bicyclists Select a scenario and we will observe the potential resolution to those scenarios. These scenarios are important to understanding the bicyclist/driver interaction.

Potential scenarios(s)

Scenario1

Week 3

Week4: Learning about shared spaces

3/20/2021

Instructions for the course

Towards safer streets: Driving on shared roads

Having the mindset for share-the-road vs a hierarchy

Interpreting the dedicated infrastructure for road sharing

Bicyclists Pathways

Sharrows

Buffered Bike Lanes

Striped Bike lanes

Protected lane

Pedestrian pathways

Sidewalks

Dedicated pedestrian pathways

Week 4

4.1.1.2.1 Week One: Introduction to Vulnerable Road users

This content aims to introduce young drivers to what makes a road user more vulnerable than a driver. The content focused on introducing the problem to young drivers to appreciate the purpose of the intervention. The content explains the levels of risk associated with different road users. The role of different road users, and the vulnerability associated with them is explained in detail. The content further explained the risk associated with different road users, attributed to impairment, lack of dedicated infrastructure, characteristics of different road users (e.g., age), and the safety culture in general. Figure 4 shows the different vulnerabilities of road users.

Figure 4 The possible risks associated with different road users

(A. Vaccaro, 2019; B. A. Vaccaro, Feldman, Staff, & Correspondent, 2020; Zezema, 2020)

4.1.1.2.2 Week Two: Drivers interaction with pedestrians

The purpose of this content is to focus on interactions between drivers and pedestrians. The content explains how pedestrians share the road and the points of conflict with young drivers. The content also explains the factors that may compromise pedestrian safety, how to carefully drive around pedestrians, and reflect on current driving practices around pedestrians. Figure 5 shows the list of factors and the level of

risk associated with pedestrians. Based on these, a rough understanding of the perceived risk associated with pedestrians can be understood. A significant contribution of this section is to convey the laws around driver interactions as shown in Figure 6. The section described how drivers must yield the right of way, slow down, or stop to yield to a pedestrian crossing under certain conditions. Pedestrians within a marked crosswalk or approaching the opposite side within 10 feet of the car require the driver to stop and yield. Additionally, drivers cannot pass other vehicles that stopped to permit a pedestrian to cross. A failure to comply with the law would result in a fine of not more than $200. Figure 6 shows the different signs and how drivers must interpret different pedestrian signs. Figure 7 shows the interactions between pedestrians and drivers, and actions related to the road users and the types of communications need to be understood.

Factor	Criteria	Learning
Age	Young	Lower risk
	Old/children	Higher risk
Type of Road	Narrow	Lower risk
	Wide	Higher risk
Time of Day	Daytime	Lower risk
	Nighttime	Higher risk
Signalized/Non-Signalized	Signalized	Lower risk
	Non-signalized	Higher risk
Weather	Cold weather	Higher risk
	Warm weather	Lower risk

Figure 5 The criteria associated with different factors and how does it impact the risk associated with pedestrians

Figure 6 The description of the right of way. (Wilson, 2021)

Pedestrian actions	Driver actions	Communication	Potential conflicts
Pedestrians leaning forward or beginning to move	Driver slows down/stops for the pedestrians	Implicit	Misinterpretation
Pedestrians moving around the vehicles on a congested street	Driver looking to make sure they give space to pedestrians	Implicit/Explicit	Not looking around sufficiently and exploring blind spots
Establishing eye contact	Driver anticipating pedestrian action and acting	Explicit	Inattention to making eye contact
Hand wave	Driver speeding up/stopping based on interpretation	Explicit	Inability to understand hand motion in context
Pedestrian walking up	Driving flashing lights indicating yield	Explicit	Forget to flash/Speeding behavior forcing mishap
Pedestrians change walking speed (up/down)	Stopping for pedestrian to complete pedestrian	Implicit	Misinterpretation of walking speeds
Pedestrian giving way to the driver	Driver taking/yielding right of way	Explicit/Implicit	Inattention/Misinterpretation

Figure 7 A summary of the different communications between pedestrians and drivers

4.1.1.2.3 Week Three: Drivers interaction with bicyclists

The purpose of this content is to focus on interactions between drivers and bicyclists on the road. The content in this intervention explains the expectations of sharing streets with bicyclists. Additionally, factors associated with bicyclists and the approach to sharing the roads were discussed. These factors can

help us understand the level of risk associated with different factors. Figure 8 shares a rough understanding of which bicyclists tend to be at a higher perceived risk.

Factors	Risk attributed to:	Relationship
Helmet usage	Wore helmet Did not wear a helmet	Lower risk Higher risk
Age	Older Riders Younger Riders Preadolescent (Particularly males)	Higher risk Lower risk Higher risk
Alcohol	BAC > 0.8 mg/ml BAC < 0.8 mg/ml	Higher risk Lower risk
Climate	Summer Winter	Lower risk Higher risk
Illumination and Visibility	Wearing night reflective gear Well-lit roads No lighting on the road Not wearing night reflective gear	Lower risk Lower risk Higher risk Higher risk
Cell phone	Using cell phones Do not use cell phones	Higher risk Lower risk

Figure 8 Factors that may influence the interactions with bicyclists

The intervention shares information about the gap between bicyclists and cars, the importance of wearing protective gear, and the perception of drivers and road users. Another observation shared in the intervention is how cyclists adapt their behavior according to expediency rather than rules. Cyclists utilize pedestrian crossings and use regular traffic and pedestrian traffic regulations interchangeably whenever requisite infrastructure is absent, making it difficult to interact with them.

4.1.1.2.4 Week Four: Towards safer streets

The purpose of this content addresses how drivers share roads and prioritize VRUs over drivers. The content focuses on interpreting the need for various infrastructures dedicated to different types of road

users. For bicyclists, the sharrow reminds road users about shared space by bicycles and cars. When the lane is colored green and includes a sharrow, the space is indicative of where the bicyclists are supposed to ride. Figure 9 shows an example of a sharrow. Additionally, buffered bike lanes create a dedicated lane for bicycles, with the added benefit of putting extra space between cyclists and passing cars, usually with a painted safeguard area of one to two feet. Drivers must stay on the left side of the buffer while driving and can only cross the bike lane when making a turn or entering an adjacent property - after checking to ensure no people are biking in the lane. Figure 10 shows the buffered bike lane infrastructure.

Figure 9 An example of a sharrow on a regular street that allows drivers and bicyclists to share roads. (Anderson & Bernbaum, 2020)

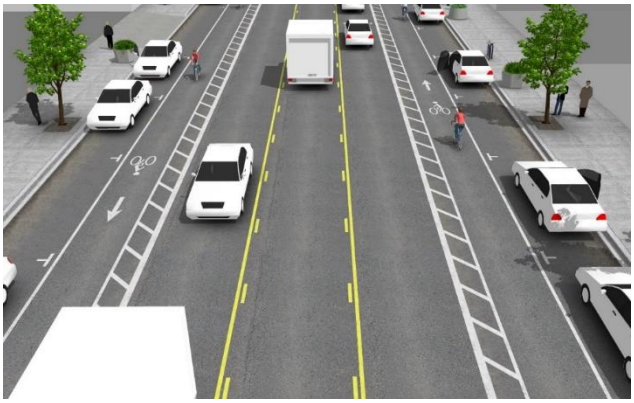


Figure 10 An example of a buffered bike lane. (National Association of City Transportation Officials, 2014)

Striped bike lanes are dedicated lanes, striped with white paint on the right side of the road. The different colors intend to draw attention for the cyclists to provide a clearer sense of where they should be on the road. A dedicated space adds a sense of safety since it is a dedicated lane for bicycles. However, since they are not protected, there are instances where they may be too close or on the same path as a car. More cities are likely to have them as it does not require authorities to construct dedicated paths, and they can accomplish bike lanes by just drawing the striped line. Figure 11 shows an example of a striped bike lane.

Figure 11 An example of a striped bike lane.(Soulliere, 2021)

A common infrastructure for bikers is protected lanes. Protected lanes distinguish between space for a road for bikes and prevent cars. The road separated by a barrier prevents regular traffic from flowing on dedicated bike lanes, which leads to enhanced safety as it gives the security of only cyclists on a lane, so the interaction between different types of road users is minimal. Figure 12 shows an example of a protected bike lane.

Figure 12 An example of a protected bike lane. (Alpert, 2014)

One of the shared infrastructures is the universally accepted sidewalk. To ensure the safety of pedestrians, they share the sidewalks on the road on certain occasions with bicyclists when there are no dedicated spaces for bicyclists. It is difficult for pedestrians to share in circumstances when the sidewalks are incomplete, damaged, are covered in snow, or are non-existent. In those circumstances, most pedestrians are likely to use curb spaces that can be too close to cars and may be dangerous, particularly in high-speed zones. In specific urban centers, the town planners and local authorities look to create spaces dedicated to pedestrians. These spaces tend to be further away from the road, have built-in protective barriers, and result in a safer setting. The most risk they may have could be with cyclists. Figure 13 shows an example of a protected pedestrian lane.

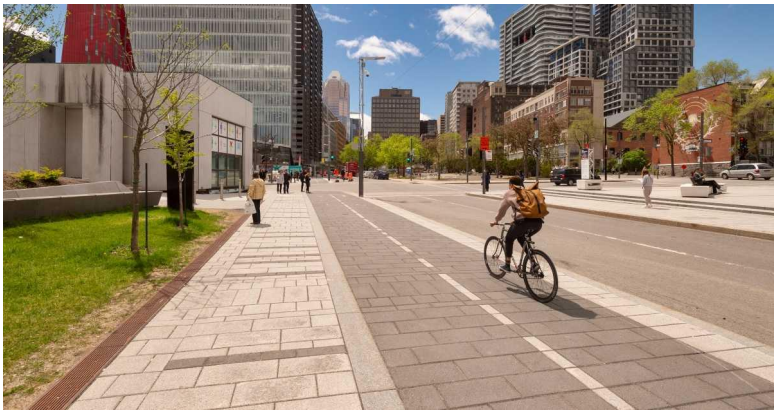


Figure 13 An example of a protected pedestrian lane. (Elliot, 2020)

To successfully navigate these shared spaces, drivers must understand and ensure they prioritize VRUs over their mobility while sharing roads. Drivers need to manage speeds by driving in control, ensuring strict lane discipline, yielding whenever required, and ensuring that they are not distracted, use alcohol, or experience fatigue. Drivers need to become even more careful to ensure shared spaces must be prioritized, respected, and prioritized for VRUs over cars.

4.1.1.3 Designing the content for the intervention

To assess the efficacy of the intervention, it is important to consider a corresponding control for comparing with the intervention. The content for the control had to be an existing intervention/content that covered the same themes. However, due to the novel nature of this research, it was not possible to have a completely replicated control for the intervention. The control content was selected to closely highlight the key aspects of each week's intervention that explains similar themes. The themes for the control content for the corresponding weekly intervention, are shown in Figure 14. The content was taken from the existing publicly available information posted by the National Highway Transportation and Safety Administration (NHTSA). An important feature of the intervention was its inherent interactivity and engaging the attention of the recipient. In contrast, the control content was presented in the form of a static PDF that was downloaded from NHTSA's website. Many of the existing interventions are static in nature themselves, so

the comparison of an interactive intervention should be done with respect to static control content. The delivery of the control content is discussed in the next section.

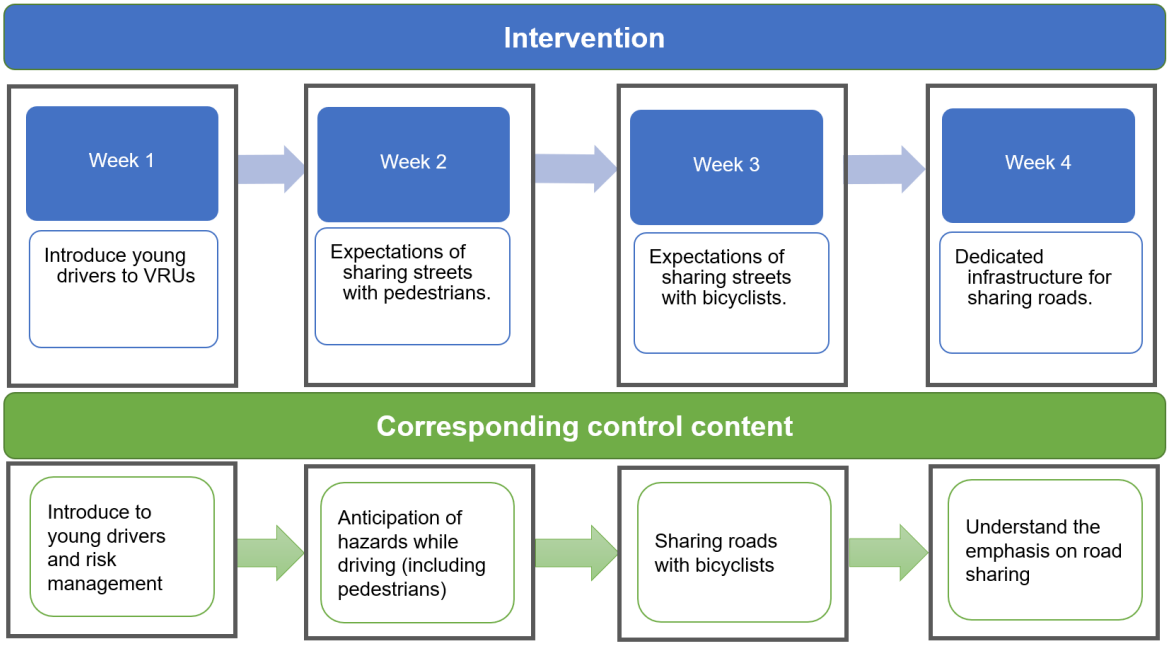


Figure 14 Weekly content and the corresponding control content

4.1.1.4 Delivery of the intervention and control

The importance of the medium of delivery is a critical component of how the recipient may develop responsiveness to the content associated with the intervention. The importance of the delivery is to ensure the quality, efficiency, utilization, access, learning, and sustainability of the delivered intervention (Bradley, Pallas, Bashyal, Berman, & Curry, 2010). Another aspect that determines the efficacy of the intervention is based on the core belief that behavior change is mostly posited in an individuals' belief in their ability to exercise control and affect change (Bandura, 2004). For this purpose, the delivery of intervention had to be delivered to each person individually. To ensure that the intervention is easily accessible, the intervention was developed and hosted as a web application through Shiny apps on R (Chang et al., 2021). The content was delivered through individualized emails that presented the information (i.e., a link to the website) and elicited responses. The progress was tracked by the researcher to ensure the participant viewed the

intervention and follow up email conversations ensured individual compliance. A major reason for the content to be delivered remotely was due to the strict social distancing and protective measures introduced in the state of Massachusetts due to the COVID-19 pandemic.

4.1.2 Participants

23 participants between 18 to 21 years old were recruited through email campaigns. Participants were required to have a valid MA driver's license. They were expected to complete the entire intervention for four weeks and respond to all the surveys and material provided. Only 1 participant did not complete the survey for Week 4. The participants were compensated $25 in the form of a gift card for completing the intervention. Additionally, the first 20 participants to complete the study received an additional $25 gift card to minimize attrition.

4.1.3 Experimental design

To understand the efficacy of the intervention, a longitudinal repeated measures experimental design was considered. The between-subject variable was the type of intervention, and the within-subject variable was the administration of content for four weeks.

4.1.3.1 Power analysis and sampling

A power analysis estimated the sample size. An initial estimation for a more significant effect size of approximately 0.4 (Power 80%), an approximate sample size of 40 participants (16 for the intervention group, 16 for the control group, and 8 for the no treatment) was deemed sufficient to assess the efficacy of the intervention. The reason for this unbalanced treatment was because the focus of analysis was intervention efficacy, and the no treatment condition was only introduced to understand behavior for those who are not exposed to any intervention. Additionally, recruitment and assignment was the result of simple random sampling and the study was not modified to ensure that the groups were balanced, leading to potential selection bias (Kahan, Rehal, & Cro, 2015). The analysis for this estimation was done using GPower3.1(Erdfelder, 2007).

While recruiting, there was a realization that data collection would only occur during the summer months and challenges due to online recruitment on a university campus led to a re-estimation of the feasible sample size. It must be noted that the intent was to survey participants on the university campus within the same semester, as significant differences would be observed in their travel behavior while they were on campus attending classes versus when they were in the summer semester. The best strategy to mitigate this effect was to recruit only participants in the summer semester. To this end, only 23 participants who met the initial selection criteria were considered for the study. The recruitment was done in the summer of 2021, with widespread restrictions imposed during the COVID-19 pandemic. Taken together, crucial decisions on the sample size had to be made due to unprecedented circumstances.

4.1.3.2 Independent Variables

For this analysis, the main independent variable is the type of treatment: whether they received the intervention, control, or no intervention. In addition to the type of treatment, demographic indicators, driving history, and risk propensity information was collected, as shown in

Table 4.

Table 4 Categorization of different measures

Variable	Measures
Demographic indicators	Age Gender Ethnicity Group
Driving history and risky behavior	History of crashes History of citations Use of mobile phones while driving. Sensation seeking measures Number of times driven each week Number of times alternate transportations were sought each week

	Instances of driving under influence Instance of when they endangered a VRU while driving Assessment of whether the intervention improved their understanding of VRUs

4.1.3.3 Description of the control

For assessing the efficacy of the interactive intervention, an equivalent control was introduced. The content for control includes articles published as part of the content included on the National Highway Traffic Safety Administration (NHTSA), which promoted better risk management and awareness of interactions with VRUs. The control content was selected based on how similar their content was representative of the weekly intervention content. This was done to ensure there was relative parity between the content presented to the different treatment groups, considering that there was no available intervention on improving driver interactions with VRUs. To ensure this parity, weekly content was compared across different sources, and the closest possible publicly available content was considered for the control content. The documents were in pdf format that included the information published on the website, and were approximately one to two pages long. For week 1, the control group received a two-page tutorial on driver risk management. For weeks 2 and 3, participants received information shared by NHTSA on interacting with pedestrians and bicyclists. In the 4th week, participants received a flyer that shared statistics on VRU crashes and the responsibility of drivers on protecting all road users. A snapshot for each week's control is shared in Figure 15.

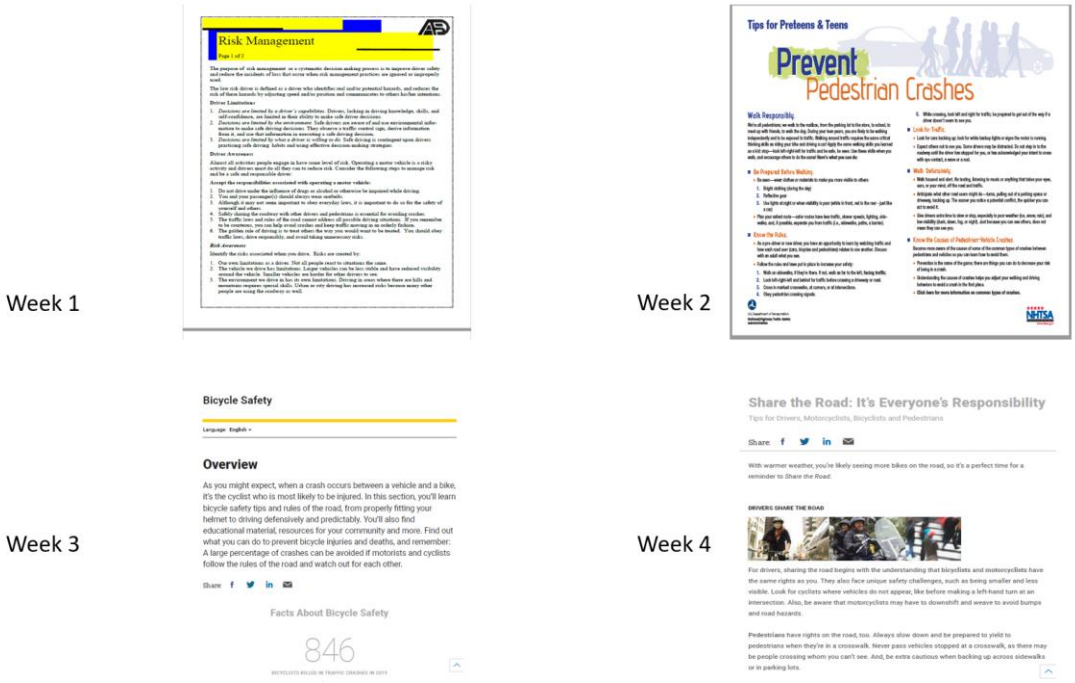


Figure 15 A snapshot of the content shared with the control group

4.1.3.4 Dependent variables

4.1.3.4.1 Self-reported driving behavior

A modified driving behavior questionnaire (DBQ) (de Winter et al., 2018) assessed the participants' likelihood of committing errors, violations, or lapses when interacting with VRUs. The three dependent variables therefore were – **errors, lapses, and violations**. For this research, modified DBQ statements helped assess scenarios where errors, violations, and lapses may occur while interacting with VRUs. The modified DBQ was pilot tested among eight volunteers. The study found that the modified DBQ was reliable and consistent (Cronbach Alpha = 0.8).

Table 5 compared statements and how they compare to the original DBQ.

Table 5 Modified DBQ comparison with original DBQ

Number	Modified Statements from DBQ	Original DBQ
Violations		
1	Do not keep sufficient space between bike and car	Drive especially close to the car in front as a signal to its driver to go faster or get out of the way
2	Cross an intersection knowing that the traffic lights have already turned red, and pedestrians are not around	Cross a junction knowing that the traffic lights have already turned red
3	Disregard the speed limits late at night or early in the morning	Disregard the speed limits late at night or early in the morning
4	Disregard the speed limits on a motorway	Disregard the speed limits on a motorway
5	Have an aversion to a particular class of road users and indicate your hostility by whatever means you can	Have an aversion to a particular class of road users and indicate your hostility by whatever means you can
6	Become impatient with a bicyclist in the outer lane and overtake on the inside (right) lane	Become impatient with a slow driver in the outer lane and overtake on the inside (right) lane
7	Get involved with unofficial 'races' with other drivers	Get involved with unofficial 'races' with other drivers
8	Angered by a pedestrian, bicyclist, or scooterists behavior, you indicate your intention of giving him/her a piece of your mind	Angered by another driver's behavior, you give chase to give him/her a piece of your mind
9	Sound your horn to indicate your annoyance if the pedestrians or other road users are going slow	Sound your horn to indicate your annoyance to another driver
10	Use the bike lane after checking there are no bikers so you can make a turn or negotiate traffic better	Stay in a motorway that you know will be closed ahead until the last minute before forcing your way into the other lane
11	Park your car in a dedicated bike lane	Park your car in a dedicated bike lane

Errors		
12	Attempt to overtake a bike/forget to yield to a pedestrian that you had not noticed to be signaling a left/right turn	Attempt to overtake someone that you had not noticed to be signaling a left/right turn
13	Miss' give way' signs and narrowly avoid collision with pedestrians having right of way	Miss' give way' signs and narrowly avoid colliding with traffic having right of way
14	Fail to notice that pedestrians are crossing when turning into a side street from the main road	Fail to notice that pedestrians are crossing when turning into a side street from the main road
15	Queuing to turn right/left onto the main road, you pay such close attention to the mainstream of traffic that you nearly hit a cyclist/pedestrian/car	Queuing to turn right/left onto the main road, you pay such close attention to the mainstream of traffic that you nearly hit the car in front
16	On turning right/left nearly hit a bike/scooter who has come upon your inside	On turning right/left nearly hit a two-wheeler who has come upon your inside
17	Fail to check your rear-view mirror before pulling out or changing lanes, etc. and miss a pedestrian/bicyclist	Fail to check your rear-view mirror before pulling out or changing lanes, etc.
18	Underestimate the speed of an oncoming vehicle when overtaking	Underestimate the speed of an oncoming vehicle when overtaking
19	Apply sudden brakes on a slippery road, or steer the wrong way in a skid	Apply sudden brakes on a slippery road, or steer the wrong way in a skid
Lapses		
20	Get into the wrong lane when approaching a roundabout or a junction	Get into the wrong lane when approaching a roundabout or a junction
21	Misread the signs and exit from the roundabout on the wrong road	Misread the signs and exit from the roundabout on the wrong road
22	Forget where you left your car in the car park	Forget where you left your car in the car park
23	Hit something when reversing that you had not previously seen	Hit something when reversing that you had not previously seen
24	Attempt to drive away from the traffic lights	Attempt to drive away from the traffic lights
25	Switch on one thing, such as headlights,	Switch on one thing, such as headlights, when you meant to switch on something else, such as wipers

	when you meant to switch on something else, such as wipers	
26	Realize you have no clear recollection of the road along which you have destination B because the latter is your more usual destination	Realize you have no clear recollection of the road along which you have destination B because the latter is your more usual destination

As can be observed from the above table, the modification was done to reflect if the original statement could be repurposed to reflect the specific interaction between drivers and VRUs. In case the statements could not be repurposed, the original statements were retained to ensure the reliability of the questionnaire. The original questionnaire was set up to be a 5-point Likert scale, which was converted to a 7-point Likert scale for this study. This was done to capture more nuanced responses from the participants and have better sensitivity to the original questionnaire. The minimum value for each statement was 1 (No relation to the statement), and the maximum value was 7 (Complete relation to the statement). The responses were captured and the mean and standard deviation of errors, lapses and violations for individual participants each week were captured and recorded for analyzing the efficacy of the type of treatment received by the participant.

