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Safe mobility: Analysis of drivers' behavior at
the stop bar of signalized intersections using
mixed-effects modeling

By
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Dedication

This thesis is dedicated to my source of inspiration and strength, my parents.

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Safe mobility: Analysis of drivers' behavior at the stop bar of signalized intersections using mixed-effects modeling

Maria Georges El Mendelek

Abstract

Transportation safety continues to be an important issue that we face daily as it results in enormous losses to human life and to the economy. This research targets safe mobility at intersections in an urban setting by analyzing drivers' behavior at the stop bar during the red-light phases. The latter analysis focuses on drivers' psychological and demographic attributes. Drivers are exposed to various scenarios and triggers using a state-of-the-art driving simulator. Three main scenarios are utilized to test drivers' responses, which include pedestrians crossing the crosswalk, police enforcement personnel and adjacent driver encroaching on the stop bar promoting the imitation behavior. A survey assessing demographics and individual traits such as impulsivity, impatience, mindfulness and driving rituals is used to complement the driving simulator experience for a total of 178 participants. Real life observations and monitoring at intersections are conducted to confirm drivers' behaviors with respect to stopping at the stop bar in the presence of various triggers. Younger males with a history of at least one severe accident are more likely to be exhibit aggressive behavior such as speeding and committing violations. Participants scoring high on the Attitudes Towards Traffic Safety and Driving Behavior Survey scales are safer drivers who show more concern about traffic laws. High scores on mindfulness and agreeableness (Big Five Personality Inventory) are associated with less violations whereas extraversion and neuroticism are

linked with impulsivity and frustration thus leading to higher acceleration rates and speeding. Symptoms of depression reduce a person's capacity to maintain attention. Thus, it is highly effective to enhance mindfulness and stress management in addition to driving risk-awareness and focus on improving the existing driving education system.

Keywords: Transportation safety, Driving behavior, Driving simulator, Pedestrians, Police enforcement, Imitation behavior, Signalized intersections, Personality traits.

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CHAPTER 1
Introduction

1.1 Background

“Nearly 3,700 people dying on the world’s roads every day” is the World Health Organization’s estimation for traffic fatalities in its Global Status Report on Road Safety (2018). Transportation safety is one of the most critical issues in Lebanon and the world today. Whether the accidents are fatal or life-altering, these losses contribute to the regression of a country’s economy and health care, in addition to the cost of human grief. According to the United Nations (2019), the deaths due to road accidents in Lebanon count up to 1,088 per year, whereas the injuries have increased to 12,340 and the economic losses are estimated at 1.2 billion U.S. dollars yearly.

This topic is of utmost importance as it affects most citizens’ way of life, especially that of the most vulnerable users; pedestrians. For pedestrians’ protection at intersections, traffic signals are installed to give them the right of way to cross over dedicated crosswalks. However, this protection is only granted under one condition: drivers respecting the dedicated crosswalk. In other words, drivers who do not achieve a full stop before the stop line but rather park their cars partially or fully on the crosswalk can cause a collision with crossing pedestrians. Unfortunately, this type of regulatory breach is often encountered amongst the Lebanese drivers’ population especially that a majority of citizens use private cars to commute daily. Choueiri et al. (2010) highlight the fact that most Lebanese drivers do not have enough or accurate background in traffic education in addition to the lack of highway and traffic enforcement. Most of the time, victims of road accidents in Lebanon are young males, whether pedestrians or passengers. This can be linked to the fact that males are more likely to disregard laws and to take safety lightly (Cordellieri et al., 2016; Fu et al., 2013; Jiang et al., 2012; Parmet et al., 2015; Vardaki & Yannis, 2013).

The Lebanese Government, and more so the local NGOs, have been recently focusing on targeting the transportation safety issue with focused efforts to enforce traffic laws and regulations and launch targeted educational campaigns, as is the case in other developed countries. However, this transfer has to be adjusted to each community's conditions and its citizens' cultural background. Therefore, it is essential to combine traffic advancements and knowledge with the already existing situation in the country and the attitudes of its drivers.

The rest of this paper is structured as follows; Section 1.B. provides a brief overview of the traffic sector and its development in Lebanon. Section 1.C. is the observation leading to the problem statement at the core of this research. The following section reviews the literature around personality traits and psychological variants as well as global traffic violations and accidents, the factors behind them, the explanation and analysis of these factors and the measures that could be tested for the enhancement of drivers' behavior. These measures are the basis of the proposed model and are further explained in Section 3: Methodology. The results of the driving model and the survey are detailed in Sections 4 and 5 with demographical and psychological factors considered. Section 6 provides field data and validation through real-life observations at three intersections in Lebanon. The last section concludes the research.

1.2 Overview of the traffic situation in the Greater Beirut Area

To accurately evaluate Lebanese drivers' behavior at intersections, it is crucial to have a clear understanding of the current transportation system first. This sector has been witnessing an important rise in demand in the recent years. This growth in private car usage is expected to continue as the population growth in the region is higher than the global averages (MOE/UNDP/GEF, 2016; WEC, 2011; Al-Ayyash et al., 2016). The Lebanese public transportation system remains underdeveloped which leads to an increase in the number of privately owned cars and their trips in and out of the Greater Beirut Area. The traffic sector is already affecting the Lebanese government's economy. The losses due to bad organization and congestion are estimated at 242 million US dollars for the year 2017 (Saroufim & Otayek, 2019). The usage of private cars and consequently the average number of trips per commuter per day are rising rapidly throughout the years. This growth in travel demand will result in the intersections' incapability to serve commuters adequately, in addition to the land transport which already lacks organization (MOE & UNEP ROWA; MoE et al., 2011). Mansour et al. (2015) believe that Lebanon's transportation system is extremely underdeveloped and unsustainable mainly due to poor law enforcements. The government has tried to implement new driving laws but their efforts were in vain as the required enforcement was not commensurate or serious to the extent that drivers would take it seriously (The Economist, 2015). The Eastern Mediterranean Region's countries ranked first in the world in the number of traffic fatalities (Soori et al., 2011).

These factors lead to drivers having unregulated and aggressive driving behavior which makes the framework of this study different than studies carried in developed countries. Peak hour commuter traffic intensifies the number of car accidents especially with the potential delinquency of drivers towards road safety rules. Subsequently, the adequate following of rules is an important pillar for the safety of all road users.