Like the original questionnaire, there are 26 questions incorporated in the modified driving behavior questionnaire. The order of the questions is the same order as the original questionnaire. The participants were unaware whether a statement was associated with errors, lapses or violations. The typical values for errors, lapses and violations with respect to their mean and standard deviation values tend to range between 0.0 to 2.0, based on initial evaluations done for validating the survey design (Reason, Manstead, Stephen, Baxter, & Campbell, 1990). It is worth noting that the upper limit may be slightly higher for this study, considering that the scale of the survey used in this study is out of 7, compared to the original survey where the survey is out of 5.

4.1.3.4.2 Survey responses

To understand the perceptions of the participants upon completion of each week's intervention, the research explored the responses to the weekly assessment. The responses varied across the participants in terms of explaining individual perspectives. However, to understand the key information from the responses, key points were extracted from all the responses. The detailed information extracted and the corresponding questions from each week have been provided in Table 6.

Table 6 Key information extracted from the weekly survey assessment responses

Week	Information extracted from the responses	Question
1	Missed out on VRU. Emotion on missing out VRU. Scenarios when missing out on VRU	Think about times when as a driver, you may have missed out on a VRU which may have resulted in you getting nervous. Describe that scenario and think of what you felt you could have done better in your driving?
1	Community action on VRU	Do you think your community does enough or should do enough for the safety of VRUs? If yes, do mention what do you think they do consider. If not, what would be your suggestions?
1	Road design considering VRU	Do you think roads should be designed for sharing or should we only have dedicated spaces for pedestrians, drivers, and other mobility users for safety?
2	Methods of communication with pedestrians	Could you think of a few methods of communication that would maybe help reduce the risk of children and older pedestrians when crossing the road?
2	How should you approach pedestrians	As a driver, what would you do differently now to improve your approach to a crossing, now that you know which pedestrians are at a higher risk?
2	Importance of trust between Drivers and peds	After discussing the role of communication between pedestrians and drivers, do you think trust between the driver and pedestrian plays a role when crossing the road? If so, in what way? If not, why not?
3	Should drivers and bikers share road	Do you think cyclists and drivers should share roads considering all the risks described in this week's discussion?
3	Nervous when bikes are on the road	As a driver, are you nervous when there is a bicycle on the road?

3	Understanding as a biker	Do you think it helps if the drivers are themselves bicyclists who can better understand the risks associated with interactions between drivers and cyclists?
4	Add more mobilities in travel	Do you think you can add other mobilities to your travel? If not, can you think of reasons why that may not be realistic?
4	Opinion on dedicated infrastructure	Which of the dedicated infrastructures are unsafe for VRUs, and what can you do as a driver to make sure how to make them safer for VRUs when driving?
4	Challenges for drivers with road sharing	What do you think are challenges for drivers to acknowledge the growing shared streets in cities?
4	Challenges for VRUs with road sharing	How can VRUs make sure that they can be safer on the shared streets when sharing spaces with drivers?

4.1.3.5 Procedure

All participants consented to participate in the study and were randomly assigned to a group (intervention, control, or no intervention). No participant was informed about which group they were assigned. Each week, the participant received the materials associated with their group, and as a follow-up, reflection responses were requested. The intervention content was delivered directly to the participants via email. All participants were to read the contents each week. Participants in the control group were sent the document, whereas the participants in the intervention group received a web app that shared the content. The third group received no treatment. The expectation was to complete the reflection responses within the next three days. After three days, the participant received the modified driving behavior questionnaire to measure their perceptions of the VRUs. The participants were requested to complete the questionnaire before the beginning of the following week. In the final week, participants completed a demographic questionnaire. The participants also completed a payment voucher to confirm they had received the payment. If the participants failed to complete the study, only a partial amount was awarded.

4.1.3.6 Data Analysis

For analyzing the survey data to measure the efficacy of the intervention, a generalized linear model was implemented. A generalized model considered the type of treatment (Intervention/Control/No treatment), the week of the treatment, and the independent variables. Additionally, the model accounted for repeated measurements (Bates & Maechler, 2008). For this analysis, a p-value < 0.05 was considered as the cut-off point for the significance of the estimate. The analysis would be using the R programming software. With respect to the assessment responses, the key information from the responses to the weekly questions were coded and documented. For analysis, the frequency of the common responses was analyzed.

4.2 Results

4.2.1 Participant characteristics of each group

For understanding the response behavior among different treatment groups, it is vital to consider the characteristics of each group and whether any differences existed prior to the experiment. The age distribution across the different treatment types was observed to be uniform, and it could be attributed to the initial recruitment restrictions that allowed only 18- to 21-year-old participants to participate. The distribution can be seen in Figure 16. Regarding gender, we observed that each group had more male participants as compared to female participants. However, the distribution of gender is similar, as observed in Figure 17. Similarly, with regards to ethnicity, all participants across each group identified as Caucasian, and only 3 participants identified as either Asian or Caucasian-Asian. The distribution is observed in Figure 18.

While demographically, the treatment groups are relatively uniform, with regards to their driving history, only three drivers received a citation while driving. No participant in the control reported having received a citation. The distribution can be seen in Figure 19. However, all groups reported some type of crash as shown in Figure 20. All participants held the license for a period between 2 to 5 years but Figure 21 shows that participants who received treatment had a higher average license duration than the other groups. Self-reported driver impairments behaviors were mainly uniform in nature, and Figure 22 shows

that only 2 participants admitted to driving under the influence. Additionally, most participants reported using a cellphone while driving at varying frequencies, as shown in Figure 23. An equal number of participants reported having recalled an incidence of endangered a VRU across the groups as shown in Figure 24.

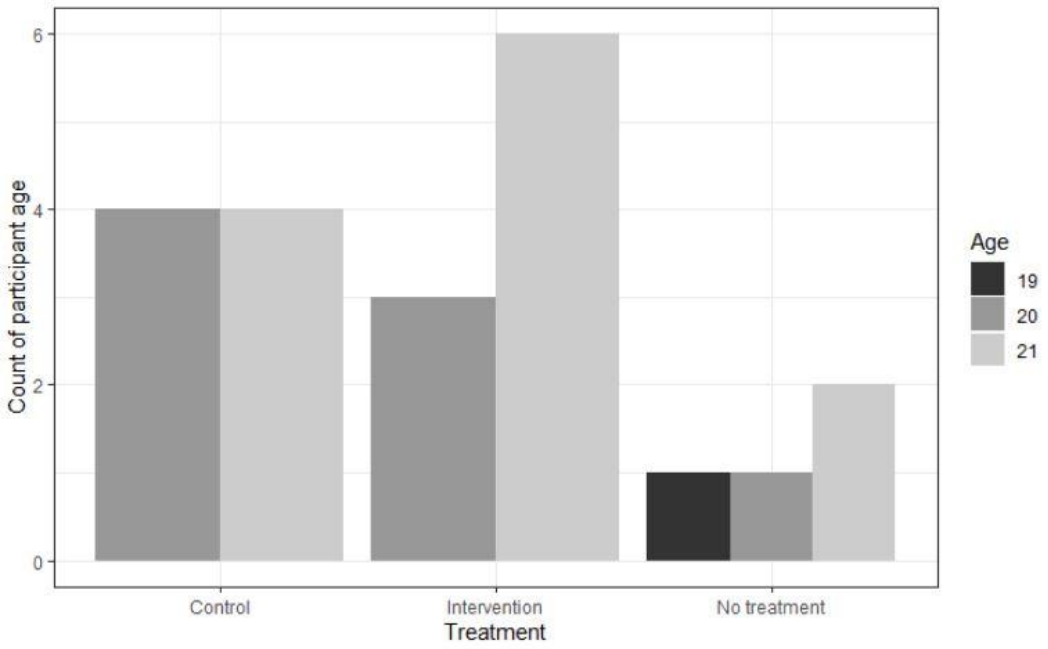


Figure 16 Age distribution

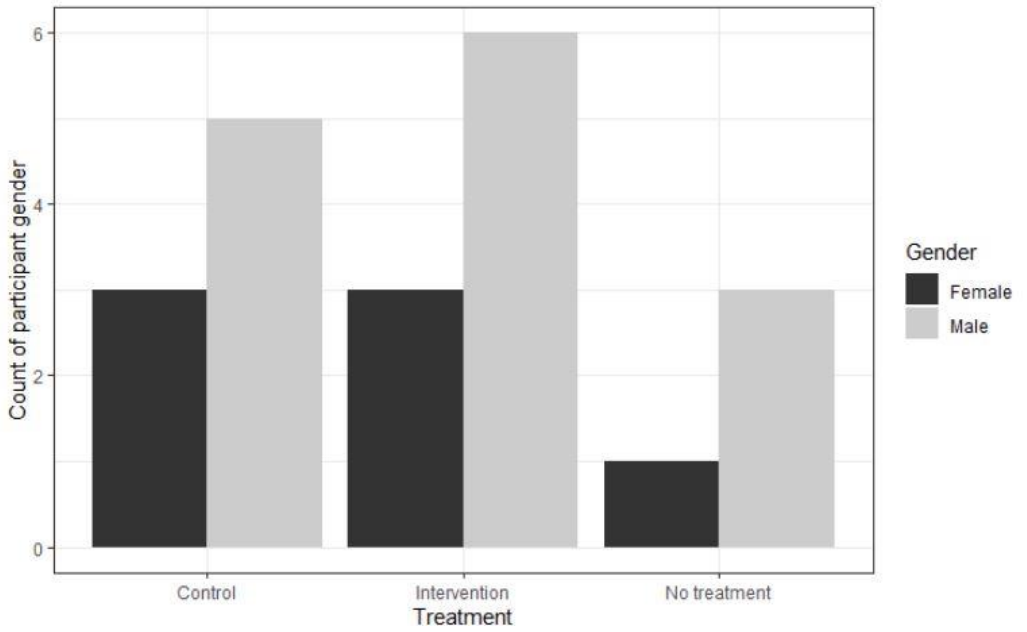


Figure 17 Gender distribution

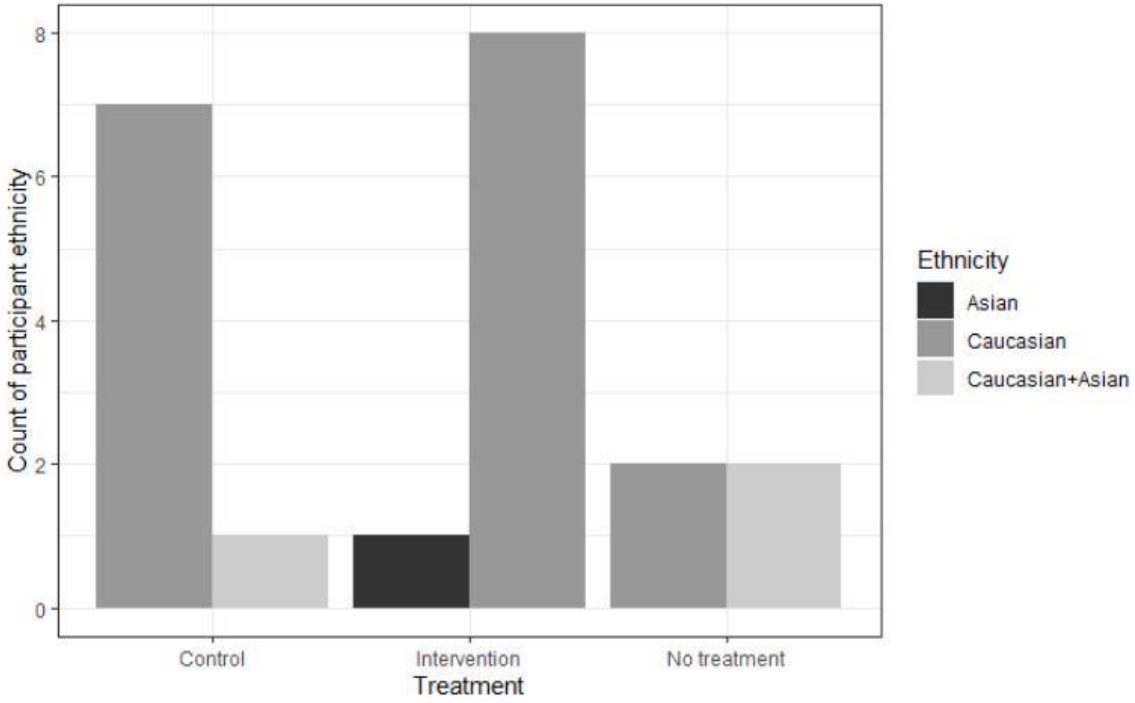


Figure 18 Distribution of ethnicity

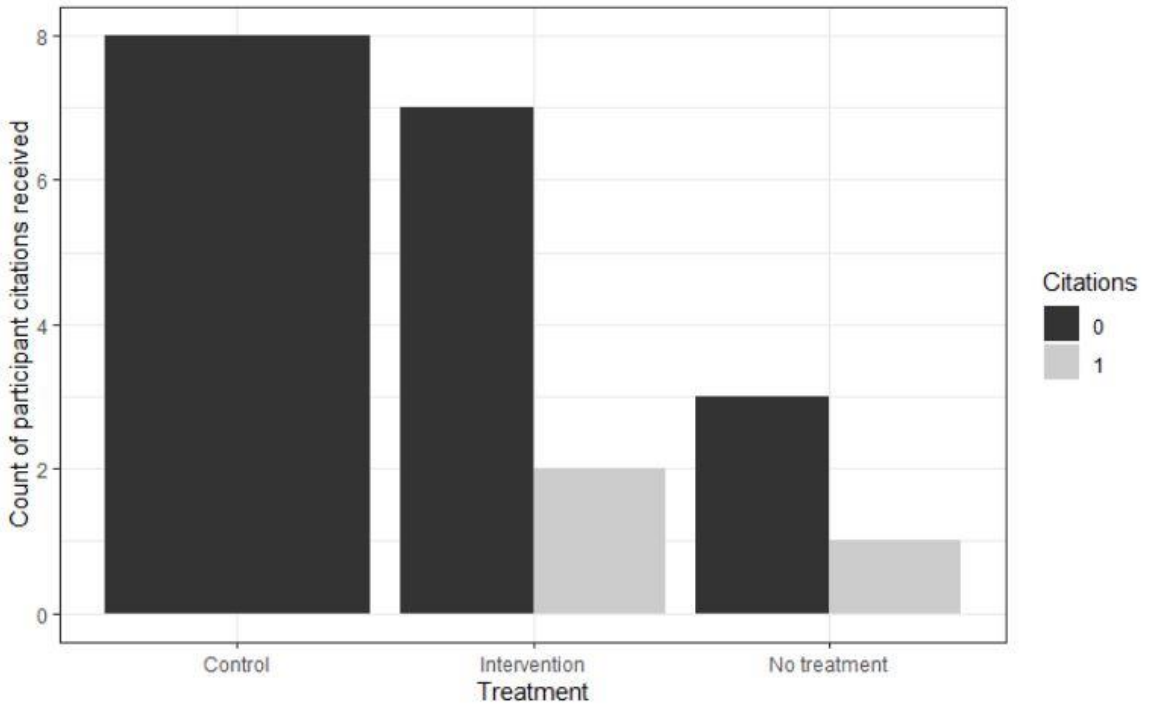


Figure 19 Citation distribution

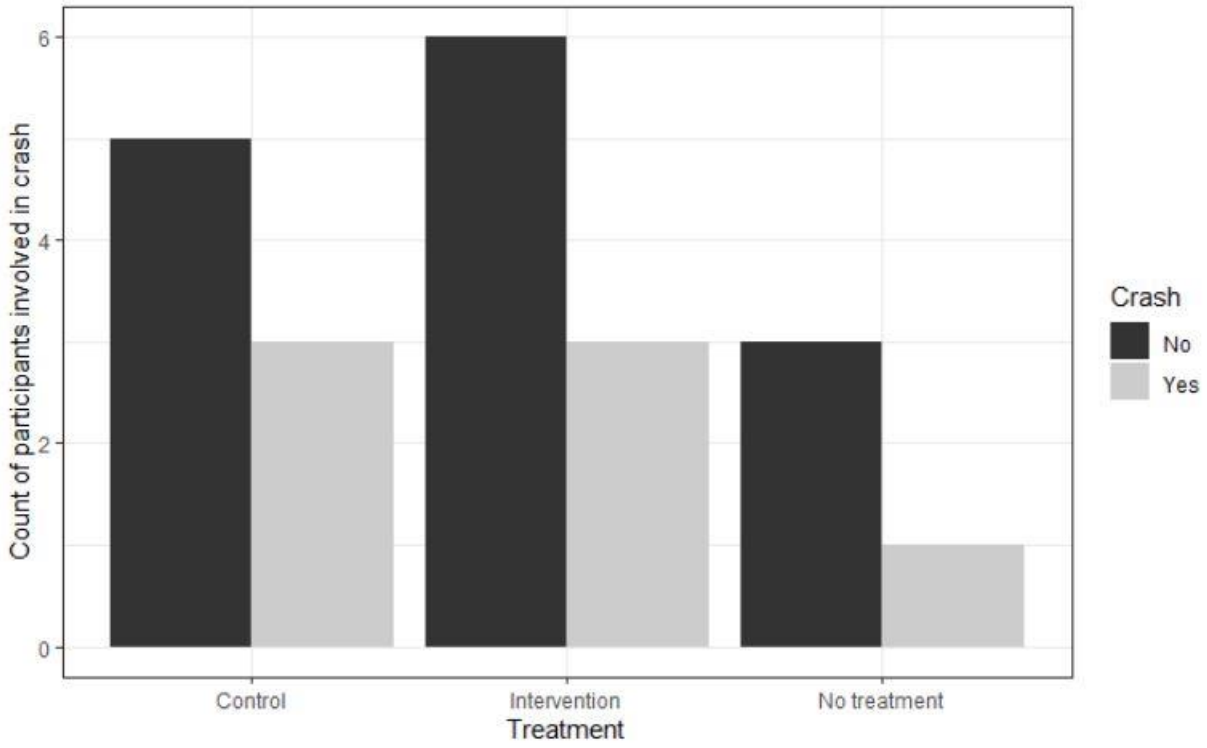


Figure 20 Crash history distribution

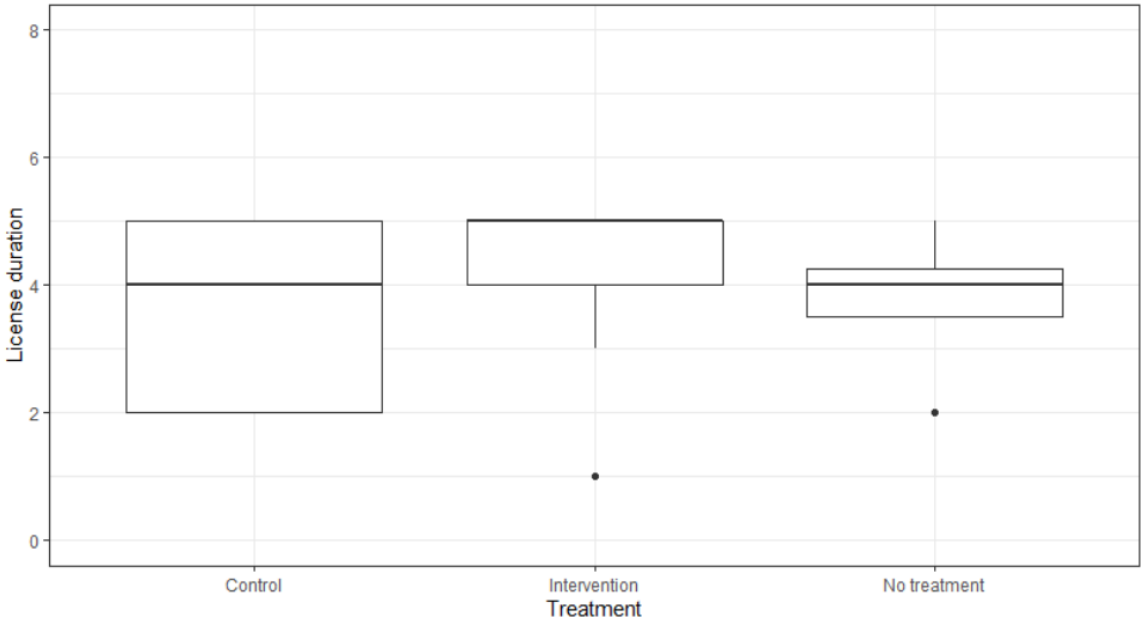


Figure 21 Duration of licensure distribution

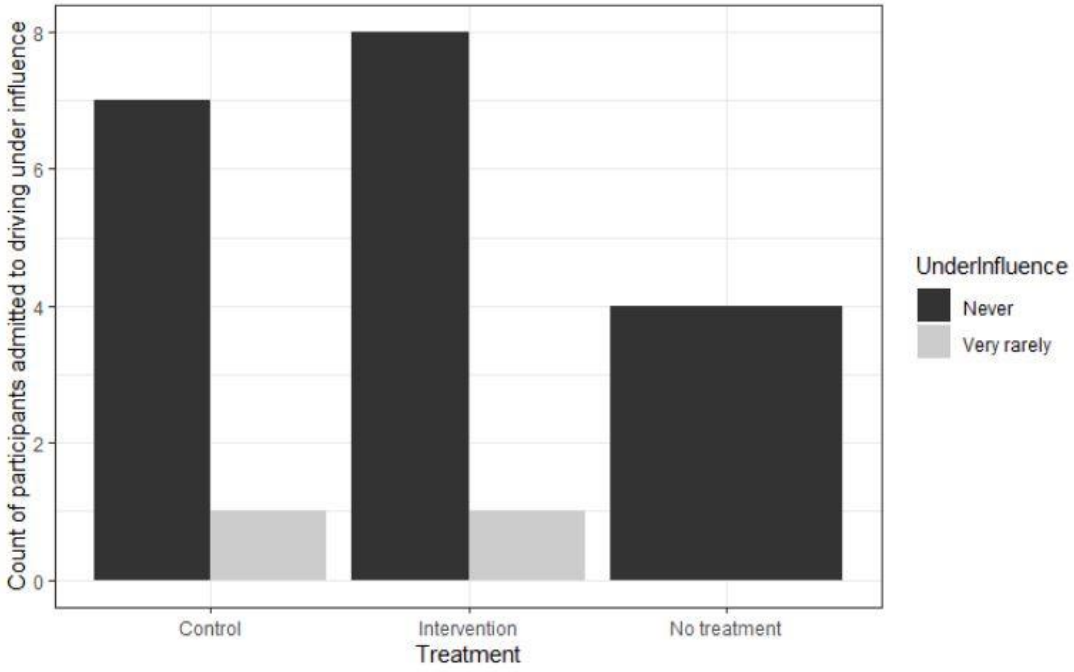


Figure 22 Distribution of participants who drove under the influence

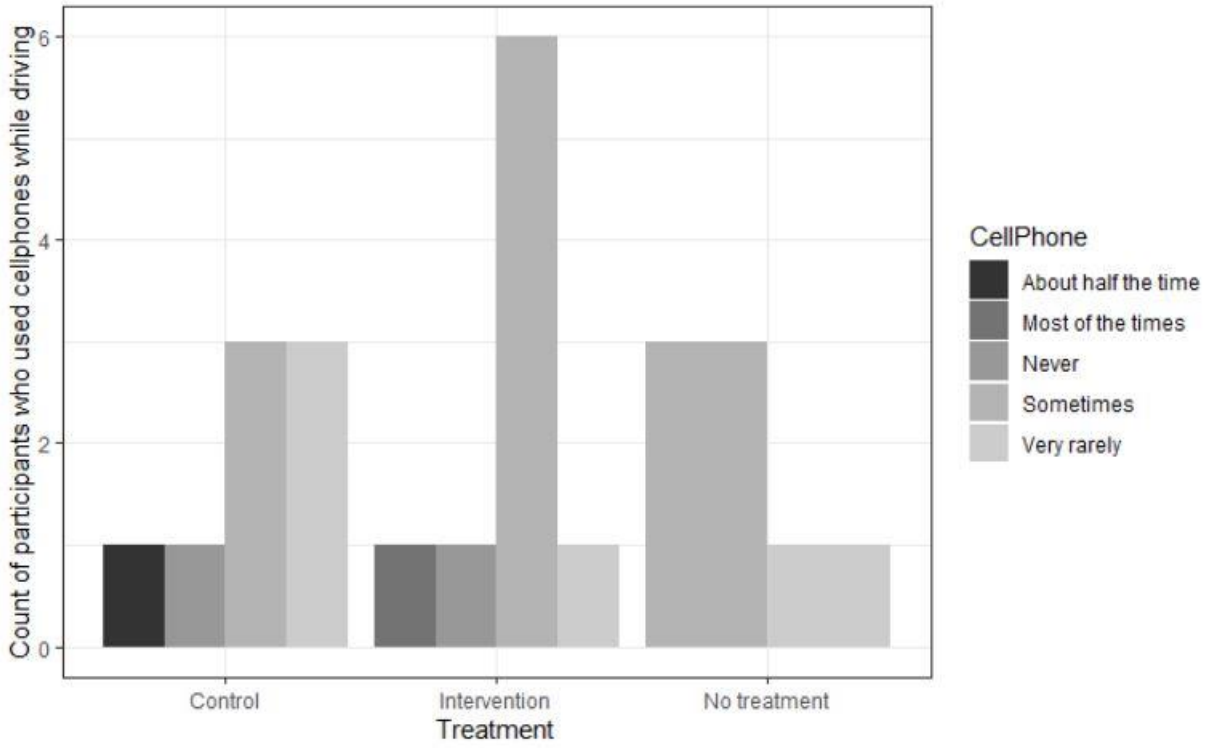


Figure 23 Cell phone usage distribution

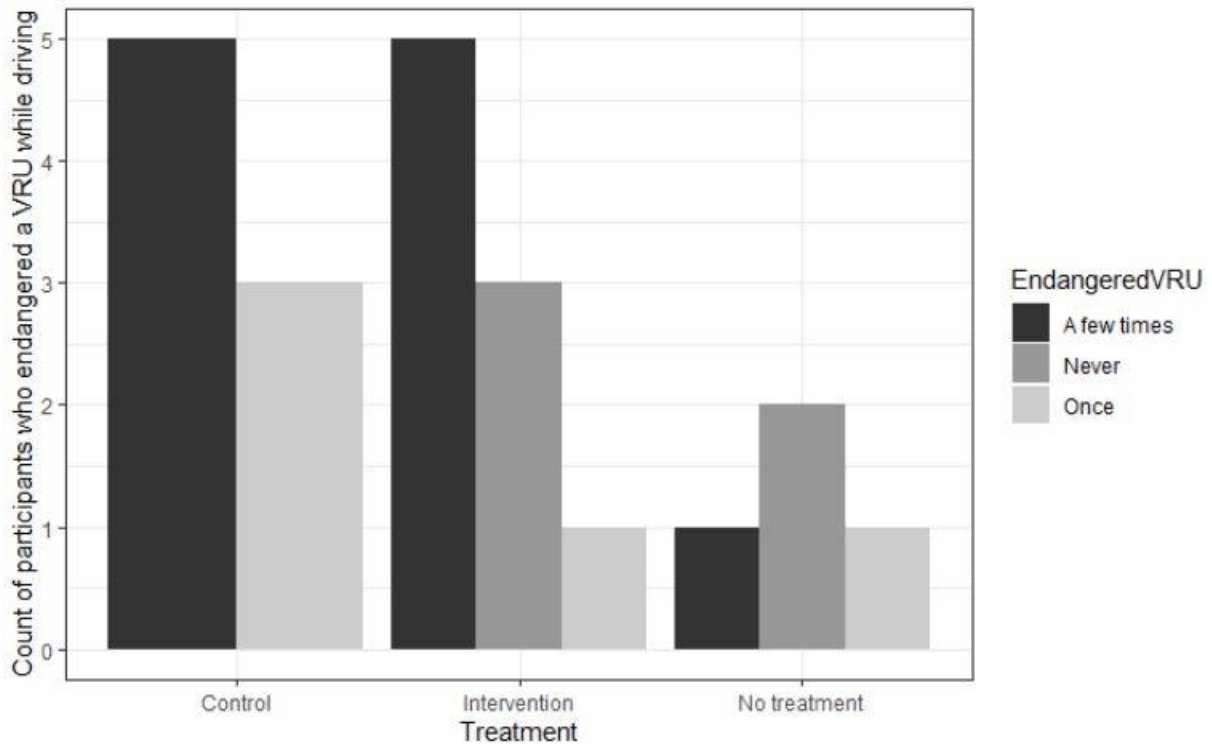


Figure 24 Distribution of participants who endangered a VRU

With regards to the usage of different modes of transportation each week, most participants in the control group drove more times each week than those who received the intervention (**Error! Reference source not found.**). Additionally, all participants used fewer alternative modes of transportation each week, as compared to them driving each week (Figure 26).