Driver's behavior is amongst the most important and complex factors of traffic operations and safety. Controlling this behavior is possible through a good driving education system, proper road signs and controls in addition to effective law enforcement. However, in Lebanon, traffic regulations are often ambiguous to the drivers who already lack basic knowledge in driving manners. Attitudes on the road which would be considered violations in the United States – such as change of lanes without signaling and driving in a no-pass zone – would not be considered illegal by a significant number of Lebanese drivers. Drivers in developed countries would be aware of the regulations and their importance whereas the caution around these regulations would be discarded in Lebanon. This careless driving behavior fosters an unsafe overall driving environment which normally leads to an increased number of accidents (Choueiri et al., 2010).

1.3 Problem statement

These violations were also observed on recordings from the Lebanese Interior Ministry's Traffic Management Center (TMC Lebanon) which provides 24/7 traffic monitoring at numerous locations across the Greater Beirut Area. The observations we made on specific intersections in the Greater Beirut Area showed an obvious delinquent behavior from drivers. The majority of cars stopping at red lights do not respect the stop bar hence becoming a source of danger to pedestrians. Whether the vehicle is a motorcycle, truck, private or public car, the drivers tend to arrive at the red light with their front end trespassing the stop line. In many cases, the whole car is stopped after the line or even after the entire crosswalk. In the case of this extreme breach of law, the violating vehicle becomes not only a hazard to pedestrians but also a danger to other commuters on adjacent segments of the intersection, as shown in Figure 1. In other words, cars coming from another direction – and having to cross in front of these violators – do not have enough safe distance in order to avoid collision on their trajectory. Figure 1 captures a pedestrian crossing perpendicularly to vehicles violating the stop bar. The pedestrian in this case is moving on an unsafe path too close to the moving vehicles who are in turn, too close to the stopped cars. These observations will be discussed in this research in addition to other factors that may or may not lead to the adherence to the stop bar.

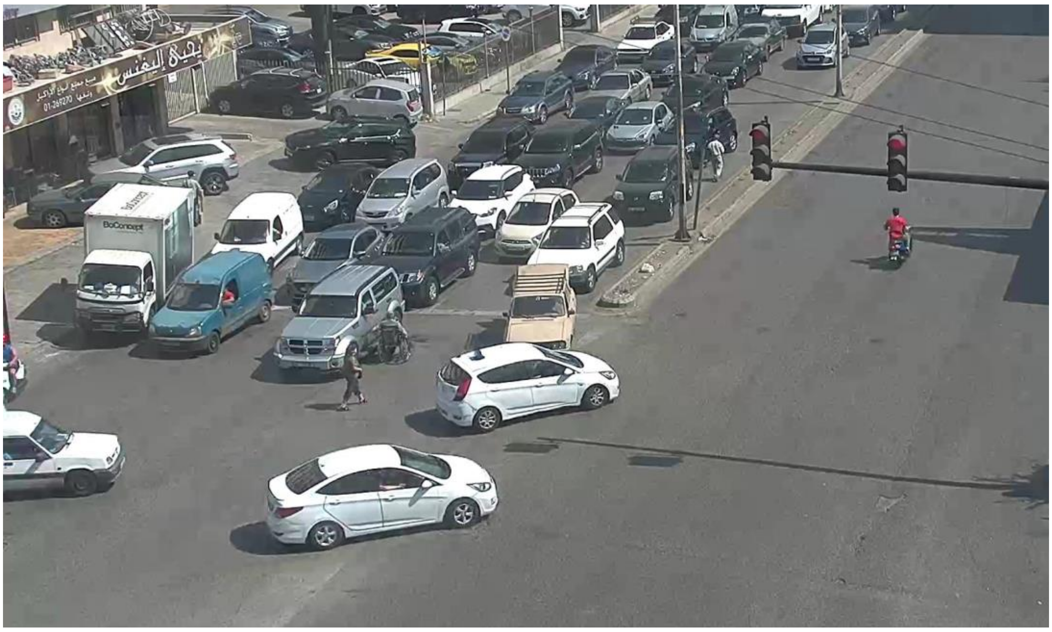

Figure 1: Red light at Dekwaneh-Nefaa intersection (source: TMC Lebanon)

Many researchers have addressed safety by examining the factors affecting drivers' behavior at intersections. Three main scenarios to assess drivers' behaviors at intersections comprise the focus of this research effort: the presence of pedestrians, the presence of other stopping cars and their respective stop location and the presence of police or law enforcement figure. A transport system is composed of different segments – infrastructure, vehicles, commuters, laws and regulations, societies and norms, etc. – that jointly interact to create a functional system. In this context, it is problematic to try and isolate one element of the system while disregarding others. As such, the factors studied in this research will be examined both separately as well as together. Psychological and demographical influences will similarly play a major part in contributing to the dynamics behind drivers' behavior and responses to stimuli. The presence of other commuters, pedestrians or law enforcement figure will present three main hypotheses all targeting the main issue: how do Lebanese drivers behave at signalized intersections with respect to the stop bar? What additions at intersections stimulate best the adherence to the stop line? How does this behavior vary with respect to demographical and psychological factors? How can this behavior be optimized to reach a safer vehicle-pedestrian environment?

CHAPTER 2
Literature review

According to the Association for Safe International Road Travel (ASIRT), each year, on average, 1.35 million deaths result from road crashes, with the addition of millions of short and long-term injuries. In its Global Status Report on Road Safety (2018), the World Health Organization categorizes road misfortunes to be the number one reason for the death of people between 5 and 29 years old. It is established that more than half of traffic victims are pedestrians or other vulnerable road facilities users, especially in developing countries.

2.1 Demographics

Fu et al. (2013) and Jiang et al. (2012) highlight the importance of studying drivers' behavior by analyzing the factors leading to the violations of road driving rules of different kinds. One of the hypotheses tested by Fu et al. (2013) is that young drivers are less concerned with traffic safety laws at intersections and tend to speed more. The findings of the study indicate that younger male drivers are more likely to commit traffic violations in general; moreover, the leading cause for such hazardous driving was their lack of attention. This outcome was verified by Cordellieri et al. (2016) who pointed to the difference in driving behavior, risk perception and adherence to road safety between young males and females. It is suggested that males tend to be less concerned about accidents' consequences and thus tend to commit more traffic violations. Additionally, another demographic comes to mind when assessing driver behavior and such an entity relies on one's age and driving experience rather than one's gender. The gender and age factors were further explored by Vardaki & Yannis (2013) and Parmet et al. (2015). Statistically, traffic rules are violated more often by drivers between the ages of 17 and

24 and mostly by males (Vardaki & Yannis, 2013). Mid-aged drivers between 26 and 64 years old are less likely to get driving citations than younger commuters between 16 and 25 years old (Jiang et al., 2012). According to Parmet et al. (2015), safety assessment and driver behavior between young novice drivers and experienced drivers vary excessively. For instance, 14 scenarios in this study were conducted through a driving simulator encompassing business and residential streets and studied several reactions and responses to hazards and the perception of dangerous events by the participants. In general, throughout the driving simulation test novice drivers approached crosswalks with high speed variability mainly due to lack of experience while the experienced drivers tend to be more cautious and decelerate promptly prior to reaching a crosswalk. The results identified that novice drivers were more reckless, careless in their driving and seemed to lack proper hazard perception in comparison with non-novice drivers that have evidently more experience in diverging away from hazards. Therefore, it is evident that novice drivers tend to suffer excessive hazards due to their lack of awareness and perception as opposed to experienced drivers.

In addition, driver behavior can be linked with other psychological, physiological environmental and cultural factors. For instance, Danaf et al. (2018) proved – through their research which conducted a comparative study of student driver behavior in Lebanon versus the United States – that Lebanese students tend to be negative risk-taking drivers around intersections while US students are more likely to commit red light violations on signalized intersections. These factors can be interpreted with respect to the strict traffic-safety measures especially on conflicting areas such as intersections. Furthermore, one could add that even though the Lebanese intersections are pre-timed, not all are consecutively synchronized to decrease trespassing situations due to a limited or inadequate cycle length or even inconvenient phase lengths. The stressful and frustrating circumstances faced by Lebanese drivers due to inadequate systems and excess urbanization leading to an immense amount of traffic influences the driver's reckless, daring and aggressive driving (Danaf et al., 2018).

Recent studies (Mayhew et al., 2017; Shell et al., 2015) validate the existence of an additional important measure that would significantly help reduce the average yearly number of crashes and violations. Undergoing a successful training and road safety education showed effectiveness in the reduction of crashes during the novice driver's first years of driving. Education programs boost young adults' driving behavior as non-educated drivers are expected to be involved in misfortunes 1.22 times more. These programs include both classroom hours and actual driving time. The training topics include general laws, traffic flow tasks, vehicle operation, substance use and abuse, insurance, mixing with traffic operations, the influence of environmental factors, elements affecting performance etc.

2.2 Environmental factors

Indeed, the more knowledgeable the drivers are about safety laws, the more careful they will be in their driving routines. However, having strict surveillance and law monitoring would boost the abidance of drivers to the law as they would be more careful not to get a serious violation. Shaaban & Pande (2018) evaluate the effect of the implementation of surveillance cameras at red lights in the State of Qatar on violations. It was verified that the presence of these regulating cameras significantly lowered the number of violations at the intersections. Approaches without cameras witnessed approximately eight times more violations than those with cameras. A similar assessment was conducted in Fairfax County, Virginia, USA where cameras were installed at intersection lights. A 36% improvement rate regarding violations was observed during the first three months of implementation which went up to 69% after six months. Consequently, the number of crashes was also reduced by 40% (Retting et al., 2008). Furthermore, a new technology implemented in the UK called "average speed enforcement" demonstrated a promising compliance with speed limits, a decrease in 85th percentile speeds, in addition to a reduction in fatal crash rates (Soole et al, 2013). This innovative technology consists of calculating the average vehicle speed by dividing a specific well-known distance between two camera sites over the time it takes the vehicle to pass through both certified camera locations. If the vehicle speed was recorded above the allowable speed limit for that road section, an automatic image is documented, and offence data are delivered to a central processor where an infringement notice is presented to the offending vehicle. Following this strict automated enforcement, a high compliance rate with posted speed limits has been recorded by several studies which further enhances road safety and illustrates a conforming driver behavior. As a result of implementing average speed enforcement, the crash rate of serious accidents improved from 33% to 85%, and the offence rates are documented to be less than 1% even on highly trafficked roads (Soole et al, 2013). Such a formidable enforcement technique can reduce crash rates at vehicular intersections that arise from driver recklessness, and lead to road safety for pedestrians and other vehicles due to the increase in driver compliance.

Similarly, another form of law surveillance is the presence of police figures at intersections. Safer facilities and police enforcement are closely linked together as the latter directly pushes drivers to be attentive to their driving behavior by conforming to traffic laws. The relation between the presence of police figures and aggressive driving is presented in Stanojević et al. (2018)'s paper since angry driving is linked to crash involvement. The study in Northern Kosovo and Serbia found that the absence of police enforcement is related to risky driving behavior. Likewise, influences of law enforcement on unsafe driving habits are validated by numerous studies (Montella et al., 2015; Walter et al., 2011). On the other hand, Feng et al. (2020) use the amount of police patrol time per day as a variant for police enforcement. It was found that for each 1% increase in patrol time, the crash frequency decreased by 0.15%. The same variant was used by Rezapour et al. (2018) in eight states in the United States with the addition of the number of officers present and amount of enforcement budget as factors too. It was found that among these three enforcement types, the one that was most successful as an indicator of highway fatality rates was the time spent by highway patrol officers on the field. Moreover, a study by Ryeng (2012) assessed three factors influencing driver's speed choice such as: the level of police enforcement, penalties for speeding, and the speed of choice of other drivers. The latter study concluded that the most influential speed reducing factors are the speed reduction of other driving vehicles on the road and the increase in law enforcement.

Walter et al. (2011) confirmed the efficiency of increased reinforcement and public campaigns in the form of signage or newspaper to be of great success in London. Ryeng (2012) agreed with Walter et al. (2011) regarding social pressure playing an essential factor in addition to police reinforcement for determining driver speed choices. The research explains the role of social pressure in the driver's speed which can also be considered as an imitation behavior. Ryeng (2012) argues that if society was to perceive fast and reckless driving as a common practice, then the driver would not be encouraged to abide by the speed limit. However, if staying below the speed limit was a norm to the driver's society in addition to solely being a legal matter, drivers would be encouraged to follow the guidelines set forth by the traffic laws, or else they would be reprimanded. As a result, it is fundamental to increase driver awareness about the level of law enforcement through media platforms and promote positive outlook on the citizens that abide by the law thus reducing unwanted reckless driving.

Another aspect of enforcement is the issuance of tickets and citations to violators.