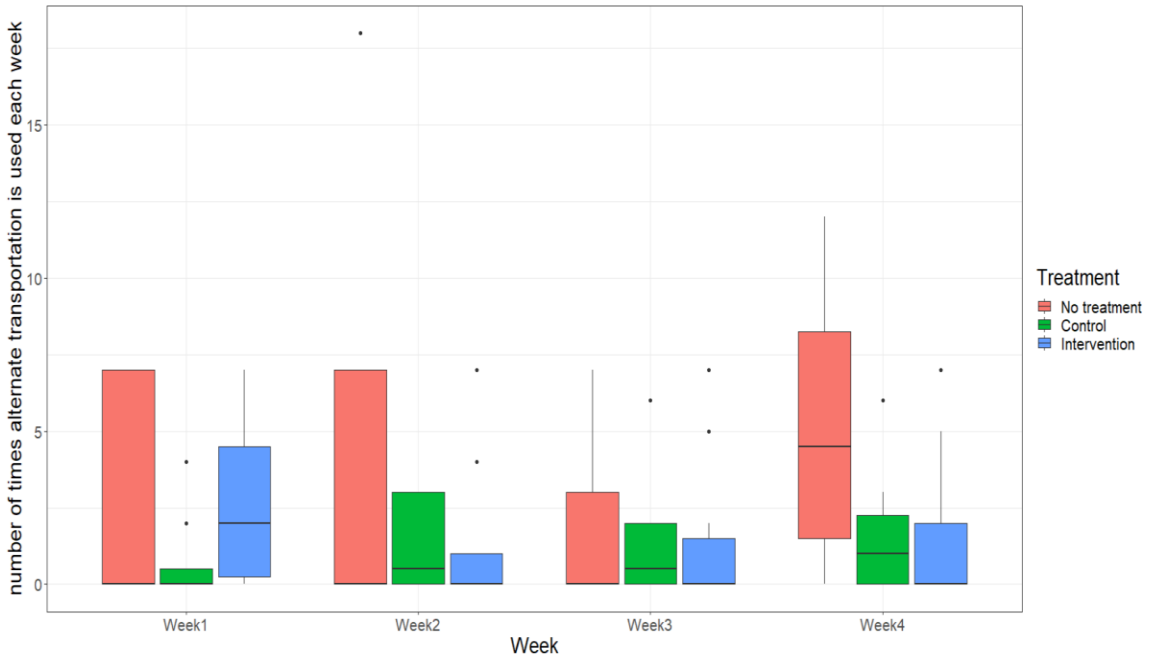


Figure 25 Distribution of the number of times alternate transportation was used each week

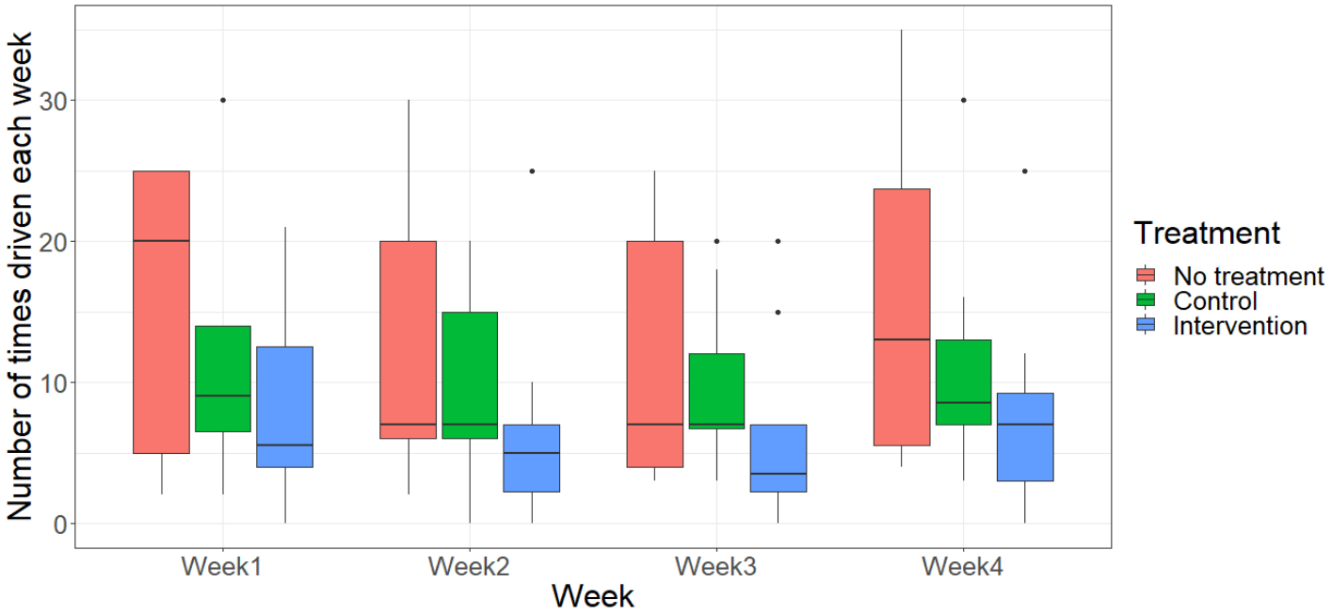


Figure 26 Distribution of the number of times driven each week

4.2.2 Descriptive statistics

Table 7 Distribution of the weekly survey responses across different treatments; means are shown in each cell and standard deviations are in parentheses

Treatment	Week	Errors	Lapses	Violations
Control	1	1.732 (0.411)	1.939 (0.679)	2.169 (0.418)
Control	2	1.438 (0.314)	1.929 (0.634)	1.897 (0.309)
Control	3	1.375 (0.211)	1.982 (0.718)	1.852 (0.348)
Control	4	1.344 (0.209)	2.000 (0.907)	1.716 (0.449)
No Treatment	1	1.781 (0.313)	2.071 (0.799)	2.091 (0.358)
No Treatment	2	1.825 (0.611)	1.829 (0.989)	2.055 (0.501)
No Treatment	3	1.225 (0.366)	1.600 (0.992)	1.946 (0.543)
No Treatment	4	1.469 (0.517)	1.929 (0.868)	2.046 (0.356)
Intervention	1	1.438 (0.909)	1.738 (1.192)	1.902 (0.68)
Intervention	2	1.638 (0.655)	1.814 (0.871)	1.918 (0.444)
Intervention	3	1.488 (0.271)	1.886 (0.548)	1.891 (0.277)
Intervention	4	1.463 (0.344)	1.814 (1.152)	1.836 (0.522)

From Table 7, we observe the trend in the self-reported values from participants in each group. Participants who received the control group showed consistent decrease in the errors over the four-week period. The control group participants showed a decrease in the number of self-reported violations. Participants in the control group showed a very slight increase in the number of reported lapses.

Participants who received the intervention showed variability in the number of errors reported. There was an increase from week 1 to week2, however there was an observed decrease in week 3. In week 4, a slight decrease in the errors was observed. Participants who received the intervention showed a slight increase in the reported lapses from week1 to week2, and week2 to week3. For week 4, the participants who received the intervention showed the same lapses as they did in week 2. With respect to the violations, participants showed an increase in the violations from week1 to week 2. However, from week2 to week3, and week 3 to week 4 showed a slight decrease in the violations.

Participants who received no treatment showed a high variability in the reported errors. From week1 to week2, an increase in the errors was observed. However, there was a sharp decrease in the errors, followed by another increase for week 4. Participants who received no treatment showed a decrease in the lapses from week 1 to week 3, however there was an observed increase in week 4. With respect to the violations, participants who received no treatment showed a decrease from week 1 to week 3, followed by another increase in week 4.

4.2.3 Inferential statistics

The summary of significant findings is shown in

Table 8 Relationship between dependent and independent variables

Table 8.

Table 8 Relationship between dependent and independent variables

DV	IV	β	SE	p value
Errors	Week	-0.1216	0.0402	0.0310
	Citations received	-0.3402	0.1379	0.0152
Lapses	Citations received	-0.9839	0.3164	0.0009
	Annual mileage	-0.1695	0.0809	0.0149
Violations	Citations received	-0.4420	0.0399	0.0009
	Annual mileage	-0.1457	0.0378	$7.49X10^{-05}$
	Sensation Seeking	0.1826	0.0573	0.0021
	Week	-0.1314	0.0422	0.0023
	Treatment X Week	0.1153	0.0553	0.0412

The analysis found that number of citations had an influence on the errors. Participants who received no citations had overall higher errors (M = 1.5411, SD = 0.4501) as compared to those who received 1 citation (M = 1.25, SD =0.2665). No participant who received a citation got assigned to the control group. A distribution of the errors over the period of intervention is shown in Figure 27. The figure represents that there is an overall lowering of the errors reported by the participants.

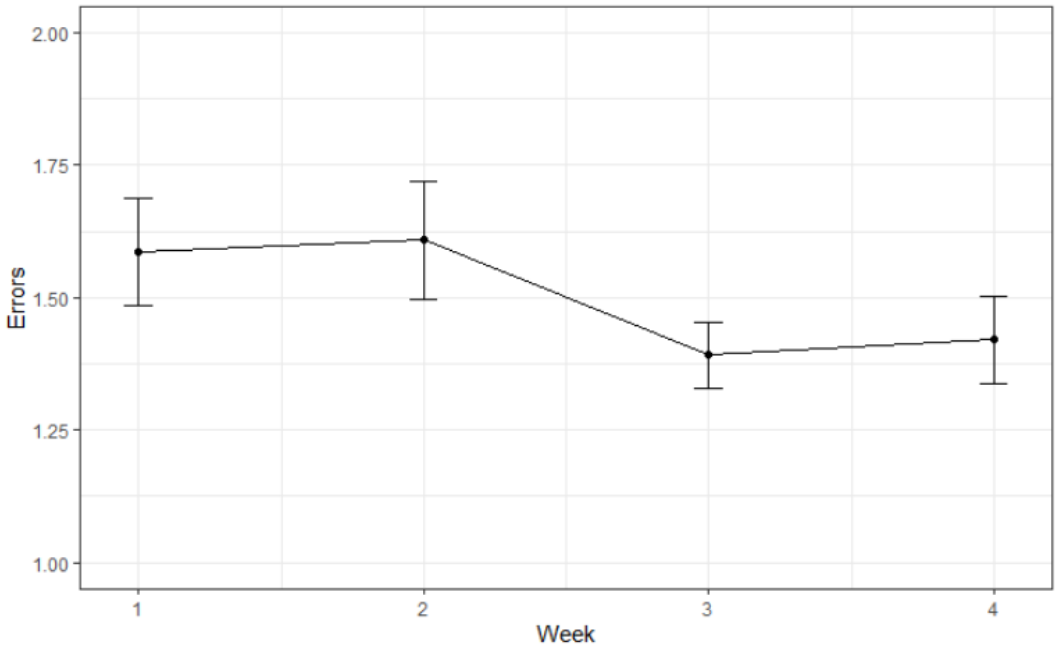


Figure 27 Errors over the four-week period (The bars show the standard errors)

The analysis found that number of citations had an influence on the lapses. Participants who received no citations had overall higher lapses (M = 1.9901, SD = 0.8488) as compared to those who received 1 citation (M = 1.1309, SD =0.1969). No participant who received a citation got assigned to the control group. Additionally, participants were observed to have lower lapses with an increase in the annual miles driven (Figure 28).

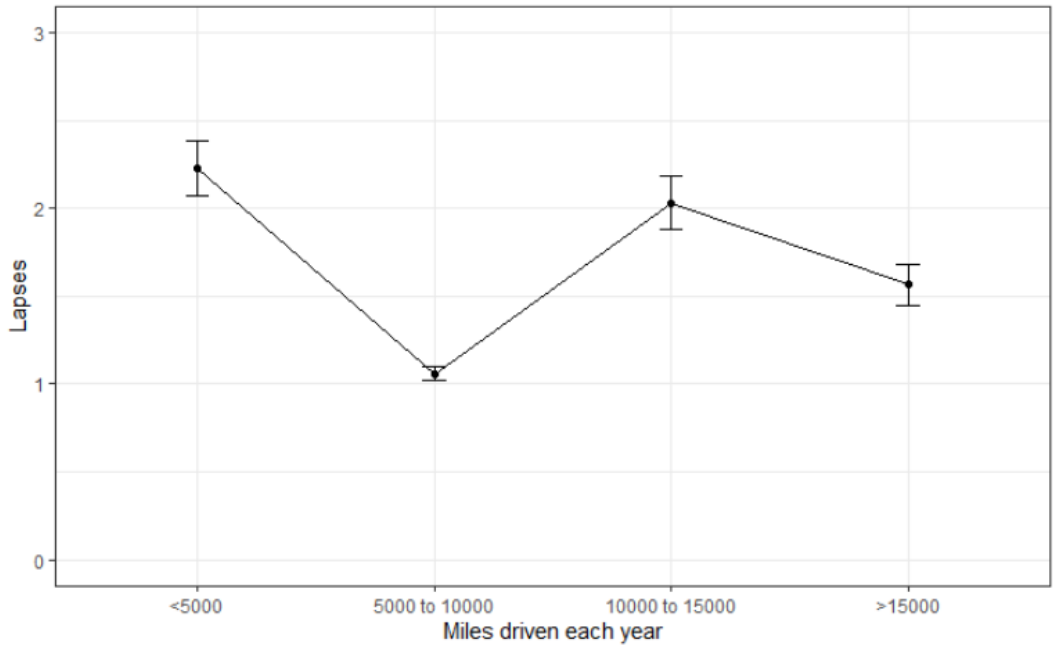


Figure 28 Relationship between annual miles driven and lapses (The bars show the standard errors)

The analysis found that number of citations had an influence on the violations. Participants who received no citations had overall higher errors (M = 1.9724, SD = 0.4187) as compared to those who received 1 citation (M = 1.5758, SD =0.2304). No participant who received a citation got assigned to the control group.

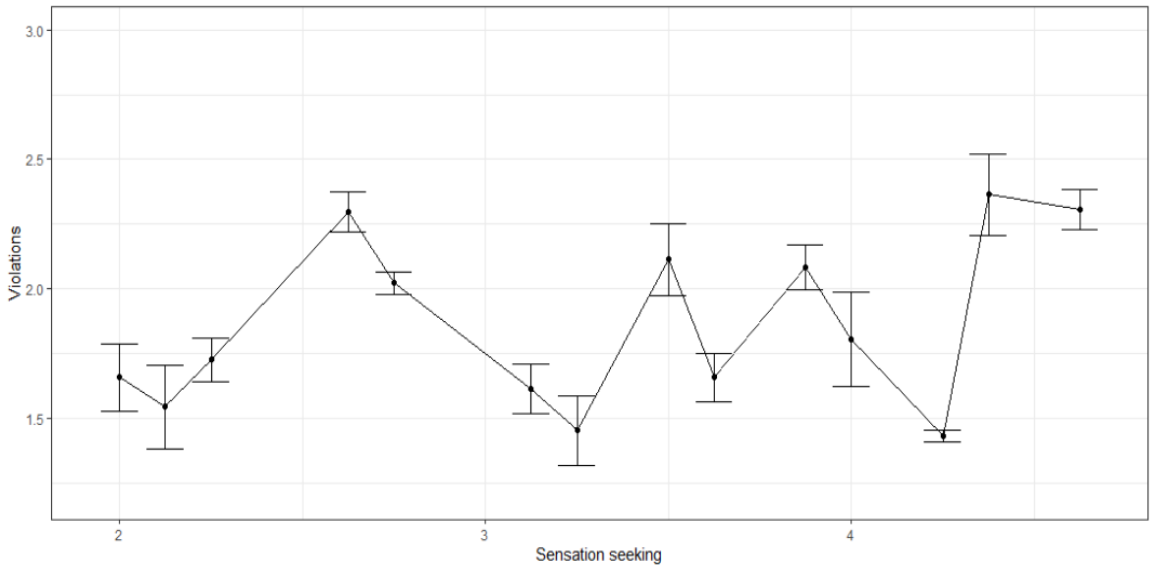


Figure 29 Relationship between sensation seeking scores and violations (The bars show the standard errors)

Figure 29 shows a higher violation reported for higher sensation seeking scores, irrespective of the type of treatment received. As sensation seeking scores increase, there is an overall increase in the mean violations. However, the trend is not definitive, and the values increase when the scores are between sensation seeking of 2 and 3.5, and between 4 and 5. Participants also reported lower violations with an increase in the annual miles driven (Figure 30). It is observed that the participants who drove less than 5000 miles had higher reported violations. However, participants who drove more than 5000 miles annually reported lower violations. It is worth observing that participants who drove between 5000 to 10000 miles, 10000 to 15000 miles, and more than 15000 miles did not have any major differences observed between them.

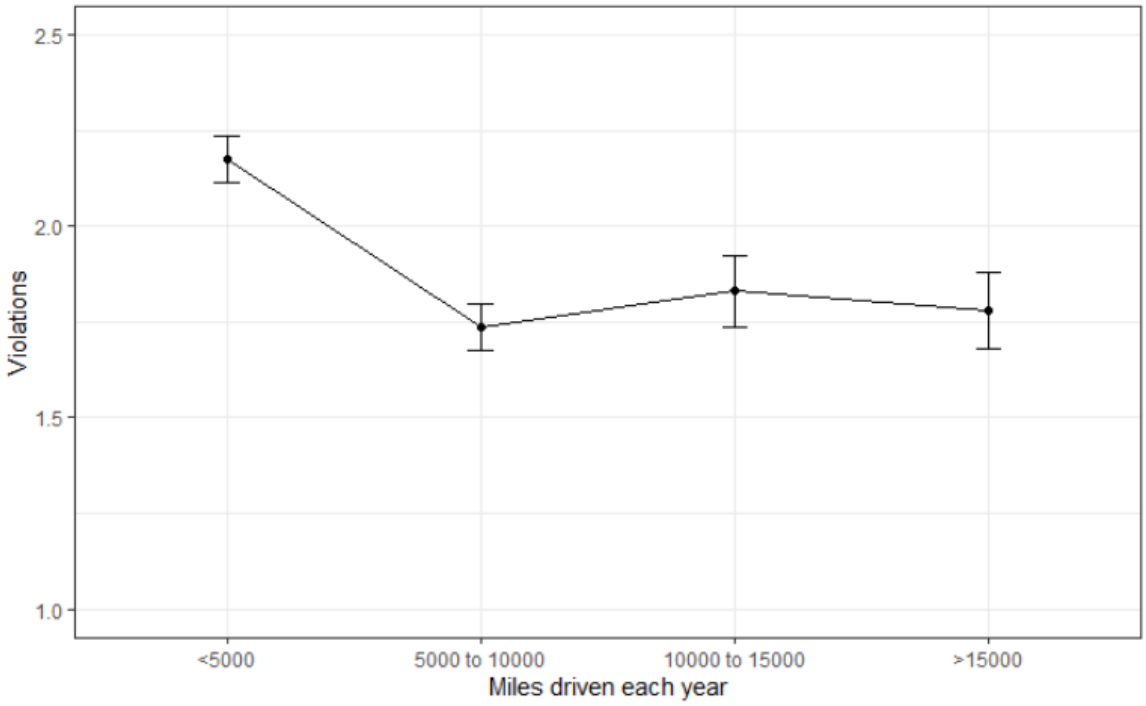


Figure 30 Relationship between annual mileage and violations (The bars show the standard errors)

An interaction effect was observed between the type of treatment and the week of intervention. Figure 31 shows the interaction effect of the that while there are no major differences observed for participants who received the treatment and no treatment, there is a sharp decrease in the mean of violations for the control group. As the number of weeks increased, there was a lower mean violation for participants who were assigned to the control group.

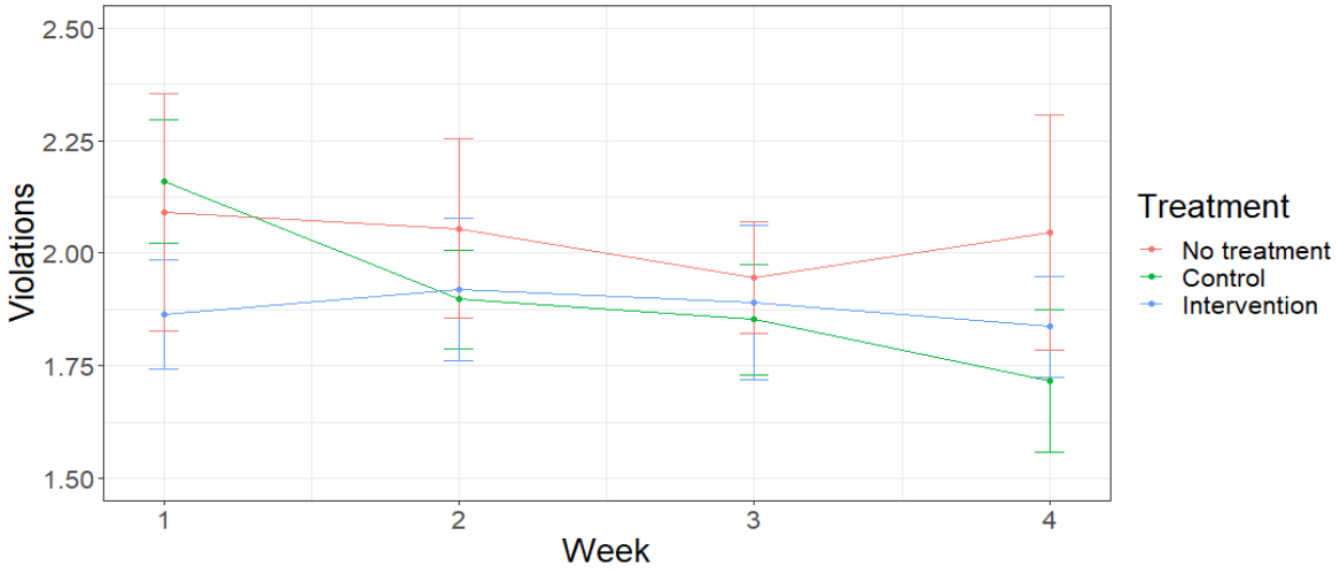


Figure 31 Interaction between Treatment and Week of Intervention for violations (The bars show the standard errors)

4.2.4 Qualitative analysis

The participants were asked to share responses to questions, as earlier described in Table 6. Since the responses are qualitative in nature, the results are presented as frequency analysis. This was done to report the number of participants who had similar responses, which provided insights on how the participants perceived the interactions with VRUs.