Rezapour Mashhadi et al. (2017) developed a negative binomial model to examine the effect of different types of citations on the number of crashes occurring during 4 years. The results show that crashes tend to occur at a significantly lower rate whenever more citations are given, especially those relating to speeding and seat belts. However, Ryeng (2012) challenges Rezapour Mashhadi et al. (2017)'s result by indicating the marginal low correlation between stricter sanction implementation and the decrease in the driver's speed of choice.

Environmental factors are proven to affect the drivers' behavior and attention, especially while approaching intersections (Werneke et al., 2014). Commuters adapt their behavior and gaze in compliance with the information given to them by their environment, whether it is other vehicles or pedestrians. This imitation behavior at intersections is demonstrated by Paissan et al. (2013), especially in countries with poor traffic education where drivers tend to behave the same as the majority of the commuters. Their research shows that drivers who receive a proper education in traffic rules are less likely to imitate rule violators that they meet on the road, whereas drivers who have poor road safety knowledge are easily drawn into the majority's driving behavior, whether safe or not. Shroeder & Rouphail (2011) confirmed the driver's tendency to imitate the consecutive of near drivers in the region. In their study, they identified a certain driver behavior pattern where drivers are more willing to yield if the adjacent vehicle has already done so in a multilane roadway. However, Shroeder & Rouphail (2011) also identified a certain yielding pattern relating to the pedestrians position on the crosswalk such that near pedestrians to the road itself or even assertive pedestrians triggers that start crossing the road may also lead the driver to yield most of the time. Even though yielding behavior is mostly required by law that sides with pedestrian's right to pass, some determinants such as convoy vehicles or even high speeding vehicles might refrain from decelerating or even stopping for the waiting pedestrian.

The previous predicament relating driver approach speed to the yielding rates was further elaborated by Bertulis & Dulaski (2014) who confirmed that drivers yield for pedestrians more often at crosswalks while driving on a relatively residential low speed street as opposed to streets with high-speed limits. Following the ASHTOO guidelines, the vehicles speeds taken under consideration were not relative to the posted speed but were subject to the environmental conditions within the area; therefore, the 85th percentile speed of the real life vehicles was taken into account for a proper reliable analysis. Furthermore, the yielding rates were at a constant high showing 63%, 73%, and 75% of yielding rates for several consecutive trials on a 20mph street. While the 30mph had yielding rates of 40%, 42%, and 52% on the contrary to 40mph that had much lower insignificant results. Such results confirmed by Bertulis & Dulaski (2014) predicament that speed is inversely proportional to yielding rates, and this in turn highlights the importance of planners and designers to reassess the pedestrian-vehicle interaction locations keeping in mind the safety and welfare of both parties.

In addition to latter yield rate determinants, the higher the pedestrian volume the lower the pedestrian walking speed when entering the crosswalk, and thus the higher probability of vehicle yielding (Obeid et al., 2017). Moreover, this study conducted at the American University of Beirut was able to uncover some Lebanese driver tendencies regarding speeding in university and non-university streets. An important assessment through the use of a driving simulator uncovered positive attributes for driving yielding behavior regarding the ban of roadside parking, the use of crosswalks and the reduced approaching speed led to the increase in yielding rates and decrease of vehicular speed near crosswalks especially when pedestrians were crossing.

Zhao et al. (2020) related the pedestrian and driver behaviors in two comparative models while dealing with vehicle-pedestrian interactions. This study reaffirms Obeid et al. (2017)'s results since it was concluded by the authors that the higher the number of pedestrians crossing the street, the more vehicular yields will occur and the longer the vehicular delay will be. This in turn is due to the steady continuous flow of pedestrians traveling at lower speed exceptionally as a result of their large volume. It was concluded that the waiting time of pedestrians crossing crosswalks at large volumes is much less than smaller groups since more time will be provided for the people to cross the street which reiterates the increase in vehicle yields as a result of low pedestrian waiting time. However, as lanes increase the vehicles are expected to yield less often for the coming pedestrian thus leading to an increase in pedestrian waiting time, and a decrease in the relative vehicular delay.

The Lebanese population's driving behavior is known to be mostly delinquent regarding traffic laws hence violations are very common as well as road injuries. As precautionary measure, Zöller et. al (2019), confirms the importance of designing intersection assistant signals simultaneously with the intersection based solely on the driver's braking behavior while considering the different environmental, cultural factors in the area; thus, decreasing hazardous accidents around intersections. The ASIRT states that some of the main factors contributing to road crashes are the unsafe commuters' behaviors and the unenforced traffic laws. While this review of previous work was done regarding drivers' behavior and traffic law violation with their different reasons, this research will target the Lebanese driver's behavior regarding violations at intersections, especially with respect to pedestrian crosswalk markings and the reasons which lead drivers to disrespect or respect stopping at the marked stop line.

2.3 Psychological aspect

Other than assessing driving behavior in relation to environmental factors, intrinsic psychological factors could also be relevant to investigate. Personal differences might arise while trying to assess the relationship between environmental factors on the road and drivers' behavior. In other words, not all people would have the same reaction while encountering a policeman or a pedestrian on the road. For example, the perception of the environmental factors or even the anticipation of hazards on the road might not be the only contributor to differences in drivers' speed. In fact, personality traits and risk-taking behavior might also have an influence (Parmet et al., 2015 and Chahine et al., 2022). Hence, one's personality could potentially affect any susceptible violation concerning speed limits on the roads. In addition, driving violations might not be only explained by the type of driving an individual engages in (whether aggressive or not), but more importantly, it might be affected by one's tendency to violate traffic rules (Danaf et al., 2018). And to investigate this tendency, personality traits and their correspondent components, like impulsivity, depression and anxiety traits, and mindfulness could be of upmost significance.

Personality Traits and Driving Behavior

Personality traits have been proven in the literature to be significant predictors of driving behavior and consequences on the road. From the Big Five perspective, openness to experience, extraversion, neuroticism, conscientiousness, and agreeableness, seem to have indirect effect on driving. Conscientiousness was believed to lead to more control over actions while driving. Consequently, this trait helped predicting less driving anger, which was also related to more emotional stability and positive driving behavior (Anitei et al., 2014). This might help explain why conscientiousness in taxi drivers negatively predicted number of fines for example (Esmaeili et al., 2012). Agreeableness as well indicates better driving behavior, for low levels of this trait predicted more aggressive driving behavior (Anitei et al., 2014), hence also a greater chance of road violations (Alavi et al., 2017). Openness however negatively predicted aberrant and aggressive behavior while driving (Anitei et al., 2014), but still predicted an elevated number of fines in taxi drivers (Esmaeili et al., 2012). These findings might indicate that there may be more than aggressive styles in driving that might lead to accidents and violations on the road.

However, in a study evaluating driving behavior in a simulator, extraversion was a significant indicator of unsafe driving (Riendeau et al., 2018). In addition, components of neuroticism such as sensation seeking and anxiety were believed to have a predicting role when it comes to risky driving (Riendeau et al., 2018). These findings are complementary to studies predicting aggressive driving behavior (excessive speed, honking, cursing, dangerous road behavior), for neuroticism helped in predicting both anxious and aggressive driving (Antei et al., 2014). Anxiety for example, was seen to increase traffic violations by 4.1 times in truck drivers, which might because anxiety makes it harder to control emotions which is more likely to reflect on their driving behavior (Alavi et al., 2017). Hence, neuroticism can be inducing anxious and aggressive driving behavior through specific components such as sensation seeking and anxiety/depression, which then influence high accident rates.

Therefore, the big five personality traits seem to be related to driving behavior and indirectly predict aspects of it. However, components related to these personality traits like impulsivity, sensation seeking, anxiety/depression, and even control over actions and mindfulness could be leading to better explanations when it comes to the investigation of this relationship.

Impulsivity

Defined in numerous different ways throughout the literature, impulsivity is mainly considered as acting or behaving with limited antecedent thought and concern about the consequences (Bıçaksız & Özkan, 2015). Most frequently, those consequences tend to rather be unfavorable to the impulsive individual, or even their surroundings. Especially when related to driving behavior, impulsivity has been linked to several traffic violations and errors. For instance, after correlating positively with aggressive driving behavior, impulsivity was a significant predictor of traffic accidents in a study held by Čabarkapa et al. (2018). Impulsivity has also been negatively correlated with harm avoidance (Le Bas et al., 2015), and positively correlated with driving risk (Le Bas et al., 2015) and risky driving behavior (Barati et al., 2020; Pearson et al., 2013) as impulsive drivers have less tendency to follow the rules. Because of the wide relationship between impulsivity and the unfavorable consequences it has on driving, many studies have sought to explain why the link between the two. A study by Barati et al. (2020), joined impulsivity with decision making and attentional bias, and these variables put together, helped infer that impulsivity might be affecting drivers' cognitive skills, and indeed affected their driving behavior. This includes that impulsivity might influence one's cognitive functioning. Furthermore, another explanation might be that impulsive drivers hold poor techniques to control their anger, and consequently could be using their vehicles to reveal what they feel (Mirón-Juárez et al., 2020). This raises the importance of finding a component that would prevent people from committing driving errors and violations, and act impulsively. Controlling impulsive thoughts and anger, and ameliorate drivers' cognitive skills while driving, might be beneficial to attenuate the influence of impulsivity on driving safety.

Mindfulness

Mindfulness, characterized by one's own state of awareness and attention concerning actions during the present moment (Young et al., 2018), has been believed as well to influence individuals' driving behaviors in different settings. More precisely, in a study conducted by Reynaud and Navarro (2019), it has been found that mindfulness sessions positively affected drivers' performances. In addition, after the mindfulness sessions, participants showed lower steering wheel turns and intervehicle time (distance with another car divided by speed) (Reynaud & Navarro, 2019). This suggests that mindfulness can help drivers ameliorate their driving behavior and focus on the roads, especially that it has been also associated with lower car crash rates, driving errors, and violations (Koppel et al., 2018). Another explanation of the positive effect of mindfulness on driving would be that it can prevent drivers from engaging in distractions that might arise while on the road. In fact, it has been negatively linked to several types of distractions, like being distracted and lost in one's own thoughts, as well as being distracted by factors inside or outside the vehicle (Young et al., 2018). These results might suggest that mindful people not only pay more attention while driving, but that they might also be more concerned about driving safety. This might bring on the other hand, the probable tendency of limited concern of individuals with low mindfulness about the outcomes and results of their actions (Abdul Hanan et al., 2010). Therefore, another potential role of mindfulness related to driving is that it might increase the drivers' consciousness about breaking the rules and committing violations. This accentuates the importance of studying mindfulness while seeking to limit the effect impulsivity has on driving behavior.

CHAPTER 3
Methodology

3.1 Research program

This research aims at analyzing Lebanese driver behavior at signalized intersections and under alternating conditions. According to numerous studies, a driving simulator is an ideal apparatus to be used in the analysis of driver behavior, and safety analysis with hazardous replicated real-life scenarios. Not only does this tool help researchers maintain controlled experimental conditions, but it also promotes the safety and welfare of the human subjects participating in the experiment. This study was modelled and designed using the UC-Win/Road Cluster Master Version 15.1, which is a simulation software that allows the researcher to model a specific scenario such as a vehicular-pedestrian conflict by eliminating disastrous results generated from real life and maintaining controlled unchanged variables. In such scenarios, aiming to make the model more identical to the real experience, the software holds a large, sophisticated library containing numerous display elements from infrastructures, vehicles, 3D characters, buildings, and traffic lights intended to illustrate a mirror of real-life onto the designed model. Therefore, such a software allows researchers to test and analyze driver behavior in certain conditions that have been deemed as death hazards in many real-life cases.

After finishing the design, this model was tested on human subjects. Such testing took place on the driving simulator vehicle powered by FORUM8 and located at the LAU Byblos ELRC labs. This machine is fully equipped with advanced technology to simulate a real-life scenario in sound, vision, and sense. It is constituted of a Mercedes Smart Car with two seats and belts, three digital 7” LCD screens to simulate the mirrors, a fully functional sound system that provides convincing driving and obstacle sounds with stereo speakers and subwoofer, driver response buttons, and a dashboard camera to record the driver’s movements.

This study is qualitative and quantitative and will be gathering data in three stages. First, the participants will be asked to drive on the simulator for about 8 minutes. At this stage, all their reactions will be recorded whether they relate to speed, reaction time, stopping location, abidance to the rules etc. When done, they will be directed to a survey to complete.