4.2.4.1 Responses from Week 1

As addressed earlier, this weeks' focus was towards creating an understanding on the vulnerabilities around VRUs. The focus of the questions was missing out on detecting VRUs, subsequent emotions, and potential community actions that could be taken to improve safety for VRUs.

4.2.4.1.1 Missing out on detecting VRUs

A large majority of the participants reported that they missed out on detecting pedestrians. A very small fraction of the participants reported missing out on bicyclists, or both bicyclists and pedestrians (Figure 32).

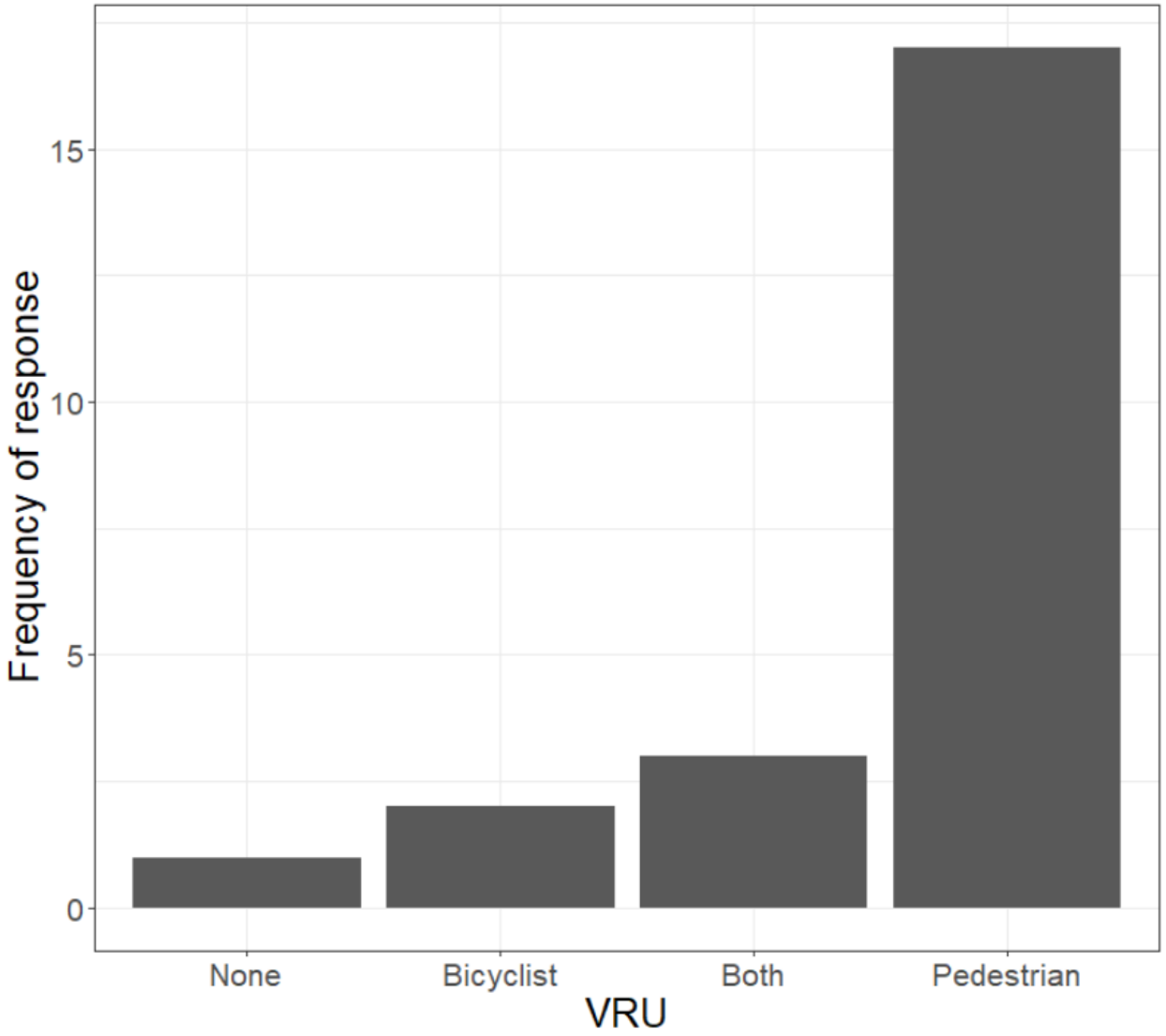


Figure 32 Frequency of participants reporting on missing out on VRUs

4.2.4.1.2 Emotion on missing out VRU

While most of the participants had reported missing out on pedestrians, almost half the participants did not feel any major emotional response to missing out on the VRU. The rest of the participants reported a myriad of emotional responses including nervousness, anxiety, frustration, scared and stress (Figure 33).

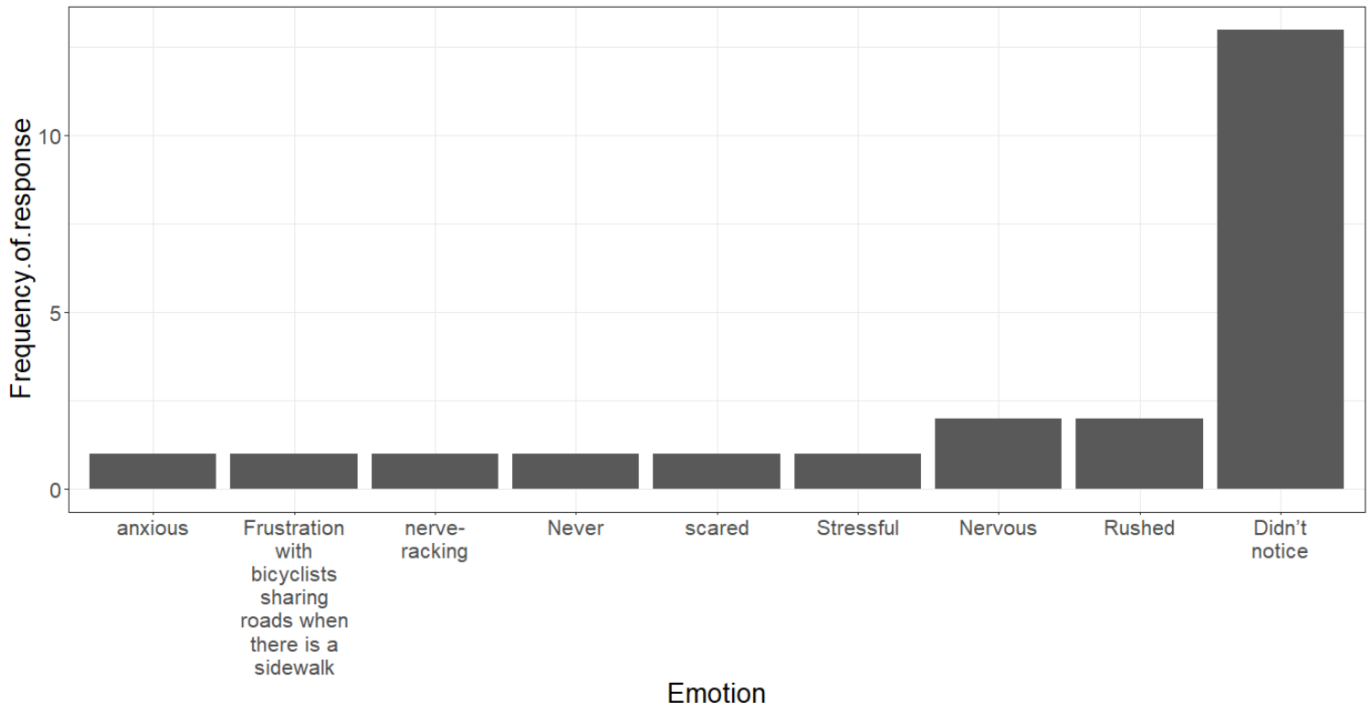


Figure 33 Frequency of emotions expressed by participants on missing out on VRUs

4.2.4.1.3 Community action on VRU

Most participants reported that they felt that the community should do more with regards to ensuring safety for VRUs. Another major factor reported was the need for sharing spaces through dedicated infrastructure. A few of the participants reported a lack of illumination, wider roads, need for crosswalks and bicyclist lanes as shown in Figure 34.

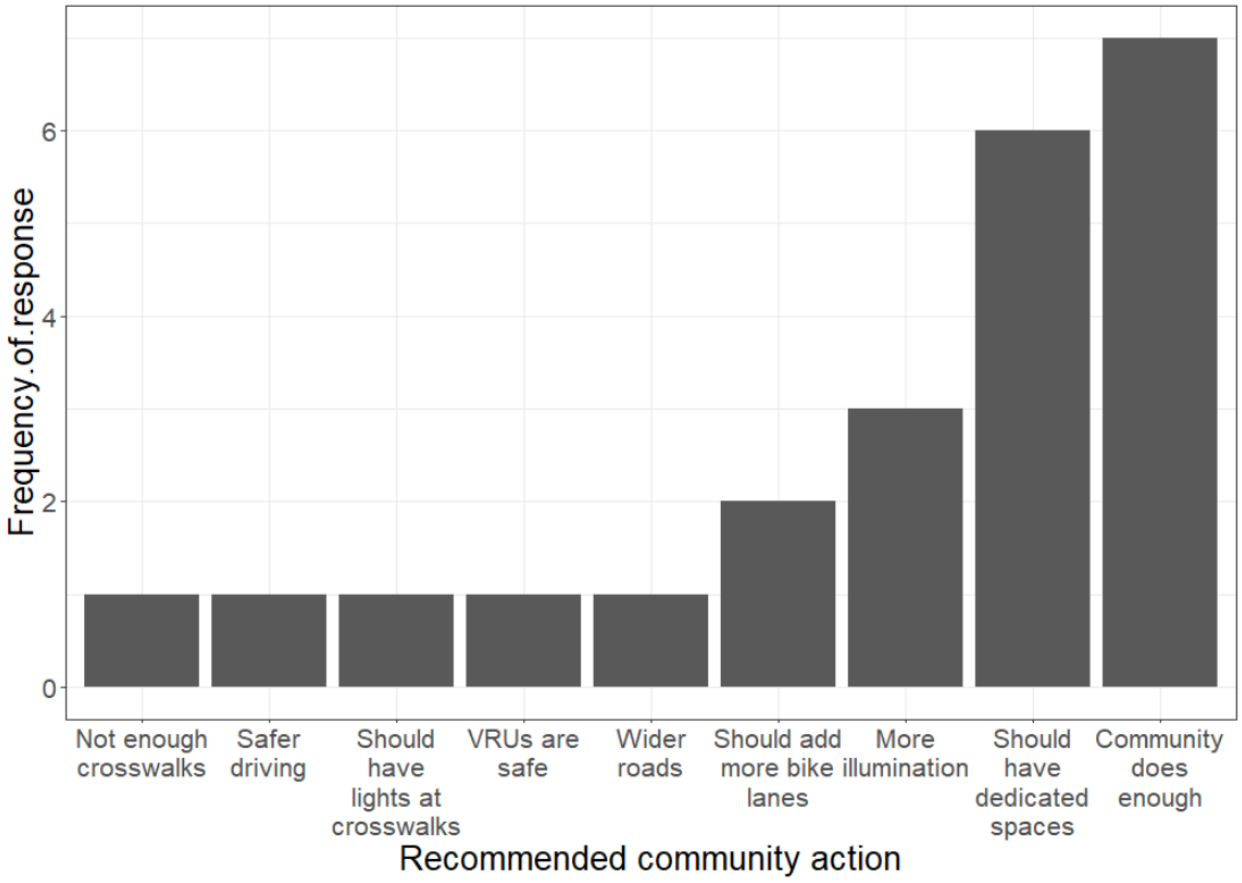


Figure 34 Frequency of community actions required from the participants' perspectives

4.2.4.1.4 Road design considering VRU

Like the previous section, most participants reported that they felt that the community should do more with regards to dedicated spaces, including road sharing and dedicated spaces on VRUs as shown in Figure 34.

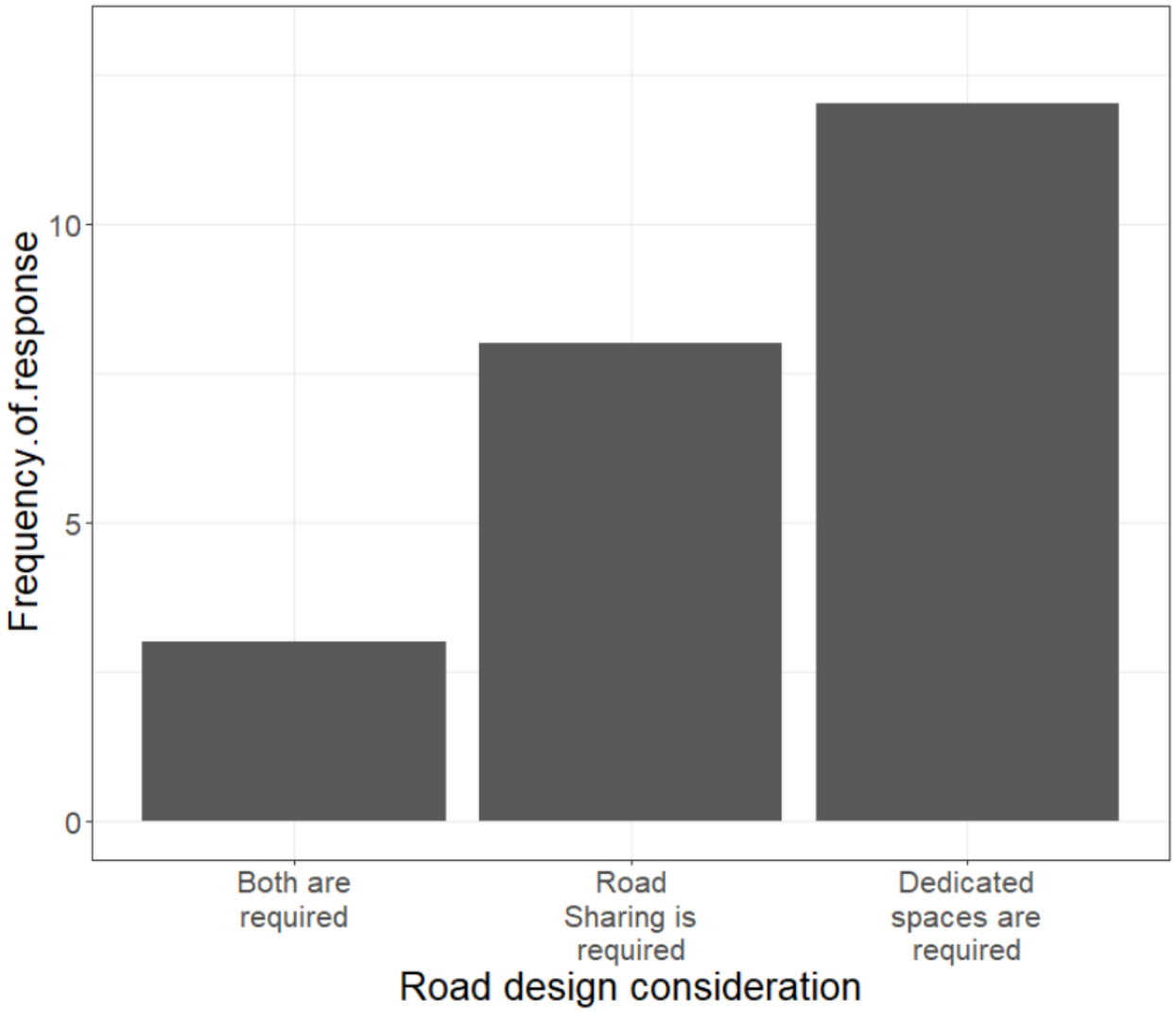


Figure 35 Frequency of responses on road design consideration

4.2.4.2 Responses from Week 2

As addressed earlier, this weeks' focus was towards creating an understanding of how drivers interact with pedestrians. The focus of the questions was around methods of drivers communication with pedestrians, approach towards pedestrians, and the drivers' perceived importance of trust for interacting with pedestrians.

4.2.4.2.1 Methods of communication with pedestrians

Many of the participants reported that the most common form of communication between drivers and pedestrians is the crosswalk flashing buttons, which alert the drivers. The rest of the participants reported gesturing through hand waving, flashing lights and beams, eye contact, readable signs, and slowing down at crosswalks. Another interesting observation is a focus of education to improve communication.

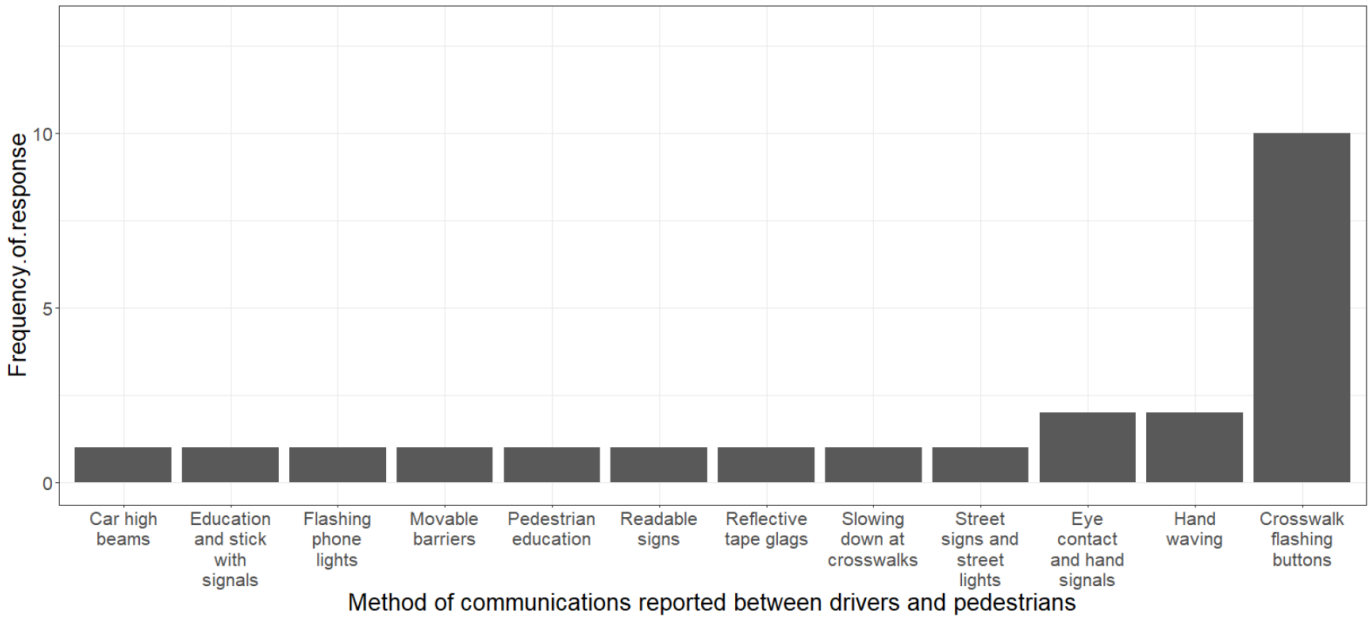


Figure 36 Frequency of participants reporting how they communicate with pedestrians while driving

4.2.4.2.2 How to approach pedestrians

Many participants slowed down and were attentive around pedestrian crosswalks and downtown areas.

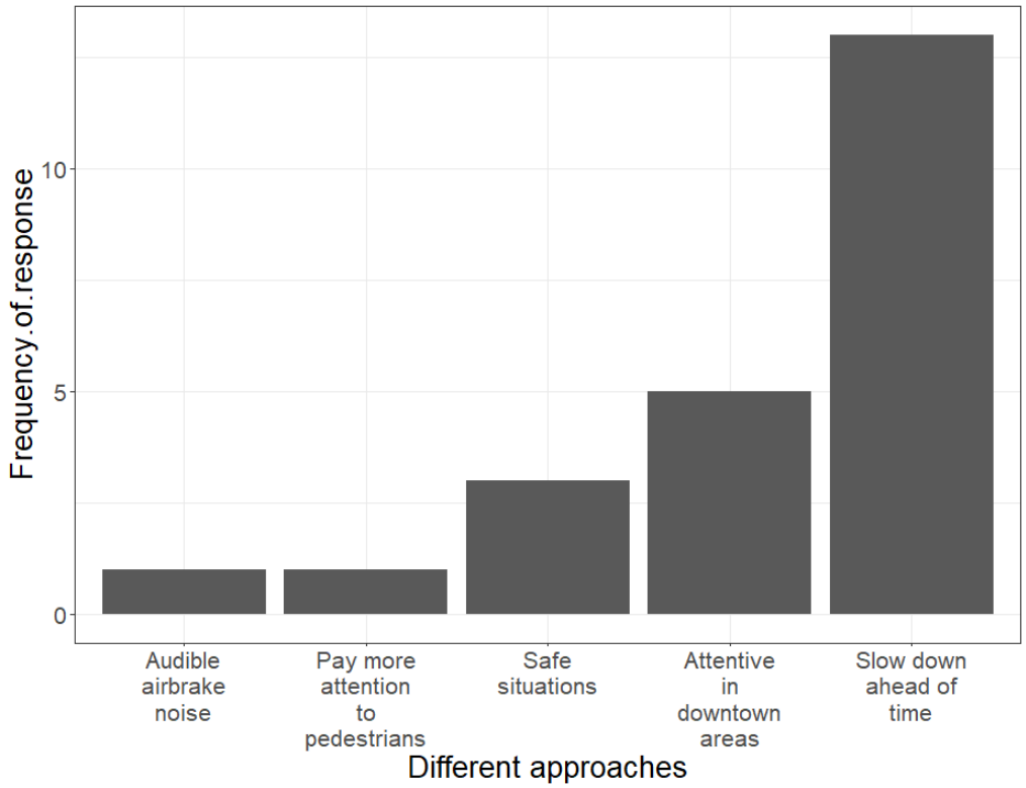


Figure 37 Frequency of participants reporting how they approach pedestrians

4.2.4.2.3 Importance of trust between drivers and pedestrians

Most participants reflected on the importance of trust between drivers and pedestrians, wholly or partially with regards to road sharing. Only one-third of the participants reported no importance of trust between the two road user groups.

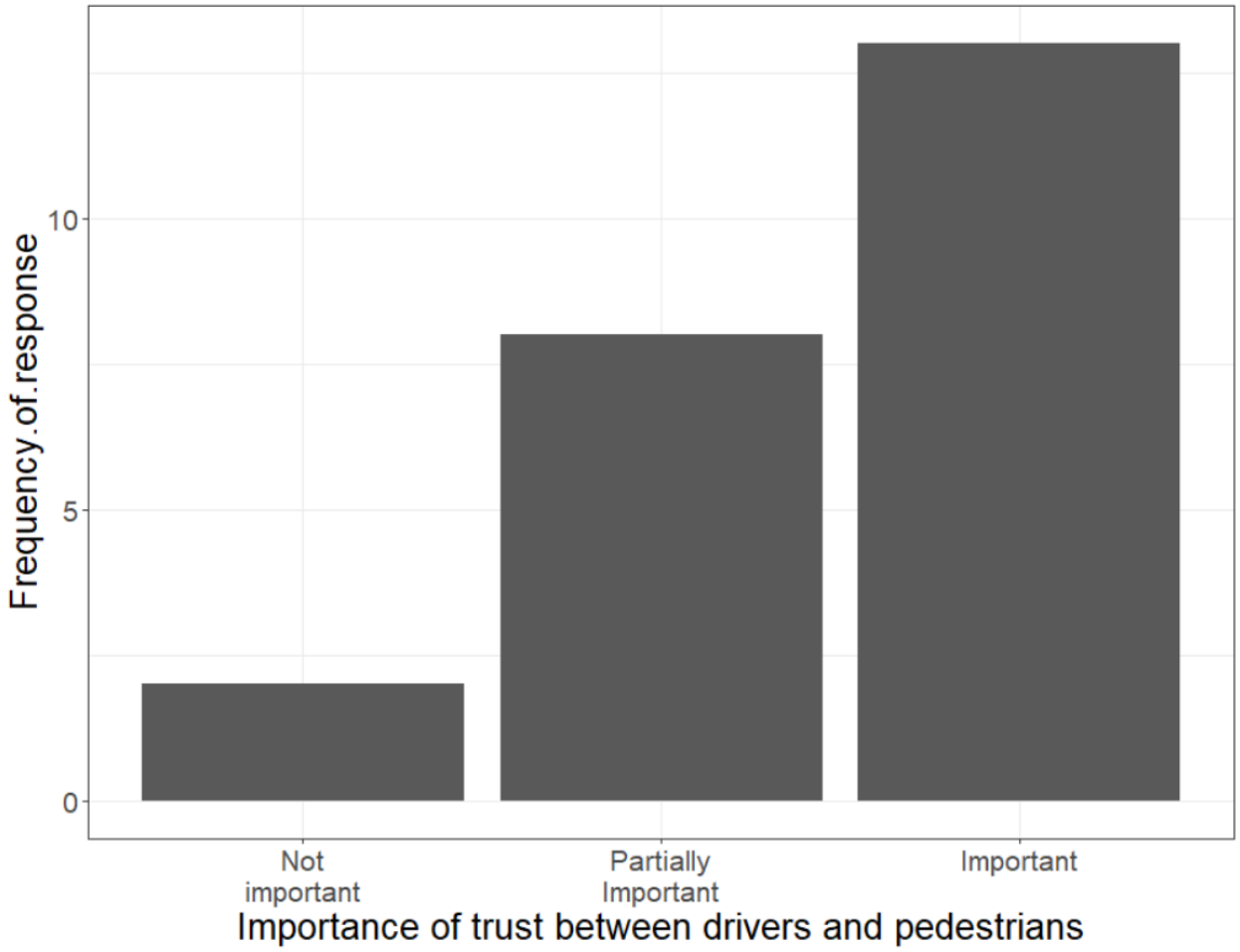


Figure 38 Frequency of participants reporting the importance of trust between drivers and pedestrians

4.2.4.3 Responses from Week 3

This weeks' focus was towards introducing ideas of road sharing with bicyclists. The focus of the questions was around how to share the roads with bicyclists, along with the merits and challenges of road sharing with bicyclists.