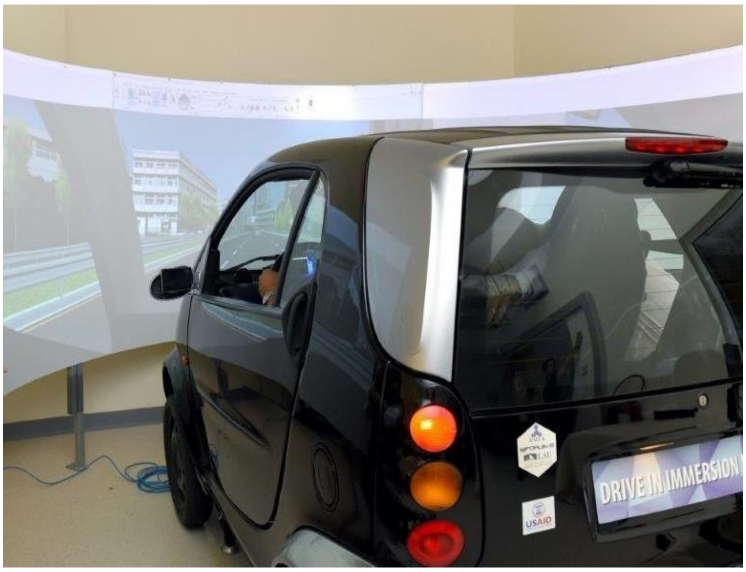

Figure 2: UC Win Road car at the LAU ELRC

Figure 3: Perspective from driving in the simulator

3.2 Model development

In this model, seven 4-armed identically shaped intersections were designed with the presence of both stop lines and crosswalks at the terminal of each arm. The model is around 8 km long with a straight leveled road throughout the seven intersections. Each road was made of 6 lanes, consisting 3 in each direction. The wide number of lanes were intended to test the effect that the imitation variable has on the driver's behavior near the crosswalk especially when other cars are occupying the neighboring lanes next to vehicle under study. The lanes were enhanced in width rather than having a standard width of 3.6 m each lane was increased by 1.4 m resulting in a lane of 5m. This planned design was a precautionary measure that would have led to a disadvantage in the model simulation later. The model is designed as such since though the 3.6 m measure is normal in real life, such a measure would appear narrow on the simulator leading the cars to feel confined inside each lane. Therefore, to better simulate the visuals of our model, and to maintain its illustration as near real life as possible, the lanes had to be increased by 5 m each. Finally, since most intersections in Lebanon are on arterial roads within urban environments, the posted speed was allocated to be 80km/h and the drivers' car was limited to a maximum possible speed of 100km/h. This maximum limit is proposed because of the possibility that some drivers might not feel their speed getting high as they would in real life and for them to be able to stop at the intersection if they wanted to.

Three variables were considered critical to the driver's behavior around signalized intersections according to the cited articles. The first element under consideration relied on the implementation of law enforcement comprised of the presence of police vehicles, surveillance cameras, and police figures at the end of the terminal to test how the driver's behavior might be altered in the light of authoritative surveillance. As for the second variable, imitation was considered extremely critical in this study since such a behavior allows one to understand and predict a driver's behavior at an intersection. This element was detected to be of great importance in Lebanon through the accumulated data from the Traffic Management Center (TMC). Such data showed that drivers were inclined to imitate near vehicular behavior, especially with respect to their parked distance relative to the crosswalk. In addition, many cited articles were keen on stressing this variable while studying driver behavior around vehicle pedestrian interactions (Paissan et al. 2013; Shroeder, & Rouphail 2011). Finally, the last variable was inspired by several articles, and by several hazardous accidents that took place on some intersections taking the lives of many due to recklessness, and law breaking (Zhao et al., 2020; Obeid et al., 2017; Bella el al., 2015; Bertulis & Dulaski, 2014; Shroeder & Rouphail, 2011). This study focused on pedestrian crossing at a red light as a last variable whilst analyzing driver behavior. The main components under investigation were the deceleration rate while approaching the intersection, the speed of the approaching vehicle, and most importantly the distance at which one stops with respect to the crosswalk whether before, after, or even on the crosswalk.

This study contains six intersections allocating one of the three variables and their relative combinations on each which helps with the sensitivity analysis; thus, they can be represented as follows: law enforcement (Pl), imitation (I), pedestrian crossings (Pd), law enforcement x imitation (PlI), law enforcement x pedestrian crossings (PdPl), and imitation x pedestrian crossings (PdI). Three random orders were delivered so that the data would be valid without allowing drivers to all have the same orderings.

As for the first scenario, law reinforcement techniques were implemented at the intersection terminal while also placing a posted speed of 80 km/h. In addition, a trigger will be place at 150 m away from the intersection to ensure that the red light is on once the vehicle is in sight of the actual traffic light. This factor highlighted great importance since it ensured that the study is only considering the driver behavior at the actual intersection without including the variable of fast perception or driver reaction time to the red light. This way the driver would anticipate a stop at the intersection and would prepare to react as such rather than be surprised by a sudden change in phase. When the driver reaches the terminal arm where they would encounter a law enforcement figure and vehicle surveilling driver behavior and making sure that the law is followed promptly. It was expected that the presence of authoritative legal surveillance would ensure higher driver attentiveness and abidance by the law at intersections with respect to the speed limit, yielding for pedestrians, and finally yielding at a safe distance behind the crosswalk as the law entails. As a result, for law enforcement, a possible guarantee for lower crashes rates between vehicles and pedestrians on the crosswalk was expected to be recorded. The main goal of inserting this element in the model was to study whether the driver upon sighting the designated law enforcement in the area will be more inclined to stop farther from the stop line or will the driver remain neglectful intolerant to the law.

Furthermore, the second scenario regarding the imitation variable required driving vehicles to occupy all neighboring lanes next to the simulation vehicle as an attempt to increase and test one’s inclination to imitate another vehicle once the terminal of the arm is reached. Like the first scenario, a trigger was placed 150 m far from the crosswalk for the driver to sight the red light from afar. The neighboring vehicles were simulated to be ahead of the driver and stopping after the stop bar for them to reach the actual stop line beforehand. If the participants were inclined to imitate the simulated vehicle’s placement, they may be able to do so due to the latter’s prior presence. Once the simulator vehicle reached the terminal, the driver would have to decide whether to imitate the already residing vehicles and stop after the stop line or follow the well-known requirement to stop before the stop line. It was expected that Lebanese drivers tend to imitate near vehicles due to the low awareness around yielding dynamics at an intersection.

Additionally, the third scenario encompassing pedestrian crossings consisted of a trigger placed 150 m away from the intersection like the previous scenarios. According to Figure 4, extracted from the Principles of Highway Engineering and Traffic Analysis Book and AASHTO (2011), the SSD required for a level road (G = 0) and a design speed of 80 km/h is 130 m. This variable might alter the driver decision to stop near the crosswalk due to the presence of a pedestrian. The 3D characters walked at a speed ranging from 3 to 6 m/s from the curb to the other side on a flightpath that is colinear to the crosswalk. It was expected that once the driver has sighted the pedestrian, they will take extra precautions to yield as far as possible from the crosswalk.

Design speed (km/h)	Brake reaction distance (m)	Braking distance on level (m)	Stopping sight distance	
			Calculated (m)	Design (m)
30	20.9	10.3	31.2	35
40	27.8	18.4	46.2	50
50	34.8	28.7	63.5	65
60	41.7	41.3	83.0	85
70	48.7	56.2	104.9	105
80	55.6	73.4	129.0	130
90	62.6	92.9	155.5	160
100	69.5	114.7	184.2	185
110	76.5	138.8	215.3	220
120	83.4	165.2	248.6	250
130	90.4	193.8	284.2	285

$$SSD = \frac{V_1^2}{2g\left(\left(\frac{a}{g}\right) \pm G\right)} + V_1 \times t_r$$

SSD values in 10 km/h increments based on above eq. and using AASHTO values of a = 3.4 m/s^2 and t_r = 2.5 sec

Assuming G = 0

Figure 4: SSD values depending on the design speed (AASHTO 2011)

As for the final three scenarios, their components were configured out of combinations among the same elements described in the first three scenarios depending on each combination under study. These scenarios helped the researchers understand the effect of each variable independently, and co-dependently on the driver's behavior, and driver’s decision while reaching an intersection at a red light.

3.3 Traffic Management Center

In this research, real life data were acquired from the traffic management center (TMC) in Lebanon constituting of three main locations all in Jdeidet el Matn area. The first intersection known as Almaza in Dora, a well-known intersection. The data recorded were from the southbound direction with a total of 352 recorded vehicles. The second intersection under consideration was in Dekwaneh region near Al Nefaa, and the recognized data were taken from both southbound and westbound directions summing up to a total of 262 vehicles. Finally, the last intersection known as Khabbaz was in Jdeideh region. Unlike the others, this intersection was old and lacked the presence of a clear crosswalk. The only clear marking present on each arm was a stop line. The number of vehicles observed in the latter was 202.

In each of these intersections, videos were retrieved from TMC and watched several times to record the data needed. In the first and second intersections the documented data were classified as vehicles stopping at a red light, before the stop line and crosswalk, after the stop line and on the crosswalk, and after both the stop line and crosswalk. The data were taken to assess the dependency of driver behavior on the imitation variable which was vividly clear in several instances of the videos. In addition, the presence of pedestrians was also considered and noted at every red light.

3.4 Surveying and testing

A total of 181 drivers, whether novice or experienced, participated in the research by driving the simulation model. Upon arrival to the LAU ELRC Lab in Byblos, each participant was presented a consent form with a code for anonymity. They were then asked to enter the vehicle and were given instructions about the vehicle's operation and expectations for the drive. They first drove on a testing road section for about 3 minutes as a practice to get familiar with the vehicle and had the option to repeat as much as they needed. The research model driven after it is about 5 minutes long. These drivers consisted of a mixture of university students and adults with an age ranging from 18 till 70. In addition, LAU staff and LAU students were called for through an email sent to the faculty and its students that aimed to recruit willing participants. The partakers had the freedom to take the test at their leisure while the certified Collaborative Institutional Training Initiative (CITI) researchers followed the guidelines of the International Review Board (IRB) for human subject testing so that the participants were granted safety, wellness, and privacy. Several factors were taken under consideration while drivers were taking the test such as: driver behavior with respect to other vehicles, speed, stopping distance with respect to the crosswalk, driver attentiveness and reaction to pedestrian presence, and yield rates.

Finally, a survey presented at the end of the test created with the help of the psychology team helped add to the analysis of driver behavior at intersections and illustrate what the Lebanese driver knows and expects to take place at such crucial locations. The questionnaire starts with questions about demographics while keeping the participant's identity hidden. It also includes three questions at the end about their experience in the simulator versus their usual driving in real life. The online survey will comprise several psychological scales that are proven to be valid and reliable. The scales included are the following:

- Attitudes towards driving safety (ATTS): Three-dimensional scale comprising 16 variables that measure attitudes related to traffic safety issues such as rule violations and speeding, other people's driving, the combination of drinking and driving etc. A five-point evaluation scale was applied.

- The UPPS Impulsive Behavior scale - short version. This is a 20 item scale which measures four dimensions of impulsivity on a 4-point Likert scale.

- Driving Behavior Survey (DBS): This is a 21-item scale that counts for anxiety-based performance deficits, exaggerated safety/ caution behavior and hostile/ aggressive behavior – measured on a 7-point Likert scale.

- The Mindful Attention Awareness Scale (MAAS). The MAAS trait is a 15-item, 6-point Likert scale designed to assess a core characteristic of mindfulness as a receptive state of mind, attention, a sensitive awareness of what is occurring in the present and observing what is taking place.

- The Patient Health Questionnaire-4 (PHQ-4). This is a four-item questionnaire answered on a four-point Likert-type scale. Its purpose is to allow for ultra-brief and accurate measurement of core symptoms/signs of depression and anxiety by combining the two-item measure (PHQ–2), consisting of core criteria for depression, as well as a two-item measure for anxiety (GAD–2).

- The Brief BFI scales. The big five personality inventory measures 5 dimensions of personality traits: Extraversion, Agreeableness, Conscientiousness, Neuroticism and Openness to Experience. The brief version is validated 15-item, 5-point Likert scale.

3.5 Data collection

All the data collected was safely stored in a file within LAU and only the researchers involved with this project had access to it. The data will be analyzed using R studio and the results summarized in this research paper. The sample size had to be above 100 participants to be representative of the Lebanese population. This number was deduced by assuming that the drivers' population in Lebanon follows a normal distribution. Specifically, we assumed a confidence level of 95% (Z = 1.96), a standard deviation of one-sixth the expected range ((7 – 1)/6 = 1) and an error of 0.2.

After approximately 4 weeks of testing, the total number of participants added up to 181. Naturally, the data collected had to be inspected and cleaned which resulted in the removal of 5 participants. The reason behind the removal of four of them was that they exhibited chaotic driving. This is expected to happen in such studies due to the nature of the testing device classified as virtual reality. The last participant removed out of the five did not complete the survey since participants were free to leave the study at any point as per IRB protocol. The resulting 176 sample used can be distributed as shown in the following table.