4.2.4.3.1 Should drivers and bicyclists share road

Many of the participants reported that they should share the roads to varying degrees when interacting with bicyclists. While participants agreed to share the road with bicyclists, a few participants were willing to share provided there were safe biking practices, more dedicated infrastructure, and increased driver

education. The rest of the participants were not open to road sharing, and some did not have a strong opinion either way.

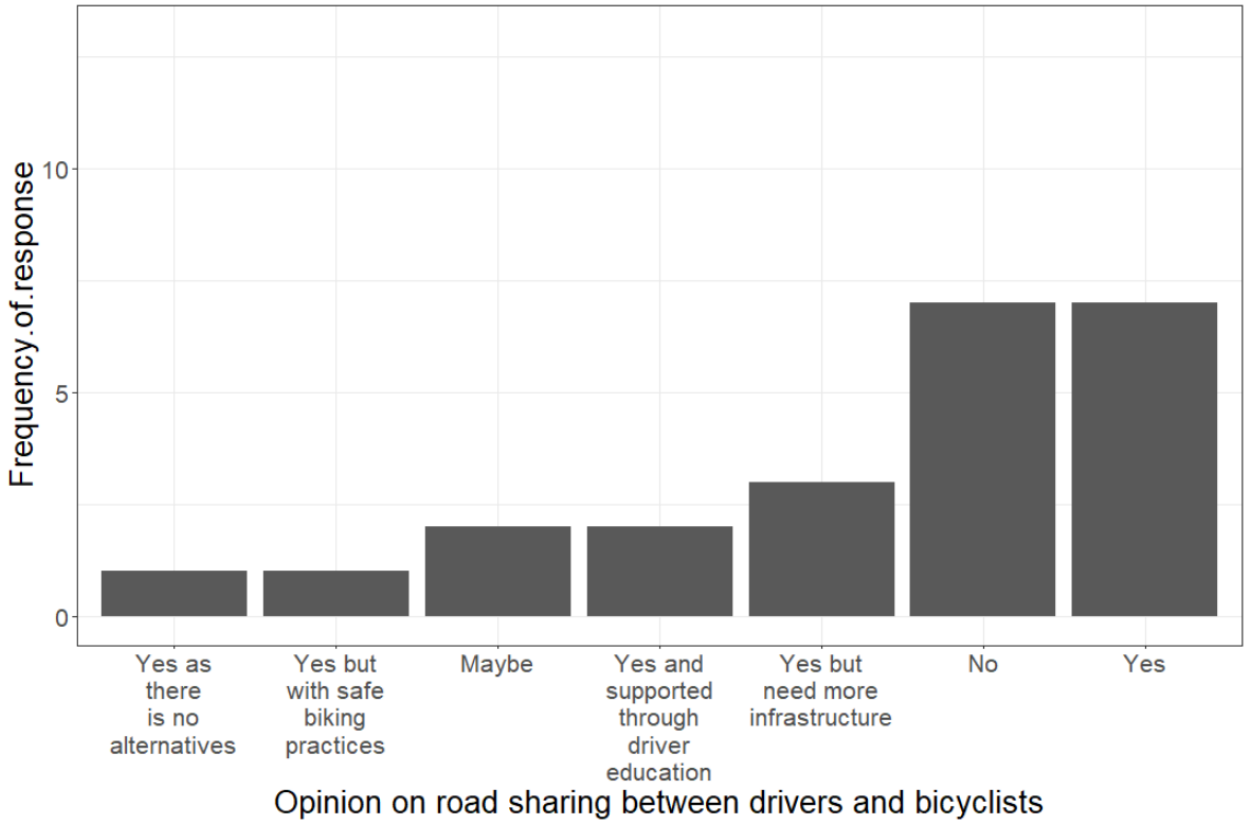


Figure 39 Response to opinion on road sharing with bicyclists

4.2.4.3.2 Nervous when bicycles are on the road

Many of the participants reported that they were nervous when bicyclists were on the road. A few participants were slightly nervous, while some participants did not express any nervousness with regards to bicyclists on the road.

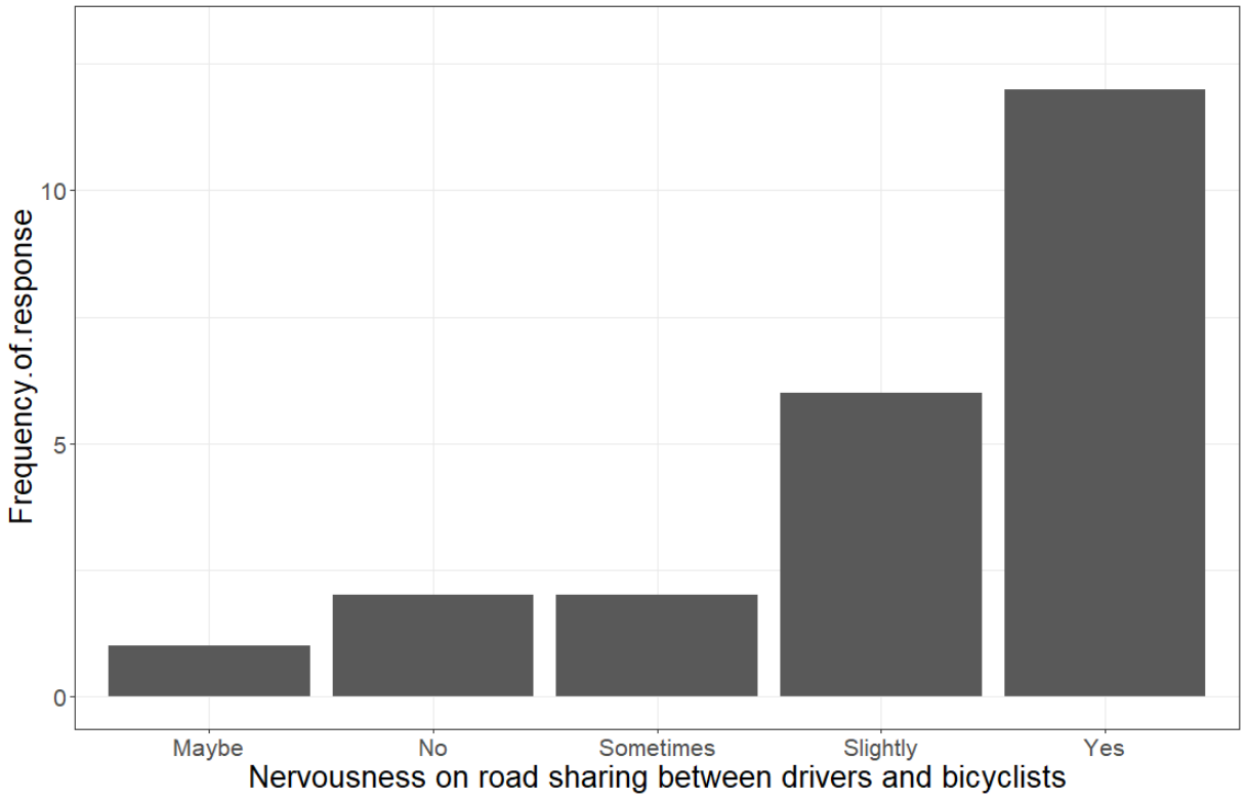


Figure 40 Reported nervousness of participants around bicyclists

4.2.4.4 Responses from Week 4

4.2.4.4.1 Add more mobilities in travel

Almost half the participants reported being in favor of adding more mobilities, whereas participants who reported not being able to add mobilities said it was due to a lack of infrastructure, personal physical state, or due to lack of comfort. A small number of participants were opened to commuting with more mobilities apart from driving, but it was conditional.

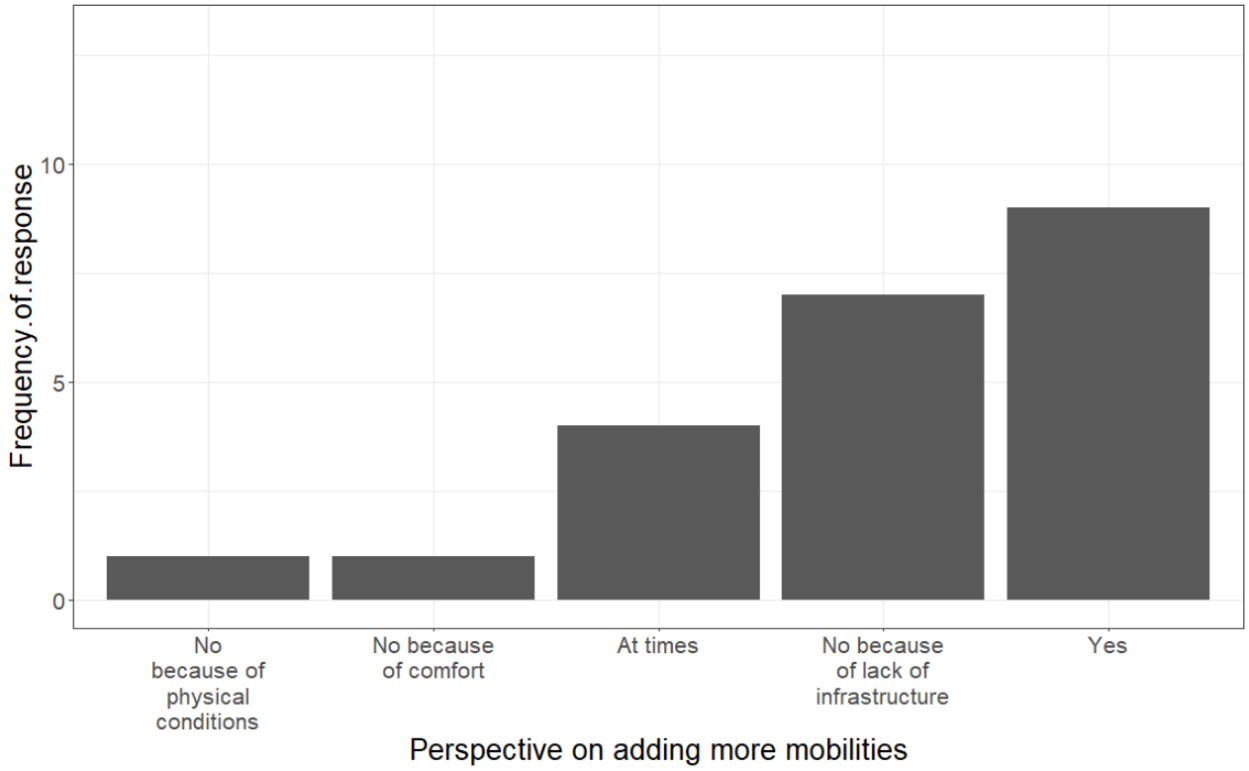


Figure 41 Participant response to whether drivers would add more mobilities to their commute

4.2.4.4.2 Opinions on dedicated infrastructure

Most participants expressed opinions on drivers maintaining more attention and caution, better need for infrastructure, slowing down on roads with no dedicated infrastructure, and using technology for safer

interactions.

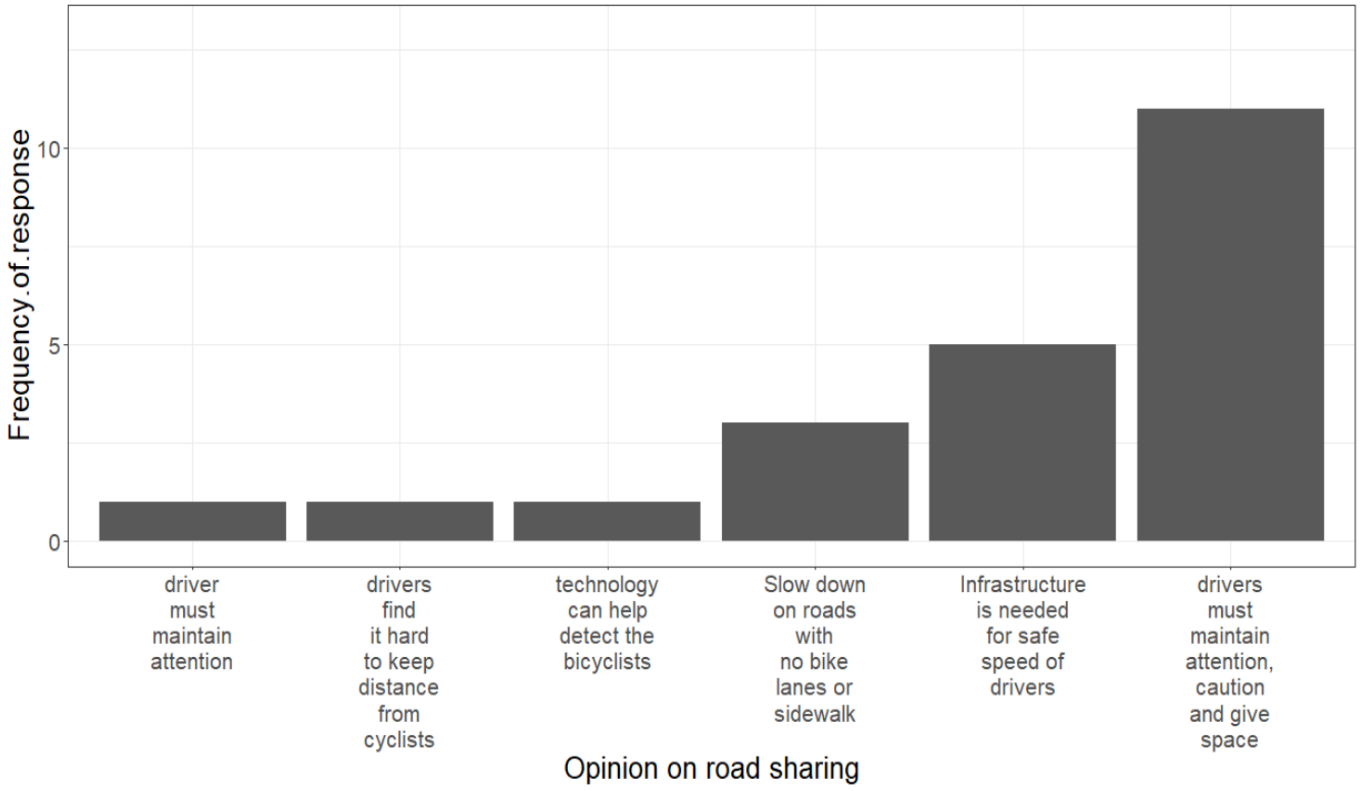


Figure 42 Response to opinions on road sharing

4.2.4.4.3 Challenges for VRUs with road sharing

Participants reported several factors that were potential challenges for VRUs when interacting with drivers. Many of the challenges were related to VRUs paying attention on the road, need for better illumination, need for VRUs to follow laws, and for incorporating education and awareness among VRUs.

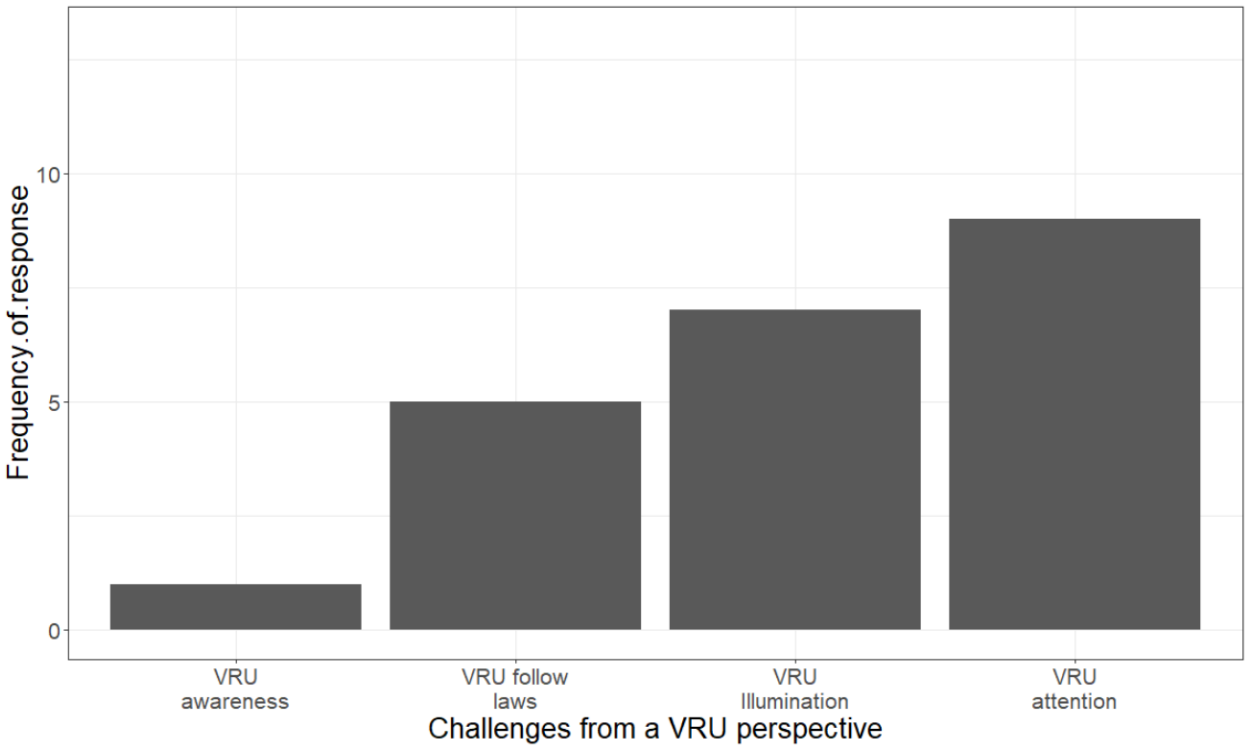


Figure 43 Challenges for VRUs for road sharing with drivers

4.2.4.4.4 Challenges for drivers with road sharing

Participants reported several challenges for drivers when interacting with VRUs, including, not acknowledging road sharing, the role of the driver and the traffic congestion when interacting with VRUs. Other challenges included lack of visibility, VRU recklessness, driver speeding, and inherent resentment towards other road users.

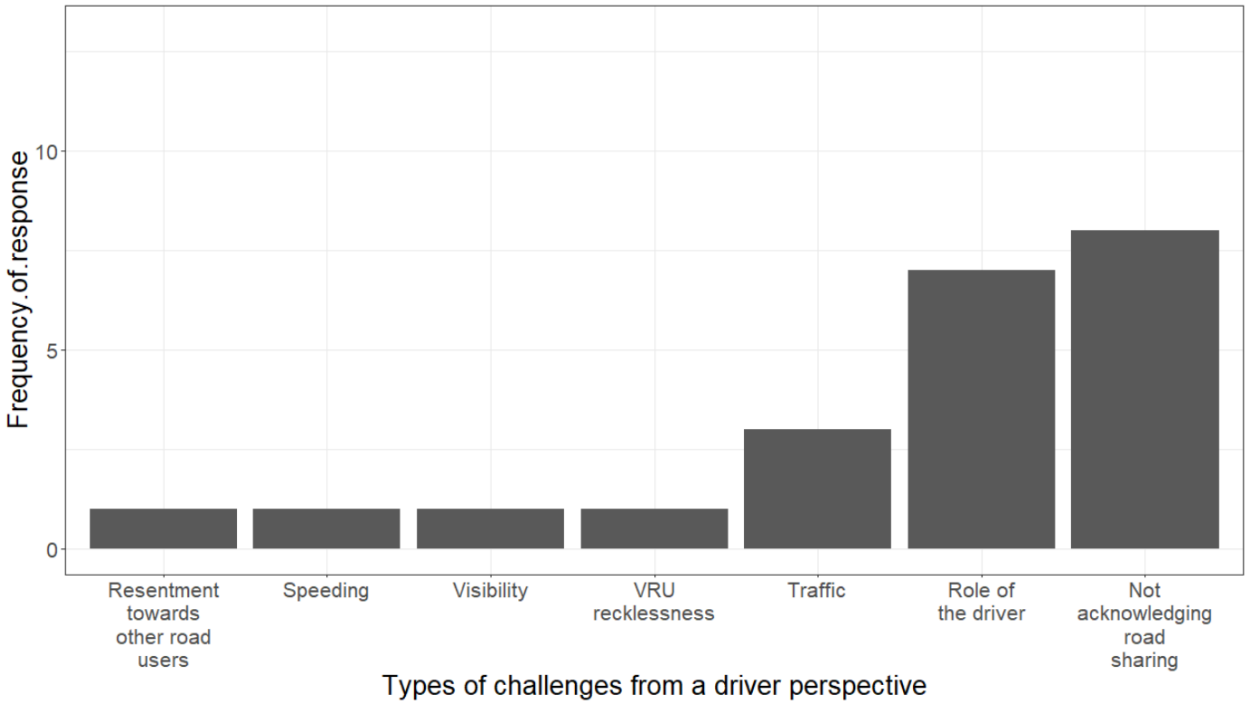


Figure 44 Frequency of challenges for drivers while sharing roads with VRUs

CHAPTER 5

DISCUSSION

5.1 Implications of the findings

This research explored the perceptions of VRUs from a young driver' perspective based on their interactions with VRUs. Qualitative interviews found prevalent themes, including young drivers' concerns when they interact with VRUs and their understanding of how they are expected to interact with VRUs. The research used the identified themes to design an intervention that would inform young drivers about VRUs. The outcome of this research is a novel methodology that supports safer driving behavior among young drivers when they interact with VRUs.

The background research explored the risk factors associated with young drivers, focusing primarily on inexperience and indulgence in risky behavior. The finding helped establish the importance of those factors, and their implications on driving performance were explored. In parallel, the background found the associated risk with VRUs, with a special focus on incorrect interactions with drivers. Through exploring the applicability of training and educational programs, the background established a case for a training intervention that could potentially improve interactions between different road users. While the applicability of training is well established in previous literature, the specific training towards VRUs is a novel contribution of this research. Additionally, the background work can be utilized for designing other studies, that could look to modify driving behavior for specific traits, like lowering speeding, smoother braking behavior, and better monitoring at intersections. McDonald et.al., (2015) leveraged the understanding of the perceptions of teen drivers towards designing programs to mitigate distracted behavior. Similar research has been explored by leveraging social influence on improving driving behavior (Roberts & Lee, 2012).

5.1.1 Findings from the interview study

The findings from the interview study examined young drivers to understand their perceptions towards VRUs. The results found young drivers tend to have a positive outlook towards VRUs in terms of negotiating shared spaces, stopping for pedestrians, and leaving spaces between themselves and bicyclists. However, it is interesting to observe that the young drivers are not clear on how to share spaces, and mostly rely on heuristics and observing how other drivers interact with VRUs. Additionally, young drivers are more comfortable with sharing spaces in an urban environment, as compared to a rural setting. These findings confirm that a lack of clarity on laws, and a lack of understanding of what spaces are to be shared with VRUs are important factors that need to be addressed. We considered these findings in designing the intervention.

5.1.2 Design of the intervention and experimental design to assess its efficacy

As described in the earlier chapter, the intervention was designed to consider the gaps in the information reported by the participants in the interview study. The previous section identifies the gaps in terms of interactions with pedestrians, bicyclists, and lack of awareness on shared spaces. Therefore, the content of the intervention had a clear focus on providing the appropriate information that could address the gaps. The content was made to be interactive, detailed, and focused on the addressing the details of the information that they reported. The medium of delivery considered how participants may develop responsiveness to the content associated with the intervention, and ensuring the quality, efficiency, utilization, access, learning, and sustainability of the delivered intervention (Bradley et al., 2010). The delivery of intervention was individualized, and was made accessible by developing and hosting the intervention as a web application through Shiny apps on R (Chang et al., 2021). The content was delivered through emails that presented the information (i.e., a link to the website) and elicited responses over the survey. The progress was tracked by the researcher to ensure that the participant viewed the intervention and follow up email conversations ensured individual compliance. It was also done to ensure that the strict social distancing and protective measures introduced in the state of Massachusetts due to the COVID-19 pandemic were adhered to. To

compare the efficacy of the intervention content, another group of participants received a control, which included comparable information to the intervention which is publicly available at the NHTSA government website. One group did not receive any treatment, and they were only asked to report the information.

5.1.3 Impact of treatment on self-reported driving behavior

Participants who received the intervention or the control showed a lowering of violations over the intervention period compared to those who received no treatment. Additionally, participants who received the intervention or control had more lapses than those who did not receive any treatment. The findings confirm that any treatment helped inform the young drivers about potential violations, which may have a higher implication on their driving in receiving citations. Peck (2011) found that training programs have had a significant beneficial effect on crashes and violations irrespective of the demographics. It is also worth noting that the study was conducted during the pandemic of COVID-19, wherein a larger number of the population is using different modalities of travel, e.g., more people walking and cycling (Now, 2020). This phenomenon may have contributed to different perceptions of participants towards VRUs, which may explain the anomalies in the results. However, such comparison needs to be done after the pandemic to establish the precise effect of the pandemic on perceptions.

5.1.3.1 The anomaly of lower violations for those who received control content

An interesting finding of the study was the overall lower violations observed for participants who received the control, compared to participants who received the intervention or no treatment. Upon reflection, a possible reason for this phenomenon could be attributed to more self-awareness among participants who received the intervention. In other words, the intervention may provide more insights to the participants, and then they may estimate their behavior according to their updated understanding towards interactions with VRUs. In comparison, the participants who received the control content may overestimate their driving ability, or then mistakenly underreport violations. While this may explain the potential anomaly, future studies could monitor the progress of the participants, and assess if the drivers are correctly estimating their abilities.

Another reason for this potential anomaly could be associated with the nature of the treatment themselves. As described in Chapter 4, the design of the intervention is based on the findings from the previous studies, and the design of the control content is the compilation of existing materials that covered similar themes to those presented to participants who received the intervention. It is possible that the lack of a definitive effect due to the treatment group, could be attributed to the potential similarities between the intervention and control group content. The reason could be that if there is a treatment, there is an effect.

5.1.3.2 Aspects of different treatment that may influence the VRU perceptions

Any type of treatment (intervention/control) results in improving the self-reported driving behavior amongst drivers. While this is a positive result, the findings do not correctly illustrate the impact due to the individual differences between the different types of treatments (Intervention/Control). It is therefore necessary to understand if there could be potential reasons for this observation. One reason for the lack of differences could be the similarity in the content which has been explored in the previous section. However, another reason could be attributed to participants finding the fixed content of control easier to perceive and read. Most participants may find it easier to go through and read the content and may not fully appreciate the interaction and visual content of the intervention. At present, the survey did not quiz the participants on these differences, but it could be a dimension to explore for future researchers.

Along similar lines, the participants may find the static files delivered over emails easier to access, read and review in comparison to the intervention, where the participants may be required to go to a link and explore a lot of content. This may be a potential reason why even though the content in the intervention may be more comprehensive, the convenience of reading and reviewing the content over static files may have more influence. It is worth noting that these are all potential reasons to explain the observations from the study, however, truly knowing whether an intervention worked can only be established through future studies.

5.1.4 Impact of treatment on participants with prior citations

The analysis found that citations influenced the errors, violations, and lapses. Participants who received no citations had an overall higher error, lapses, and violations than those who received a single citation. While there are very few studies that have focused on the impact of citations on future violations, evidence suggests that introducing educational programs may influence the future violations among the young driver population (Hassan & Abdel-Aty, 2013). However, most of these studies have focused on survey responses, and validating them with driving data may provide helpful conclusions. A significant relationship was the influence of the average sensation-seeking score on the violations. Aggressive driving has been found to impact excessive speeding, the likelihood of citations, and potential crashes (Lambert-Belanger, Dubois, Weaver, Mullen, & Bedard, 2012). This may help explain that their personality may influence the behavior of young drivers.

An interaction effect was observed between the type of treatment and the week of intervention for violations. While there are no significant differences observed for participants who received the treatment and no treatment, there is a sharp decrease in the mean of violations for the control group. A possible explanation for this phenomenon could be better awareness of the intervention group about the type of interactions they have with VRUs, compared to the control group, who may not completely comprehend all facets of interactions and may underreporting. However, there is no way to account for such a phenomenon in the current framework, and it remains a limitation of the current study. Participants who received the control had lower lapses with an increase in the annual miles driven. However, participants who received no treatment were observed to have higher lapses with the increase in the annual miles driven. This may be explained by the influence on education programs that may help inform the drivers about their performance and lead to lower lapses.

5.2 Limitations and Future Work

This research has proposed an intervention-based approach that helped improve the perception of young drivers towards VRUs and thereby help facilitate safe interactions. While this approach has shown promise

and addresses a problem which has not been researched extensively, there are inherent limitations to this research. This section is focused on exploring different limitations to the current work. Additionally, the future work that is informed by these limitations is discussed.

5.2.1 Understanding the perceptions of young drivers

The current research has been able to interview and understand the perceptions of young drivers. However, the approach leverages semi-structured interview format to understand their perceptions. These perceptions are then tallied with the prevalent themes, which are presented in the current intervention. However, one step this research overlooks is to validate the themes with the interviewees. This would ensure that the design of the intervention is validated with a population of young drivers, which would help assess their understanding of what would help with their education. Additionally, the qualitative data analyzed was not validated by a secondary researcher. Future studies must ensure that coding is validated to ensure that the results were reliable. Future studies could leverage techniques such as focus groups, participatory design methods, heuristic evaluation and A/B testing to evaluate the intervention content, to assess the presentation and prioritization of the content. Additionally, this technique would also help evaluate the interaction of the intervention.

5.2.2 Delivery of the intervention

The current delivery of the intervention is through an online delivery system. While, this is an effective delivery mechanism, it is critical that future studies capture the areas of the intervention that were assessed by the participants in more detail. Existing technologies can help capture the level of interaction for each user around the application and can help inform researchers about the focus areas for each week's intervention content. Future research could capture the interaction information and eye glance behavior towards the intervention content to validate parts of the intervention that participants paid more attention towards, as compared to those which were skimmed through.

5.2.2.1 Content and delivery for future assessments

While measuring the level of interaction can help understand the efficacy of the intervention, there are potential changes that can be done to make the intervention more interactive. For instance, to assess the efficacy and interaction of the participants towards the intervention, in-person delivery can help assess different aspects of the intervention. Due to the constraints of the pandemic, this was not possible at the time of the assessment and delivery. Additionally, presenting the information through aspects of gamification can help personalize the learning experience and may have more efficacy than the present version of the intervention (Orji, Tondello, & Nacke, 2018). Additionally, utilization of a focus group/in-person intervention delivery mechanism can help the experimenter understand the subtle differences in terms of the types of questions and discussions that the participants may have due to engaging with the content.

5.2.3 Evaluation of the intervention

The current evaluation is based on the survey-based data collection, which helps assess the propensity of errors, violations, and lapses that the participant may commit each week. While survey methods have efficacy in determining the driving behavior, use of simulators can provide better information about the efficacy in terms of driving behavior. Additionally, recording the young drivers naturalistic driving behavior can help understand efficacy. This study has considered data for twenty-two participants over the summer, which may not be completely representative of the population. Considering a medium effect size, and larger population sample may help assess efficacy better. A follow-up completely randomized controlled trial with larger samples may also be beneficial.

5.2.3.1 Improving the method of evaluation for future assessments

For assessment of the efficacy, participants could be required to log their driving activities on an electronic record and comply with how they have performed each week. They would also be required to record how long, and which alternate mode of transportation they used instead of driving. Additionally, participants who be required to participate in driving simulator studies that study the interactions that the

participants may have with pedestrians and bicyclists. Measures may include time to braking, lane positioning with bicyclists, speeding behavior around pedestrian zones, and the overall attentiveness of the drivers. Additionally, for all the assessments, a baseline measurement would be added to ensure that the true nature of the participants is recorded to compare the individual performance trajectories more efficiently.

To assess the overall efficacy of the intervention, periodic assessments could be done to assess if the information shared had a longer-term impact on the driver. Conducting follow up analysis, over time periods of 3 to 6 months, may provide researchers with an understanding of persistence of the impact of the intervention, which could be a great indicator for the overall impact of the treatment.

5.2.3.2 Consideration of different population groups for future assessments

A larger more diverse population of non-college students, more participants across genders, demographics and different driving experiences may help create a better understanding of the efficacy of the intervention in a comprehensive manner. In addition, it is important to observe as shown in the results, participants who received the intervention had reported that they drove fewer trips per week, as compared to other groups. Responsiveness to the different treatments could be attributed to the different behavior observed amongst the different groups, which could be a potential pitfall of randomization where simple randomization may not completely account for such differences. It could be worth exploring the possibility of using a different sampling method, which could help account for potential differences between the groups.

5.3 Conclusion and contributions

VRUs comprise 27% of all traffic-related fatalities in the world, according to World Health Organization and World Bank reports (World Bank & World Health Organisation, 2013). Conflicts between different road users cause crashes, and injuries involving cars and VRUs are rising (Bella et al., 2017; Bieshaar et al., 2018a; Shinar, 2012). The increase in the fatalities involving pedestrians (Balk, 2014) and year-on-year increase in bicyclist fatalities (Stimpson et al., 2013) have forced the larger research community and policy makers to innovate on how to lower this crash rate. Considering the rise in crashes

related to VRUs, and a focus of cities to push for more shared spaces (Laplante & McKann, 2008), it is imperative that the problem of facilitating safer road user interactions is studied. Additionally, programs should be designed to help improve road users' perceptions and lower a potential crash and subsequent fatalities.

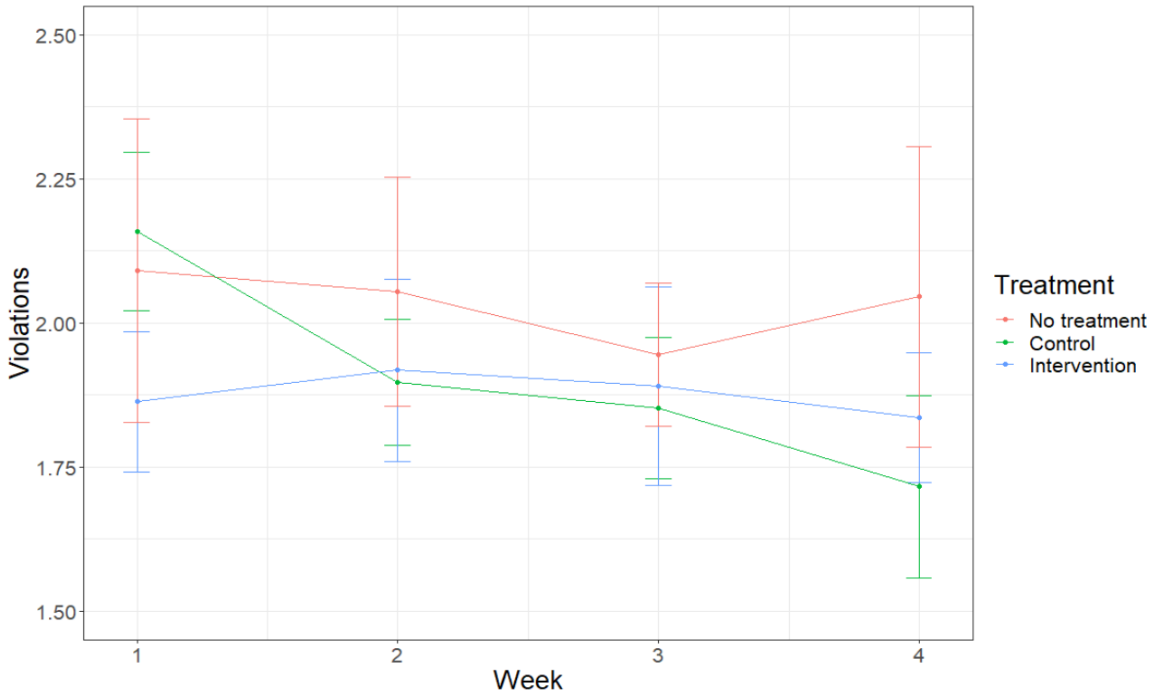
This research proposes a novel intervention that helps understand and improve the perceptions of young drivers towards VRUs. Young drivers have been found to have a higher likelihood of crashes, and therefore may put VRUs at a higher risk. Through interviews, this research was able to identify the critical perceptions of VRUs amongst the young driver community. It is essential to consider these perceptions, as it values their practical experiences, and translating those perceptions into actionable training programs can help target the specific interactions to ensure a higher efficacy of any future training. An example from this research was the interview study's reported hesitancy of young drivers while approaching pedestrian crossings. The intervention during the week on pedestrian-related information laid down a significant emphasis on the laws, types of interactions, and expected behavior from the driver towards approaching pedestrian crossings. While the efficacy of these specific interactions can only be measured through actual driving behavior, it is crucial to provide a framework that can facilitate those measurements in the future. This research provides a formal framework for improving and assessing similar critical interactions. A contribution of this research is to lay down continuous assessment tools created to measure the efficacy of the intervention. The tools allow for continuous education and assessment in the context of young drivers, an approach that can be used for designing future interventions that may help influence young drivers towards positive driving behavior. Another contribution is finding the influence of citations on potential future violations by the participants who received the intervention. This may inform how future drivers who have received citations may be provided with supplementary training to help improve their behavior.

Overall, this research contributes towards informing the design of future training for young drivers, drivers who may require specific training regarding VRUs, and helps continuously assess their progress over the intervention period to track the efficacy. The research has broader implications on informing the

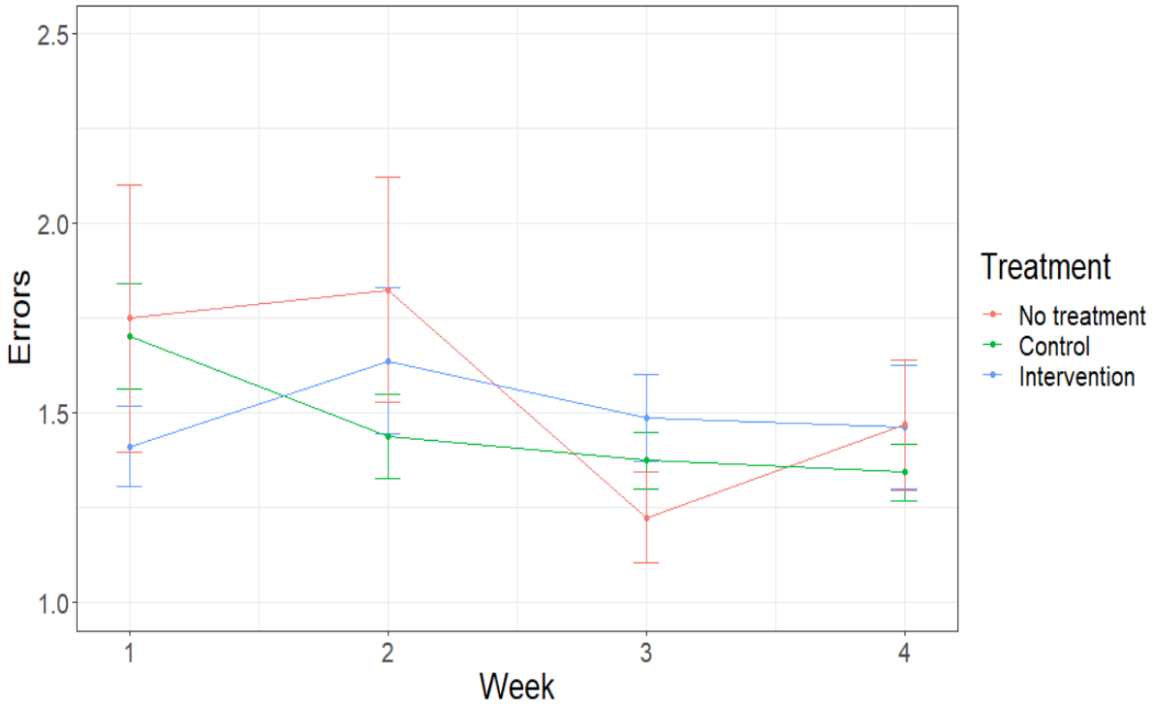
design of the training programs and can help shift the perceptions of young drivers from nervous towards confident while interacting with VRUs. This research could potentially contribute towards streets genuinely belong to all road users and not just vehicle owners.

APPENDIX

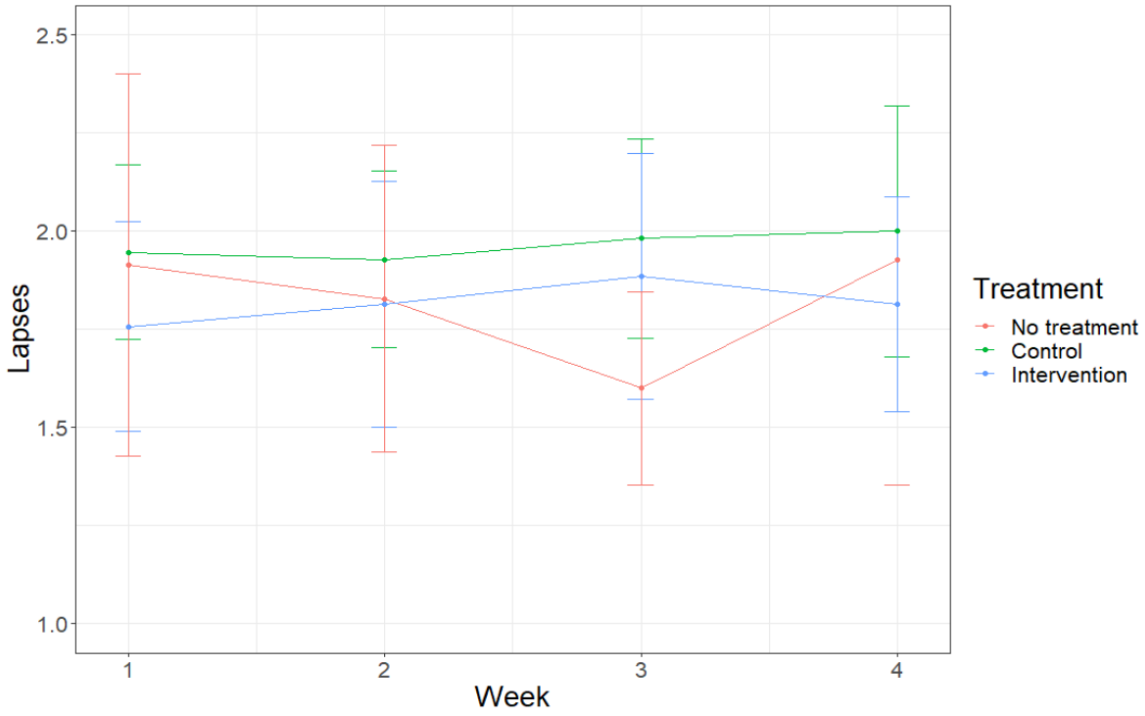
A1. Distribution of Dependent variables by treatment type



The graph above shows the differences between the groups with regards to the self-reported violations each week. The analysis found that for participants who received a treatment, had different responses with regards to the violations. Participants who received the control had lower violations, there were no major changes to the intervention, and those who received no treatment reported higher violations.

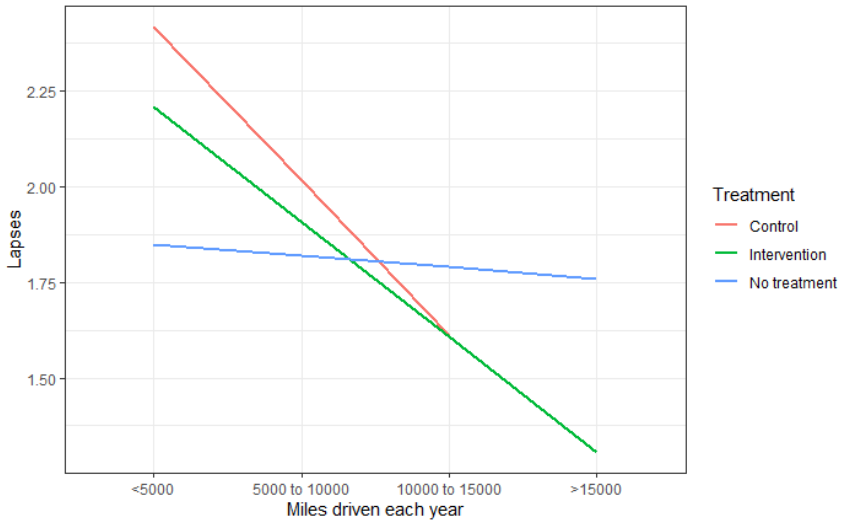


The graph above shows the differences between the groups with regards to the self-reported errors each week. The analysis found that for participants who received a treatment, had different responses with regards to the errors. Participants who received the control had lower errors, there were no major changes to the intervention, and those who received no treatment reported lower errors after week 2.



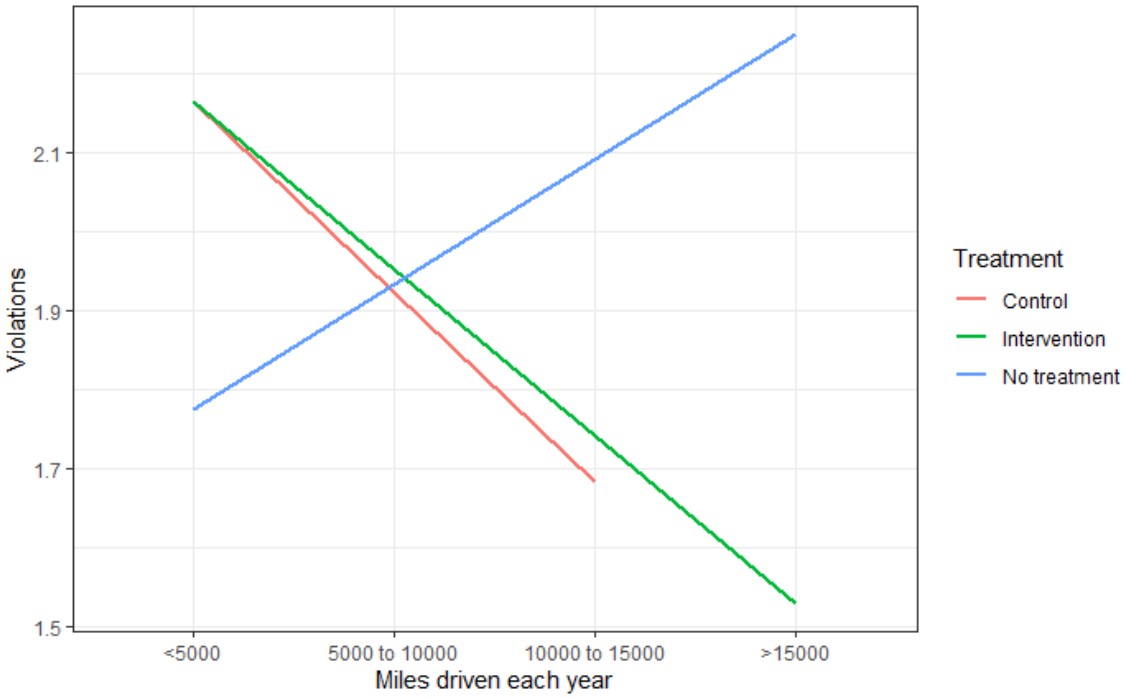
The graph above shows the differences between the groups with regards to the self-reported lapses each week. The analysis found that for participants who received a treatment and control had almost no changes reported in their self-reported lapses. However, participants who received no treatment showed initial decrease and then an increase in the lapses.

A2. Follow up analyses on significant independent variables by treatment type



Relationship between annual miles driven and Violations by each treatment

The graph above shows the differences between the groups with regards to the annual mileage and the self-reported lapses. The analysis found that for participants who received a treatment, they had lower lapses. There was very little decrease in the mean lapses for participants who did not receive any treatment.



Relationship between annual miles driven and Violations by each treatment

The graph above shows the differences between the groups with regards to the annual mileage and the self-reported violations. The analysis found that for participants who received a treatment, they had lower violations. There was an increase in the mean violations for participants who did not receive any treatment.

A3. Methodology – Weekly Intervention as presented to the participants

Week One: Who are vulnerable road users?

Instructions for the course

Welcome to this short course on improving your ability to share roads with vulnerable road users. The purpose of this course is to introduce drivers between the ages of 18-20 to the complexities of interacting with vulnerable road users, understanding the changing landscape of road sharing, and how to improve your perceptions of vulnerable road users. This is week 1 of the course. There will be a total of 4 weekly courses that will look to cover the basic concepts. It is important to make a note of a few important points:

• Please read the content carefully each week. Each reading will teach you about interactions with vulnerable road users

• The course will help you get a better understanding of how to interact with vulnerable road users.

• After completion, you will be required to share your understanding of the course material. The questions will be listed under a section called reflections. You will be given a link to share your reflections.

• After each module, you will be sent a survey with questions that are based on the week's content.

• In case you find a lack of clarity in any of the materials, please reach out to Shashank at smehrotra@umass.edu and he will respond to your questions

Who are vulnerable road users?

Vulnerable road users include pedestrians, bicyclists, and scooter users. The vulnerability of road users refers to how likely they are to get hurt when involved in a crash. More vulnerable road users are likely to face more injury or harm when they are involved in a crash The reason for vulnerable road users risk is because of two distinct disadvantages:

they are exposed and have no shield to protect themselves in case of a collision (except for helmets being worn by bicyclists),

the difference in mass between them and cars/trucks, with whom they may collide, is very large.

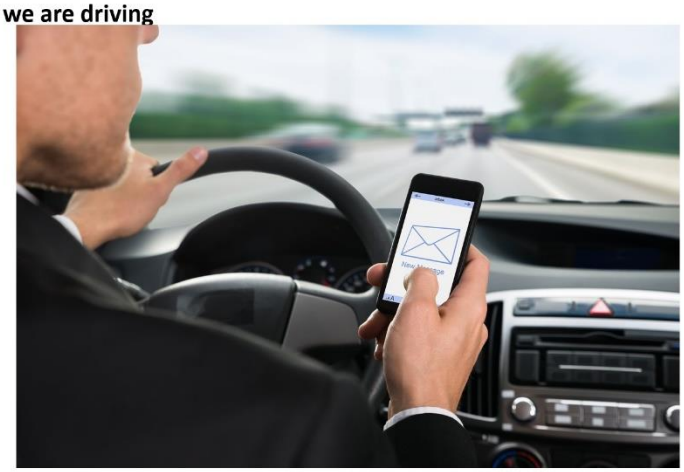
Typical road users navigating their commute. [1]

Understanding risks associated with road users

Crash risk is pertinent for all road users, irrespective of their vehicle, or mobility. Drivers must understand that while other road users are more vulnerable, it does not mean that they have higher crash risk. Drivers are more likely to be impaired (e.g., under the influence of alcohol, distracted, or fatigued), non-compliant (e.g., not wearing a seatbelt or speeding), or lack experience/ability (e.g., teen and older drivers), which may increase their crash likelihood. This is incredibly important to grasp as it tends to be a common misconception that vulnerable road users have higher crash risk. All road users must reduce crash risk, which can lead to better interactions between different road users. However, the vulnerability of other road users remains the same and thus needs to be understood and respected.

We are all at risk when we are on the road…

- When we are driving



- When we are walking

- **When we are biking**

- **When we are trying out a new scooter**

References [2][3][4][5]

Select the type of road user to understand the risks associated with them

Types of road user(s)

Driver

Driver

Drivers are more likely to be impaired (e.g., under the influence of alcohol, distracted, or fatigued), non-compliant (e.g., not wearing a seatbelt or speeding), or just not at risk due to lack of experience or due to aging (e.g., teen and older drivers), which may increase their likelihood of crashes.

Why does the problem exist?

Crashes with VRUs while constituting a small portion of the total number of crashes, are over-represented in the proportion of severe injuries and fatalities. Several reasons can be attributed to this fact. Select from the dropdown to explore possible reasons for this problems.

Potential factor(s)

Infrastructure

Infrastructure

Some of the crashes can be related to poor infrastructure design, which could explain a lack of communication between drivers and pedestrians.

Reflections

Think about times when as a driver, you may have missed out on a VRU which may have resulted in you getting nervous. Describe that scenario and think of what you felt you could have done better in your driving?

Do you think your community does enough or should do enough for the safety of VRUs? If yes, do mention what do you think they do consider. If not, what would be your suggestions?

Do you think roads should be designed for sharing or should we only have dedicated spaces for pedestrians, driver's and other mobility users for safety?

References

[1] https://commons.wikimedia.org/wiki/File:Cyclists_on_Queen_Toronto_2010.jpg
[2] https://www.bostonglobe.com/metro/2019/01/22/gov-baker-proposes-ban-handheld-cellphone-use-while-driving/ZBUWIBjxnLstojpB4COTvN/story.html
[3] https://www.bostonglobe.com/metro/2015/05/22/boston-commuters-love-walk-work/aXMxiG1kgr6TZ5pxRrGH0N/story.html
[4] https://www.nytimes.com/2009/08/09/us/09bike.html
[5] https://www.bostonglobe.com/metro/2019/04/01/brookline-launches-electric-scooter-pilot-program/yz4pcGSAV8THoZeIclZB9L/story.html

Week Two: An introduction to issues related to pedestrians

Instructions for the course

Welcome to this short course on improving your ability to share roads with vulnerable road users. The purpose of this course is to introduce drivers between the ages of 18-20 to the complexities of interacting with vulnerable road users, understanding the changing landscape of road sharing, and how to improve your perceptions of vulnerable road users. This is week 2 of the course. There will be a total of 4 weekly courses that will look to cover the basic concepts. It is important to make a note of a few important points:

• Please read the content carefully each week. Each reading will teach you about interactions with vulnerable road users

• The course will help you get a better understanding of how to interact with vulnerable road users.

• After completion, you will be required to share your understanding of the course material. The questions will be listed under a section called reflections. You will be given a link to share your reflections.

• After each module, you will be sent a survey with questions that are based on the week's content.

• In case you find a lack of clarity in any of the materials, please reach out to Shashank at smehrotra@umass.edu and he will respond to your questions

Problems related to pedestrian interactions in the United States

Crashes between drivers and pedestrians, while small, have a higher injury and fatality risk. As discussed last week, pedestrians are less protected in a crash. This problem not only exists in the United States, but also in other developed/industrialized countries. In developing countries, most of the population consists of pedestrians as compared to industrialized countries where the pedestrian population is substantially lower.

Researchers have found that the higher rate of pedestrian fatalities in developing countries as compared to US, Europe etc. can be attributable to:

Researchers have found that the higher rate of pedestrian fatalities can be attributable to:

lower socioeconomic status in developing countries

lower infrastructure in developing countries

low urbanization in developing countries

higher motorization in developing countries

When more industrial countries have lower pedestrian injuries, and more motorized countries have higher pedestrian injuries, then what does it mean in the larger scheme of things? The answer is an inverse relationship between the risk of being killed as a pedestrian and the level of motorization and affluence, what is referred to as Smeed's Law. In essence, what it implies is that as people have more money, they tend to complete more trips using cars and fewer trips while walking. The consequence is that people in poorer communities tend to be at a higher risk as pedestrians as compared to richer communities.

How to understand if a pedestrian is at risk?

These factors can help us understand the level of risk associated with being a pedestrian. Based on the table presented, we can get a rough understanding of which pedestrians tend to be at a higher perceived risk

Factor	Criteria	Learning
Age	Young	Lower risk
	Old/children	Higher risk
Type of Road	Narrow	Lower risk
	Wide	Higher risk
Time of Day	Daytime	Lower risk
	Nighttime	Higher risk
Signalized/Non-Signalized	Signalized	Lower risk
	Non-signalized	Higher risk
Weather	Cold weather	Higher risk
	Warm weather	Lower risk

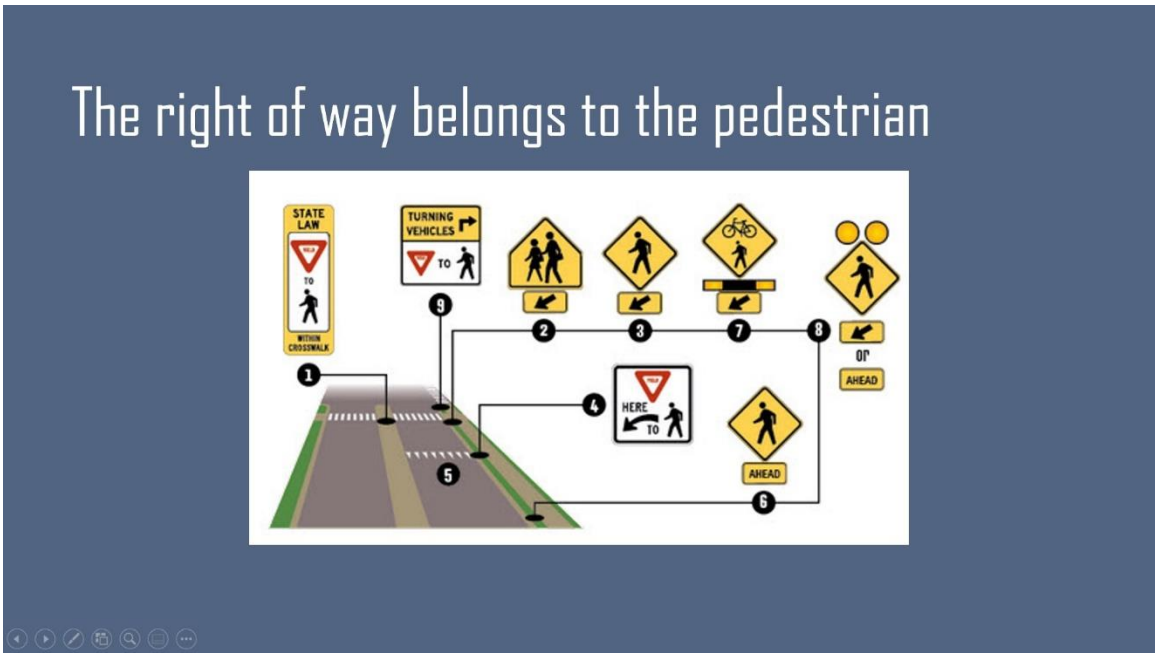
Different factors impact on pedestrian risk

How to interact with pedestrians on the road?

Following the laws

The driver must yield the right of way, slow down or stop to yield to a pedestrian crossing within a marked crosswalk. A driver cannot pass any other vehicle that has stopped at a marked crosswalk to permit a pedestrian to cross. Failure to comply results in a fine of not more than $200.

The image below describes the typical signages that help drivers yield to pedestrians.



The description of the right of way. [1]

Resolving other potential conflicts

We will discuss potential conflict scenarios with pedestrians. Select a scenario and we will observe the potential resolution. These seven scenarios are important to understand the potential conflicts between pedestrians and other road users.

Potential scenarios(s)

Scenario1

Scenario1

Pedestrian Action: Pedestrians leaning forward or beginning to move Driver Action: Driver slows down/stops for the pedestrians Communication: Implicit Potential conflict: Misinterpretation between pedestrian and drivers

Here is a summary of all the scenarios that describe the explicit and implicit communication between pedestrians and drivers.

Pedestrian actions	Driver actions	Communication	Potential conflicts
Pedestrians leaning forward or beginning to move	Driver slows down/stops for the pedestrians	Implicit	Misinterpretation
Pedestrians moving around the vehicles on a congested street	Driver looking to make sure they give space to pedestrians	Implicit/Explicit	Not looking around sufficiently and exploring blind spots
Establishing eye contact	Driver anticipating pedestrian action and acting	Explicit	Inattention to making eye contact
Hand wave	Driver speeding up/stopping based on interpretation	Explicit	Inability to understand hand motion in context
Pedestrian walking up	Driving flashing lights indicating yield	Explicit	Forget to flash/Speeding behavior forcing mishap
Pedestrians change walking speed (up/down)	Stopping for pedestrian to complete pedestrian	Implicit	Misinterpretation of walking speeds
Pedestrian giving way to the driver	Driver taking/yielding right of way	Explicit/Implicit	Inattention/Misinterpretation

A summary of the different communications between pedestrians and drivers

Reflections

Could you think of a few methods of communication that would maybe help reduce the risk of children and older pedestrians when crossing the road?

As a driver, what would you do differently now to improve your approach to a crossing, now that you know which pedestrians are at a higher risk?

After discussing the role of communication between pedestrians and drivers, do you think trust between the driver and pedestrian plays a role when crossing the road? If so, in what way? If not, why not?

References

[1] https://bikewalkcentralflorida.org/resources/laws/

Week Three: Drivers interaction with bicyclists

Instructions for the course

Welcome to this short course on improving your understanding of sharing roads with vulnerable road users. This week is focused on looking at issues related to interactions between bicyclists and drivers. It is important to make a note of a few important things before this week

• Please read the content carefully each week. Each reading will teach you about interactions with vulnerable road users

• The course will help you get a better understanding of how to interact with vulnerable road users.

• After completion, you will be required to share your understanding of the course material. The questions will be listed under a section called reflections. You will be given a link to share your reflections.

• After each module, you will be sent a survey with questions that are based on the week's content.

• In case you find a lack of clarity in any of the materials, please reach out to Shashank at smehrotra@umass.edu and he will respond to your questions

The dilemma of bicycle use with regards to safety

Bicycles as a medium for transportation are an anomaly. You do not have to register them or take a test to ride a bike. You can use them on the road, you can travel through dense traffic, and you are perhaps the only vehicle that is good for the environment. The only reason they are discouraged is because they are unsafe, in comparison to using public transit or driving. This leads us to certain questions with regards to bicycle use.

Why are bicycles considered unsafe compared to cars or public transit?

Even though we know it's good for your health to bicycle, the safety of bicycle riders has been a cause for concern. To address these concerns, it is important to consider what makes bicycling unsafe. Researchers attribute certain risks with bicyclists such as:

Vulnerable in crash

Unpredictable in behavior

Inconspicuous at night

Unstable i.e., easy to fall

Differing abilities i.e., all people cannot bike at the same skill level

By exploring these factors, we understand that bicyclists have higher variability in their behavior. Since they must rely on their physical abilities and skills, it can be difficult to have the same expectations from each bicyclist. Also, unlike pedestrians, there are fewer instances of dedicated bicycle infrastructure, and most roads are shared with bicyclists. With the current pandemic and an increase in awareness and usage of bicycles, they are more vulnerable than ever before.

How to understand the risks associated with bicyclists?

These factors can help us understand the risk associated with different factors. Based on the table presented, we can get a rough understanding of which bicyclists tend to be at a higher risk.

Factors	Risk attributed to:	Relationship
Helmet usage	Wore helmet	Lower risk
	Did not wear a helmet	Higher risk
Age	Older Riders	Higher risk
	Younger Riders	Lower risk
	Preadolescent (Particularly males)	Higher risk
Alcohol	BAC > 0.8 mg/ml	Higher risk
	BAC < 0.8 mg/ml	Lower risk
Climate	Summer	Lower risk
	Winter	Higher risk
Illumination and Visibility	Wearing night reflective gear	Lower risk
	Well-lit roads	Lower risk
	No lighting on the road	Higher risk
	Not wearing night reflective gear	Higher risk
Cell phone	Using cell phones	Higher risk
	Do not use cell phones	Lower risk

Factors that may influence the interactions with bicyclists.

How to interact with bicyclists on the road?

A common observation in road sharing is when bicyclists and drivers share the same lane, with most drivers looking to leave a gap between themselves and bicyclists. Drivers who observe bicyclists wearing reflective cycling gear, wearing a helmet, and looking like “biking pros”, are more comfortable overtaking them. In comparison, if drivers saw bicyclists who were wearing common clothes, and did not appear to be like typical bicyclists make them nervous when overtaking them. Additionally, drivers tend to not keep a sufficient distance of 1.5 m between themselves and the bicyclists while overtaking.

Another interesting observation has been that bicyclists tend to adapt their behavior according to expediency rather than based on rules. Bicyclists utilize pedestrian crossings, use regular traffic and pedestrian traffic regulations interchangeably whenever requisite infrastructure is absent, which makes it difficult to interact with them.

With regards to interacting with bicycles, while passing a bicycle traveling in the same direction, a right turn is not allowed. Similarly, no abrupt turns are allowed right after passing a bicycle. Sufficient distance – 3 feet – must be maintained, as bicyclists cannot be squeezed into a narrow lane. When drivers are turning left, they must yield the right of way to the bike from the opposite direction like they would to any other vehicle. These interactions are based on Massachusetts state laws.

Resolving potential conflicts

We will discuss potential conflict scenarios with bicyclsts Select a scenario and we will observe the potential resolution to those scenarios. These scenarios are important to understanding the bicyclist/driver interaction.

Potential scenarios(s)

Scenario1

Scenario1

Bicyclist Action: Bicyclist waves the hand and requests to turn Driver Action: Driver slows down and yields for the bicyclist Communication: Explicit Potential conflict: Inability to understand hand motion in context

Reflections

Do you think cyclists and drivers should share roads considering all the risks described in this week's discussion?

As a driver, are you nervous when there is a bicycle on the road?

Do you think it helps if the drivers are themselves bicyclists who can better understand the risks associated with interactions between drivers and cyclists?

Week4: Learning about shared spaces

Instructions for the course

Welcome to this short course on improving your understanding of sharing roads with vulnerable road users. This week is focused on looking at things' drivers must keep in mind, when they are driving in shared spaces It is important to make a note of a few important things before this week

• Please read the content carefully each week. Each reading will teach you about interactions with vulnerable road users

• The course will help you get a better understanding of how to interact with vulnerable road users.

• After completion, you will be required to share your understanding of the course material. The questions will be listed under a section called reflections. You will be given a link to share your reflections.

• After each module, you will be sent a survey with questions that are based on the week's content.

• In case you find a lack of clarity in any of the materials, please reach out to Shashank at smehrotra@umass.edu and he will respond to your questions

Towards safer streets: Driving on shared roads

Throughout the course, the focus has been on understanding how to improve interactions with vulnerable road users. This would result in lowering injury and fatality rates, making roads better for all modes of transportation. With cities looking to push for multi-modal transportation, the driver needs to become acquainted with sharing the roads and becoming a safer driver. This material will try to look at a few shared spaces and how drivers should be mindful of them.

Having the mindset for share-the-road vs a hierarchy

Our general perceptions around roads follow a hierarchy of usage is based on the vehicle rather than the road user. For instance, designing streets with low-level speeds should be designed always with the bicyclist, pedestrians, and other micro-mobility users. While state legislators and policymakers have introduced signage and speed calming methods, more work needs to be done to to help drivers understand the importance of different mobilities, sharing streets, and what implications that may have on drivers. This is particularly true with the increase in bike-sharing programs.

Interpreting the dedicated infrastructure for road sharing

Now that we understand that bicycles and roads share the same roads, we understand that having dedicated infrastructure for the usage of the roads, it is necessary to understand how bicyclists share the road.

Bicyclists Pathways

Now that we have an appreciation for that multiple users that use the road, it is necessary to understand how bicyclists share the road.

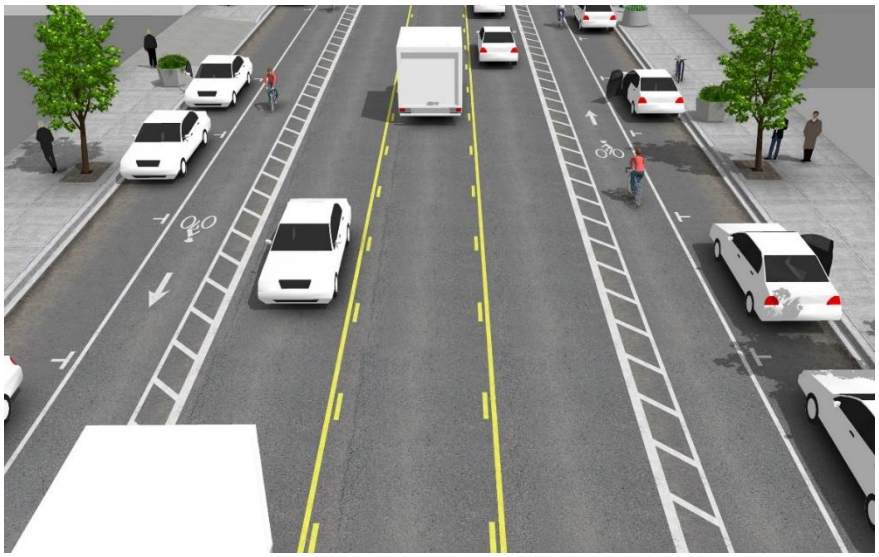
Sharrows

Sharrow is a clever wordplay on the word's "share" and "arrow". Think of a sharrow as a marker on the road to remind road users that space is meant to be shared by bikes and cars. They can be used by both cars and bikes at the same time. In cases where the lane is colored green and includes a sharrow, the space is indicative of where the bicyclists are supposed to ride. An example of a sharrow is below.

An example of a sharrow on a regular street that allows drivers and bicyclists to share roads [1]

Buffered Bike Lanes

Buffered bike lanes create a dedicated lane for bicyclists, with the added benefit of putting extra space between bicyclists and passing cars, usually with a painted safeguard area of one to two feet. Drivers must stay on the left side of the buffer while driving and can only cross the bike lane when making a turn or entering an adjacent property - after checking to be sure no people are biking in the lane, of course.



An example of a buffered bike lane. [2]

Striped Bike lanes

As the name suggests, striped bike lanes are dedicated lanes, striped with white paint on the right side of the road. The separate color is intended to draw attention for the bicyclists to provide a clearer sense of where they should be on the road. With a dedicated space, it gives clarity in understanding and an added sense of safety, since it is a dedicated lane for bikes. However, since they are not protected, there are instances where they may be too close or on the same path as a car. Also, more cities are likely to have them as it does not require authorities to construct dedicated paths and they can accomplish bike lanes by just drawing the striped line.

An example of a striped bike lane. [3]

Protected lane

Protected lanes distinguish between space on a road for bikes. The road is divided by a barrier that prevents regular traffic from flowing on dedicated bike lanes. This leads to enhanced safety as it gives the security of only bicyclists on a lane, so the interaction between different types of road users is extremely limited.

An example of a protected bike lane. [4]

Pedestrian pathways

Now that we have an appreciation for that bicycle infrastructure, it is necessary to understand how pedestrians share the road

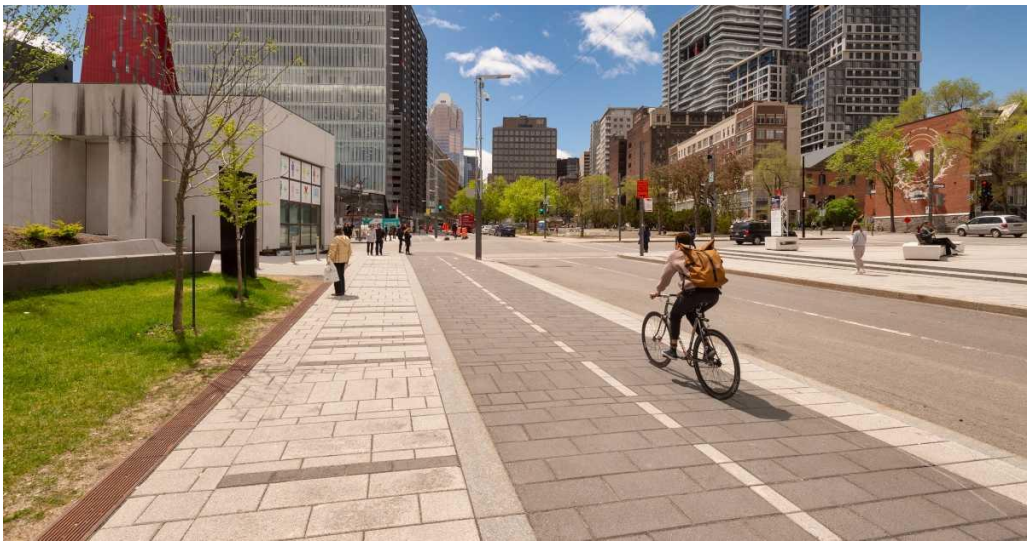
Sidewalks

To ensure the safety of pedestrians, they use the sidewalks. They share the sidewalks with bicyclists when there are no dedicated spaces for bicyclists. It is difficult for pedestrians to share in circumstances when the sidewalks are incomplete, damaged, have snow, or are non-existent. In those circumstances, most pedestrians are likely to use curb spaces, which can be too close to cars and may be dangerous, particularly in high-speed zones.

An example of a sidewalk. [5]

Dedicated pedestrian pathways

In certain urban centers, the town planners and local authorities are looking to create spaces dedicated to pedestrians. These spaces tend to be further away from the road and may have protective barriers that are built-in and may result in a safer setting.



An example of a dedicated pedestrian lane. [6]

How are drivers expected to negotiate with pedestrians and bicyclists?

The short answer is – by understanding their use and making sure they prioritize vulnerable road users over their mobility while sharing roads. Drivers need to manage speeds, maintain control, practice lane discipline, yield when required, and ensure that they are not impaired due to distraction, use of alcohol, or fatigue. Drivers need to become even more careful to ensure shared spaces must be prioritized, respected, and prioritized for vulnerable road users over cars.

##Resolving potential conflicts

We will discuss potential conflict scenarios with the different road features that enable road sharing. Select a feature and we will observe the potential conflicts and resolutions for those features.

Potential conflicts

Sharrows

Sharrows

Potential conflict: Inability of cars to yield path to Bicyclists Potential resolution: Cars must keep sufficient distance between themselves and the bicyclists

Conclusions

Drivers who use different modes of transportation are likely to have a better understanding of shared streets. Becoming a shared street user requires to use public transportation, cycle, use e-scooters, and simply walk. This has added benefits like better health and wellness, but also helps drivers understand street sharing from the point of view of vulnerable road users .

Reflections

Do you think you can add other mobilities to your travel? If not, can you think of reasons why that may not be realistic?

Which of the dedicated infrastructures are unsafe for VRUs, and what can you do as a driver to make sure how to make them safer for VRUs when driving?

What do you think are challenges for drivers to acknowledge the growing shared streets in cities?

How can VRUs make sure that they can be safer on the shared streets when sharing spaces with drivers?

References

[1] https://macwright.com/2020/12/04/sharrows.html
[2] https://nacto.org/publication/urban-bikeway-design-guide/bike-lanes/buffered-bike-lanes/
[3] https://www.smartcitiesdive.com/ex/sustainablecitiescollective/lanes-and-sharrows-and-buffers-oh-my-four-types-bike-lanes-explained/1200740/
[4] https://ggwash.org/view/36684/cycletrack-protected-bike-lane-what-do-you-call-them
[5] https://simple.wikipedia.org/wiki/Sidewalk
[6] https://www.mtlblog.com/en-ca/news/montreal/montreal-is-creating-327-km-of-bike-and-pedestrian-paths-so-you-can-still-enjoy-the-summer

A4. Methodology – Weekly Control content as presented to the participants

Week1

Risk Management

The purpose of risk management or a systematic decision making process is to improve driver safety and reduce the incidents of loss that occur when risk management practices are ignored or improperly used. The low risk driver is defined as a driver who identifies real and/or potential hazards, and reduces the risk of these hazards by adjusting speed and/or position and communicates to others his/her intentions.

Driver Limitations

1. *Decisions are limited by a driver's capabilities.* Drivers, lacking in driving knowledge, skills, and self-confidence, are limited in their ability to make safe driver decisions.
2. *Decisions are limited by the environment.* Safe drivers are aware of and use environmental information to make safe driving decisions. They observe a traffic control sign, derive information from it, and use that information in executing a safe driving decision.
3. *Decisions are limited by what a driver is willing to do.* Safe driving is contingent upon drivers practicing safe driving habits and using effective decision-making strategies.

Driver Awareness

Almost all activities people engage in have some level of risk. Operating a motor vehicle is a risky activity and drivers must do all they can to reduce risk. Consider the following steps to manage risk and be a safe and responsible driver:

Accept the responsibilities associated with operating a motor vehicle:

1. Do not drive under the influence of drugs or alcohol or otherwise be impaired while driving.
2. You and your passenger(s) should always wear seatbelts.
3. Although it may not seem important to obey everyday laws, it is important to do so for the safety of yourself and others.
4. Safely sharing the roadway with other drivers and pedestrians is essential for avoiding crashes.
5. The traffic laws and rules of the road cannot address all possible driving situations. If you remember to be courteous, you can help avoid crashes and keep traffic moving in an orderly fashion.
6. The golden rule of driving is to treat others the way you would want to be treated. You should obey traffic laws, drive responsibly, and avoid taking unnecessary risks.

Risk Awareness

Identify the risks associated when you drive. Risks are created by:

Our own limitations as a driver. Not all people react to situations the same.

2. The vehicle we drive has limitations. Larger vehicles can be less stable and have reduced visibility around the vehicle. Smaller vehicles are harder for other drivers to see.

3. The environment we drive in has its own limitations. Driving in areas where there are hills and mountains requires special skills. Urban or city driving has increased risks because many other people are using the roadway as well.

Risk Management

Manage the risks by first identifying them and then making adjustments to your driving techniques to minimize those risks. We know that it is impossible to eliminate the risks so you must learn how to best minimize them.

1. Increase time to respond to threats through position and/or speed adjustments
2. Increase vehicle control through position and/or speed adjustments
3. Separate the risks through speed and/or position adjustment

Human Errors

Human errors can be significantly reduced when drivers develop effective decision making capabili-ties.

1. *Not choosing an action because one does not know it as a possibility.* Drivers typically fail to consider their options because they execute the first response that enters their head. Drivers tend to be more erratic drivers than more mature drivers because they make impulsive driving adjust-ments in the immediacy of the moment.

2. *Choosing an action even though one does not know the possible outcomes.* Drivers rarely con-sider the possible outcomes of their actions. They tend to rely on a gamblers mentality and blind faith that everything they do will work out in their favor. Acting without thinking about the con-sequences is an inherent aspect of the driver.

3. *Underestimating or overestimating the importance of certain information.* Valid and reliable in-formation is required to make safe and responsible driving decisions. Drivers who rely on inaccu-rate information or who underestimate or overestimate the value of information they receive are placing themselves and others at risk.

4. *Relying on myths or assumptions in choosing an action.* Cognitive distortions and faulty beliefs run counter to reason, often with dire consequences. For, example, drivers may believe that all motorists stop at STOP signs, vehicle engines that start must be mechanically sound, and the most vehicular collisions crashes occur far way from home. Armed with these thoughts, drivers are likely to engage in dangerous driving behaviors.

Three options novice must recognize:

1. Risk avoidance - when the potential for personal risk to life or property is high, individuals need to choose not to attempt the activity.
2. Risk Prevention - Most driving situations pose a variety of dangers that can be corrected before the driver gets behind-the-wheel.
3. Risk Reduction - While risk prevention actions are applied in advance of being exposed to the risk, risk reduction methods are applied while participating in the task.

This fact sheet was developed using the following:

ADTSEA Curriculum version 2.0

Week2

Walk Responsibly.

We're all pedestrians; we walk to the mailbox, from the parking lot to the store, to school, to meet up with friends, to walk the dog. During your teen years, you are likely to be walking independently and to be exposed to traffic. Walking around traffic requires the same critical thinking skills as riding your bike and driving a car! Apply the same walking skills you learned as a kid: stop—look left-right-left for traffic and be safe, be seen. Use these skills when you walk and encourage others to do the same! **Here's what you can do:**

Be Prepared Before Walking. Be seen—wear clothes or materials to make you more visible to others: Bright clothing (during the day)
Reflective gear
Use lights at night or when visibility is poor (white in front, red in the rear - just like a car)

Plan your safest route—safer routes have less traffic, slower speeds, lighting, sidewalks, and, if possible, separate you from traffic (i.e., sidewalks, paths, a barrier).

Know the Rules. As a pre-driver or new driver, you have an opportunity to learn by watching traffic and how each road user (cars, bicycles and pedestrians) relates to one another. Discuss with an adult what you see.

Follow the rules and laws put in place to increase your safety: Walk on sidewalks, if they're there. If not, walk as far to the left, **facing traffic**.
Look left-right-left and behind for traffic before crossing a driveway or road.
Cross in marked crosswalks, at corners, or at intersections.
Obey pedestrian crossing signals.
While crossing, look left and right for traffic; be prepared to get out of the way if a driver doesn't seem to see you.

Look for Traffic. Look for cars backing up; look for white backup lights or signs the motor is running. Expect others not to see you. Some drivers may be distracted. Do not step in to the roadway until the driver has stopped for you, or has acknowledged your intent to cross with eye contact, a wave or a nod.

Walk Defensively. Walk focused and alert. No texting, listening to music or anything that takes your eyes, ears, or your mind, off the road and traffic.

Anticipate what other road users might do—turns, pulling out of a parking space or driveway, backing up. The sooner you notice a potential conflict, the quicker you can act to avoid it.

Give drivers extra time to slow or stop, especially in poor weather (ice, snow, rain), and low visibility (dusk, dawn, fog, or night). Just because you can see others, does not mean they can see you.

Know the Causes of Pedestrian-Vehicle Crashes.

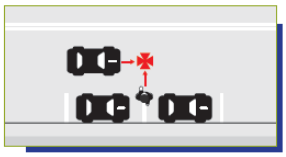
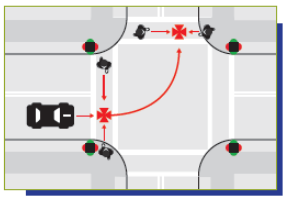
Become more aware of the causes of some of the common types of crashes between pedestrians and vehicles so you can learn how to avoid them. Prevention is the name of the game; there are things you can

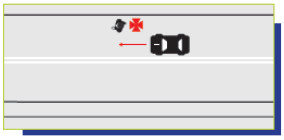
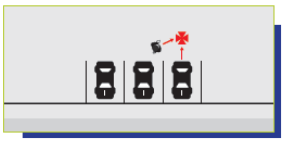
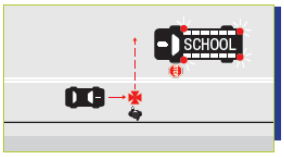
do to decrease your risk of being in a crash. Understanding the causes of crashes helps you adjust your walking and driving behaviors to avoid a crash in the first place.

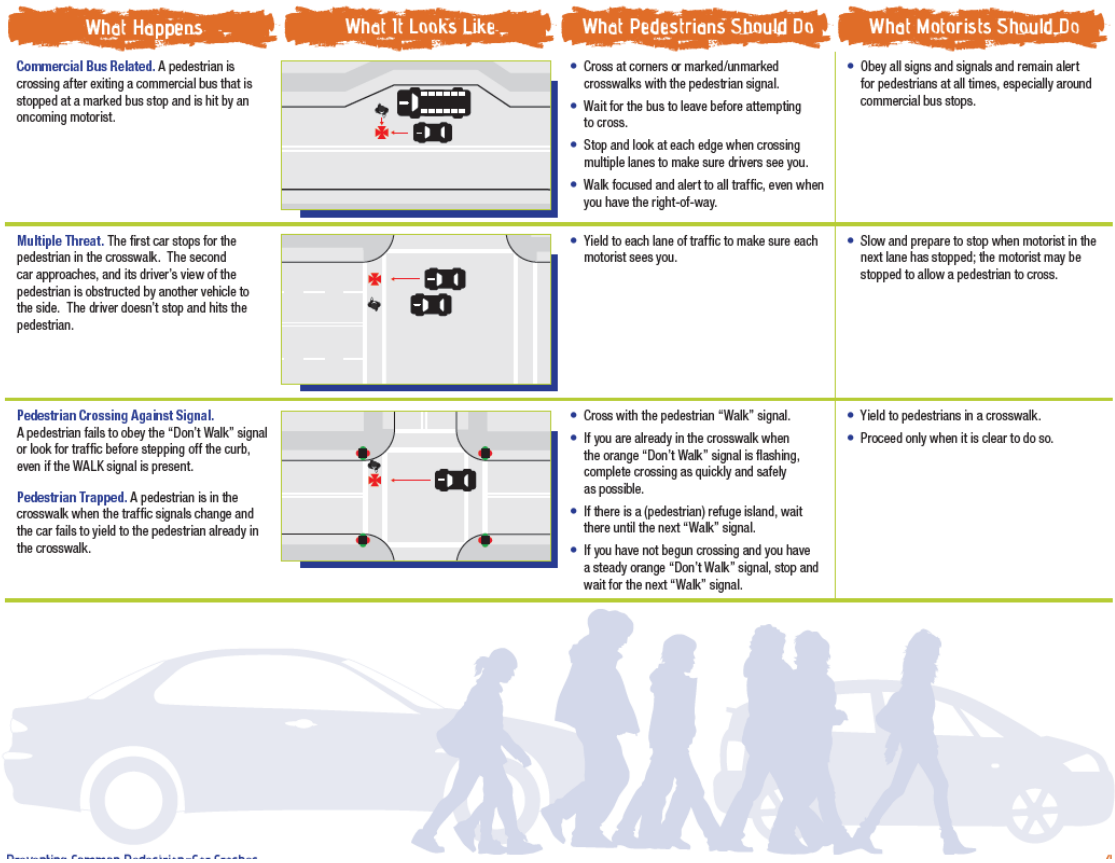
Common Crash Types Between Pedestrians and Cars:

The following are some common crash types involving cars and youth pedestrians (Cross, Fischer, Hunter, Stutts, 1995).

Note: Distraction on the part of all road users (motorists, bicyclists and pedestrians) can be an underlying cause or influencing factor in almost all of the crashes included. Distracted driving, bicycling and walking is an ongoing threat to everyone's safety. The simple solution is to always stay focused and alert to traffic and the roadway.

What Happens	What It Looks Like	What Pedestrians Should Do	What Motorists Should Do
Pedestrian Darts/Steps Out Midblock. A pedestrian runs or walks out into the roadway in an unmarked area in the middle of the block (not in a crosswalk or at an intersection) and is struck by a vehicle. Groups of youth are playing sports (football, hockey, etc.) in roadway or run into the street to retrieve a ball.		• Cross at a crosswalk using pedestrian crossing signals, when available. • If crossing midblock, wait at each edge for traffic to clear from both directions. • Play sports in areas away from traffic. If your ball goes into the roadway, stop and look for traffic before entering.	• Slow down. • Be aware of your surroundings, especially in residential areas, school zones or shopping centers. Watch for pedestrians (especially children) on the side of the road; be prepared for unpredictable behavior.
Vehicle Makes a Turn (Right or Left) at an Intersection. A vehicle turns or merges into the path of a pedestrian without yielding. This includes a vehicle turning into or out of a driveway or alley, or a right turn on red.	 	• Be alert for turning vehicles and those who may not stop at red lights or stop signs. • Stay in crosswalks and obey traffic signals. If possible, communicate (e.g., eye contact, hand gesture) with drivers before crossing the roadway.	• Before turning, look for other vehicles, pedestrians and bicyclists and yield to them. • Yield to pedestrians with the "Walk" signal and those already in a crosswalk, as required by law. This includes continuing to yield if the pedestrian is crossing and the "Walk" signal has expired. • When turning right on red, come to a complete stop and scan for all traffic, including pedestrians and bicyclists. Proceed only when clear.

What Happens	What It Looks Like	What Pedestrians Should Do	What Motorists Should Do
Pedestrian Walking or Jogging Along the Road. A pedestrian walking or jogging in roadway in same direction as motorized traffic fails to recognize a vehicle approaching behind them. A crash could occur if the driver is not paying attention or does not see the pedestrian and the pedestrian fails to recognize the threat and try to quickly get out of the way.		• Walk or run facing traffic. • Use sidewalks or paths to separate you from moving traffic. If no sidewalk is present, stay on the shoulder and/or as far away from traffic as possible. • Wear bright, contrasting colors during the day and use reflective wear and lights if walking at night.	• Slow down. • Watch for persons walking or running along the road, especially in the absence of sidewalks. • Drive alert and focused. • Use extra caution driving at night, remaining alert for all traffic, including pedestrians.
Backing Vehicle. A driver fails to look for or see traffic when backing from driveway, private road, or parking lot. A pedestrian walks behind a moving vehicle or fails to stay alert and recognize a vehicle preparing to back up.		• Be alert for drivers who are parking, idling in a parking space, or backing out of a parking space. • Make your presence known to drivers. If you are unsure, do not walk near the vehicle. • In parking lots, pedestrians should walk as far away from rows of parked cars as safely possible. This provides both the driver and pedestrian better visibility and reaction time to stop.	• Look behind, to the left and right for traffic (including pedestrians) **before** backing up. If possible, ask passengers to also check for pedestrians or other hazards. • Walk behind parked car before getting in to make sure no children are playing there. Note: Large vehicles have especially large blind spots.
Distracted Motorist and/or Pedestrian. A motorist or pedestrian is distracted by electronic devises or talking to others and is hit. **Motorist or Bicyclist Rides Through Stop Signal or Red Light.**		• Avoid distractions; be alert to vehicles and your surroundings at all times.	• Avoid distractions; direct your full attention to the road and all road users. • Obey all signs and signals. • Come to a complete stop at signs and look for all traffic before going. Come to a complete stop at red lights. Only turn right on red when traffic is clear.
School Bus-Related. A motorist fails to obey school bus stop arm and flashers as required by law. A pedestrian fails to look for traffic when crossing to get to school bus or after getting off the bus.		• Cross in front of the school bus, never behind. • Make eye contact with the school bus driver. They will indicate when to cross in front of the bus. • Stop at the edge of the school bus and look to make sure traffic behind the bus has stopped as they are required to do by law. • Arrive at bus stop early to minimize the need to rush to catch the bus. • Stop and look for traffic before you cross the street to catch the bus; watch for traffic as you are crossing. While you have the right-of-way, take extra care by walking defensively.	• Obey speed limits, especially on school days when children are getting picked up or dropped off by school buses. • Know the specific laws for your State and jurisdiction. Note: **It is illegal** to pass a stopped school bus with its red lights flashing and stop-arm extended.



What Happens	What It Looks Like	What Pedestrians Should Do	What Motorists Should Do
Commercial Bus Related. A pedestrian is crossing after exiting a commercial bus that is stopped at a marked bus stop and is hit by an oncoming motorist.		• Cross at corners or marked/unmarked crosswalks with the pedestrian signal. • Wait for the bus to leave before attempting to cross. • Stop and look at each edge when crossing multiple lanes to make sure drivers see you. • Walk focused and alert to all traffic, even when you have the right-of-way.	• Obey all signs and signals and remain alert for pedestrians at all times, especially around commercial bus stops.
Multiple Threat. The first car stops for the pedestrian in the crosswalk. The second car approaches, and its driver's view of the pedestrian is obstructed by another vehicle to the side. The driver doesn't stop and hits the pedestrian.		• Yield to each lane of traffic to make sure each motorist sees you.	• Slow and prepare to stop when motorist in the next lane has stopped; the motorist may be stopped to allow a pedestrian to cross.
Pedestrian Crossing Against Signal. A pedestrian fails to obey the "Don't Walk" signal or look for traffic before stepping off the curb, even if the WALK signal is present. **Pedestrian Trapped.** A pedestrian is in the crosswalk when the traffic signals change and the car fails to yield to the pedestrian already in the crosswalk.		• Cross with the pedestrian "Walk" signal. • If you are already in the crosswalk when the orange "Don't Walk" signal is flashing, complete crossing as quickly and safely as possible. • If there is a (pedestrian) refuge island, wait there until the next "Walk" signal. • If you have not begun crossing and you have a steady orange "Don't Walk" signal, stop and wait for the next "Walk" signal.	• Yield to pedestrians in a crosswalk. • Proceed only when it is clear to do so.

Week3

Overview

As you might expect, when a crash occurs between a vehicle and a bike, it's the cyclist who is most likely to be injured. In this section, you'll learn bicycle safety tips and rules of the road, from properly fitting your helmet to driving defensively and predictably. You'll also find educational material, resources for your community and more. Find out what you can do to prevent bicycle injuries and deaths and remember: A large percentage of crashes can be avoided if motorists and cyclists follow the rules of the road and watch out for each other.

Bicycle Safety

Americans are increasingly bicycling to commute, for exercise, or just for fun. By law, bicycles on the roadway are vehicles with the same rights and responsibilities as motorized vehicles. NHTSA's bicycle safety initiatives focus on encouraging safer choices on the part of bicyclists and drivers to help reduce deaths and injuries on our roads.

Helmets

Every bike ride begins with putting on a helmet. But it's equally important that you ensure a proper □t so your helmet can best protect you.

Size can vary between manufacturers. Follow the steps to fit a helmet properly. It may take time to ensure a proper helmet fit, but your life is worth it. It's usually easier to look in the mirror or have someone else adjust the straps. For the most comprehensive list of helmet sizes according to manufacturers, go the Bicycle Helmet Safety Institute (BHSI)

Avoid Crashes

DECREASING RISK OF CRASHES
6/1/2021 Bicycle Safety | NHTSA https://www.nhtsa.gov/road-safety/bicycle-safety 5/11

There are two main types of crashes: the most common (falls), and the most serious (the ones with cars). Regardless of the reason for the crash, prevention is the name of the game. There are things you can do to decrease your risk of a crash. First, know some bicycle safety facts:
Regardless of the season, bicyclist deaths occurred most often between 6 p.m. and 9 p.m.
Bicyclist deaths occur most often in urban areas (75%) compared to rural areas (25%) in2017.
Bicyclist deaths were 8 times higher for males than females in 2017.
Alcohol was involved in 37% of all fatal bicyclist crashes in 2017.
Ride responsibly and remember: All states require bicyclists on the roadway to follow the same rules and responsibilities as motorists.

BE PREPARED BEFORE HEADING OUT

Ride a bike that suits you—if it's too big, it's harder to control the bike.

Ride a bike that works—it really doesn't matter how well you ride if the brakes don't work.

Wear equipment to protect you and make you more visible to others, like a bike helmet, bright clothing (during the day), reflective gear, and a white front light and red rear light and reflectors on your bike (at night, or when visibility is poor).

Ride one per seat, with both hands on the handlebars, unless signaling a turn.

Carry all items in a backpack or strapped to the back of the bike.

Tuck and tie your shoelaces and pant legs so they don't get caught in your bike chain.

Plan your route—if driving as a vehicle on the road, choose routes with less traffic and slower speeds. Your safest route may be away from traffic altogether, in a bike lane or on a bike path.

Be focused and alert to the road and all traffic around you; anticipate what others may do, before they do it. This is defensive driving—the quicker you notice a potential conflict, the quicker you can act to avoid a potential crash:

Drive with the flow, in the same direction as traffic.

Obey street signs, signals, and road markings, just like a car.

Assume the other person doesn't see you; look ahead for hazards or situations to avoid that may cause you to fall, like toys, pebbles, potholes, grates, train tracks.

No texting, listening to music or using anything that distracts you by taking your eyes and ears or your mind off the road and traffic.

DRIVE PREDICTABLYBIKE RIDING SAFETY **RULES OF THE ROAD**
By driving predictably, motorists get a sense of what you intend to do and can react to avoid a crash. Drive where you are expected to be seen, travel in the same direction as traffic and signal and look over your shoulder before changing lane position or turning.
6/1/2021 Bicycle Safety | NHTSA https://www.nhtsa.gov/road-safety/bicycle-safety 7/11

Avoid or minimize sidewalk riding. Cars don't expect to see moving traffic on a sidewalk and don't look for you when backing out of a driveway or turning. Sidewalks sometimes end unexpectedly forcing the bicyclist into a road when a car isn't expecting to look for a bicyclist. If you must ride on the sidewalk remember to:
Check your law to make sure sidewalk riding is legal;
Watch for pedestrians;
Pass pedestrians with care by first announcing "on your left" or "passing on your left" or use a bell;
Ride in the same direction as traffic. This way, if the sidewalk ends, you are already riding with the flow of traffic. If crossing a street, motorists will look left, right, left for traffic. When you are to the driver's left, the driver is more likely to see you;
Slow and look for traffic (left-right-left and behind) when crossing a street from a sidewalk; be prepared to stop and follow the pedestrian signals; and
Slow down and look for cars backing out of driveways or turning.

IMPROVE YOUR RIDING SKILLS
No one learns to drive a vehicle safely without practice and experience; safely riding your bike intraffic requires the same preparation. Start by riding your bike in a safe environment away from traffic (a park, path, or empty parking lot).
Take an on-bike class through your school, recreation department, local bike shop or bike advocacy group. Confidence in traffic comes with learning how to navigate and communicate with other drivers, bicyclists, and pedestrians. Review and practice as a safe pedestrian or bicyclist is great preparation for safe riding.

Drivers: Share the Road

People on bicycles have the same rights and responsibilities as people behind the wheel of a vehicle.

Yield to bicyclists as you would motorists and do not underestimate their speed. This will help avoid turning in front of a bicyclist traveling on the road or sidewalk, often at an intersection or driveway.

In parking lots, at stop signs, when packing up, or when parking, search your surroundings for other vehicles, including bicycles.

Drivers turning right on red should look to the right and behind to avoid hitting a bicyclist approaching from the right rear. Stop completely and look left-right-left and behind before turning right on red.

Obey the speed limit, reduce speed for road conditions and drive defensively to avoid a crash with a cyclist.

Give cyclists room. Do not pass too closely. Pass bicyclists as you would any other vehicle—when it's safe to move over into an adjacent lane.

Week4

Share the Road: It's Everyone's Responsibility

Tips for Drivers, Motorcyclists, Bicyclists and Pedestrians

Share:

With warmer weather, you're likely seeing more bikes on the road, so it's a perfect time for a reminder to *Share the Road*.

DRIVERS SHARE THE ROAD

For drivers, sharing the road begins with the understanding that **bicyclists** and **motorcyclists** have the same rights as you. They also face unique safety challenges, such as being smaller and less visible. Look for cyclists where vehicles do not appear, like before making a left-hand turn at an intersection. Also, be aware that motorcyclists may have to downshift and weave to avoid bumps and road hazards.

Pedestrians have rights on the road, too. Always slow down and be prepared to yield to pedestrians when they're in a crosswalk. Never pass vehicles stopped at a crosswalk, as there may be people crossing whom you can't see. And, be extra cautious when backing up across sidewalks or in parking lots.

MOTORCYCLISTS, BICYCLISTS AND PEDESTRIANS SHARE THE ROAD

Just like drivers behind the wheel, **bicyclists** and **motorcyclists** must obey signs and signals. Ride defensively, assuming others cannot see you, and don't let yourself be distracted by music, an electronic device, or anything else that takes your focus off the road. Bicyclists should always ride with traffic, use bike lanes when available and avoid riding on sidewalks when possible.

Pedestrians should also follow the rules of the road and obey signs and signals — which are there to protect you. If there isn't a sidewalk, walk facing traffic and as far from vehicles as possible. Always cross streets at crosswalks when they are available; drivers know to look for you there. If there isn't a crosswalk, cross at a well-lit place where drivers can best see you.

PREVENT A DEADLY CRASH

As more Americans choose to ride bikes and walk to stay healthy, and as an alternative to driving, pedestrian and cyclist deaths in motor-vehicle-related crashes have increased over the past decade.

Bicyclists: There were 846 bicyclists killed in collisions with vehicles in 2019, up from 718 bicyclist deaths in 2008.

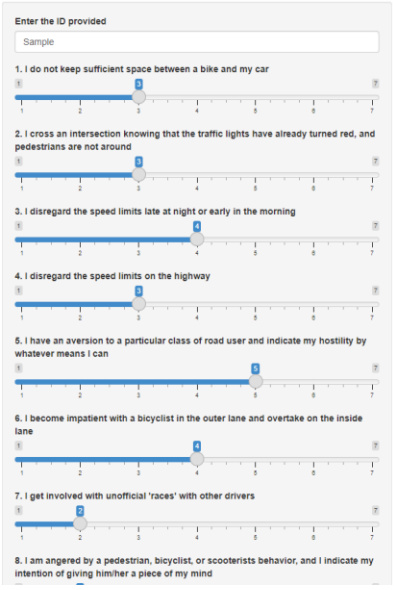
Pedestrians: In 2019, 6,205 pedestrians died in traffic crashes, up from 4,414 in 2008.

Motorcyclists: The number of people killed on motorcycles in 2019 was 5,014.

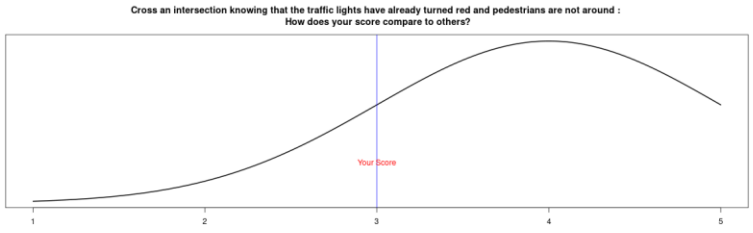
Join us in helping to keep everyone safe on the road. Remember, no one — no driver, cyclist, or pedestrian — has sole rights to the road. It's a shared space where we all have rights and responsibilities.

A5. Methodology – Continuous Assessment [Sample Response]

How much do you relate to these statements. Please select a value from 1 to 7, where 1=> No relation and 7=> Can completely relate



Name	Value
Errors	3.09
Violations	3.09
Lapses	3.09



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