Table 1: Sample distribution by demographics

Gender	Male	114
	Female	62
Age	18-19	36
	20-21	69
	22-27	45
	28-39	10
	40+	16
Marital Status	Single	153
	Married	22
	Separated	1
Children	Yes	19
	No	157
Years of	Less than 1 Year	12

Driving Experience	1-5	107
	6-10	28
	11-20	11
	20+	18
Accident History	No.	89
	Yes, Minor accident.	71
	Yes, Major accident.	16

3.6 Reliability analysis

Cronbach (1951) challenged the problem of reliability in order to evaluate the relationship between items within a certain psychological scale. The coefficient reflects the degree to which an individual's score is a biased assessment of his latent score. Cronbach's alpha ranges from 0 to 1 with a higher score representing highly correlated elements. The coefficients for this study are summarized in the below table and were obtained for each general psychological scale as well as for its subscale items.

Table 2: Reliability analysis using Cronbach's alpha

Scale	Number of items	Cronbach's alpha
ATTS Scale	16	0.80
ATTS Subscale: Rule violations and speeding	11	0.80
ATTS Subscale: Careless driving of others	3	0.67
ATTS Subscale:	2	0.83

Drinking and driving		
UPPS Scale	20	0.73
UPPS Subscale: Negative urgency	4	0.72
UPPS Subscale: Lack of perseverance	4	0.72
UPPS Subscale: Lack of premeditation	4	0.68
UPPS Subscale: Sensation seeking	4	0.7
UPPS Subscale: Positive urgency	4	0.72
DBS Scale	21	0.77
DBS Subscale: Anxiety based performance deficits	7	0.69
DBS Subscale: Exaggerated safety behavior	7	0.71
DBS Subscale: Aggressive behavior	7	0.83

MAAS Scale	15	0.88
PHQ Scale	4	0.83
PHQ Subscale: Anxiety	2	0.86
PHQ Subscale: Depression	2	0.75
BFI Scale	10	0.35
BFI Subscale: Extraversion	2	0.49
BFI Subscale: Agreeableness	2	0.15
BFI Subscale: Conscientiousness	2	0.32
BFI Subscale: Neuroticism	2	0.52
BFI Subscale: Openness to experience	2	0.057

The resulting alpha coefficients are acceptable (0.70-0.79) and good (0.80-0.89) except for the BFI scale with a coefficient of 0.35. However, for this scale specifically, it is expected to have a low coefficient because of the differences within one scale and the fact that subscales with only two items are involved (Balgiu, 2018).

CHAPTER 4
Results and Discussion

4.1 Overview

To analyze the results of the study, the simulator outcome variables were each joined with demographic and psychological data as well as simulator input variables to determine their effects. The simulator outcome variables include the information coded from the raw data and gathered from each participant at each intersection, mainly:

- The "stopping difference" which is the distance in meters between the stop bar of each intersection and the most advanced location at which the driver was at the end of the red light phase of that intersection. It is measured from the front of the car and can take a positive or negative value.
- The "final rolling length" which is the distance travelled while rolling with a speed less than 15 km/h after a full stop was made or while approaching the intersection within the last 5 seconds of the red phase.
- The "acceleration" in m/s^2 of the car after the driver came to a full stop and accelerated again after the green light. It is taken as an average for 2 seconds around the maximum reached acceleration within 10 seconds after the green light onset.
- The "reaction time" which is the time it took the driver approaching the intersection with a green light to see the change in phase and get his foot off the gas pedal.
- The "overall speed" which is the averaged speed around the maximum in km/h and for 5 seconds. It is taken far away from the two adjacent

intersections in order to reflect the speed drivers would usually drive at in such setting.

These variables are recorded for 6 scenario and 176 participants so 1,056 instances in total. The simulator input variables mentioned above are those introduced in the simulating software at intersections which are the presence of pedestrians, police, imitation behavior and their combinations.

4.2 Exploratory analysis

A representation of a driver's speed going through the simulation is shown in the following figure. The random driver "P6" stopped at the 7 intersections and his maximum reached speed was around 80 km/h. For some intersections he had a longer wait while stopping, for others he rolled a little then stopped again and he might also have started rolling while the light was red until he could accelerate at the green light onset.

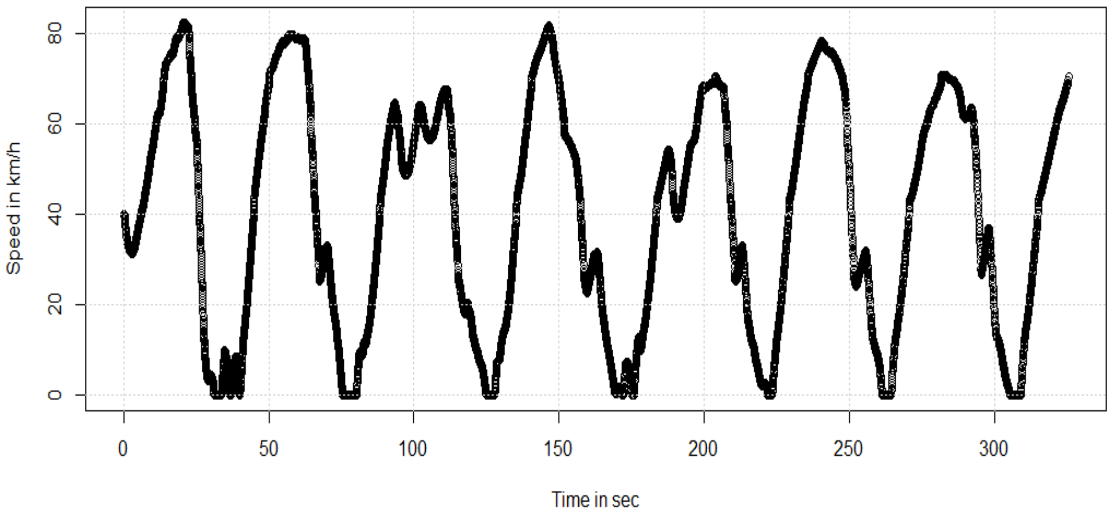

Figure 5: Exploratory analysis for random participant

Not all participants however have the same profile while driving which is why it is important to check the normality and distribution of the overall speed to determine the course of action for the model later. The following plots show the distribution for the overall speed which connotates non-normality and suggests that participants mostly drove at a speed around 80 km/h away from the intersections, which is the posted speed limit. However, many of them drove at a slow speed or exceeded the speed limit as expected.

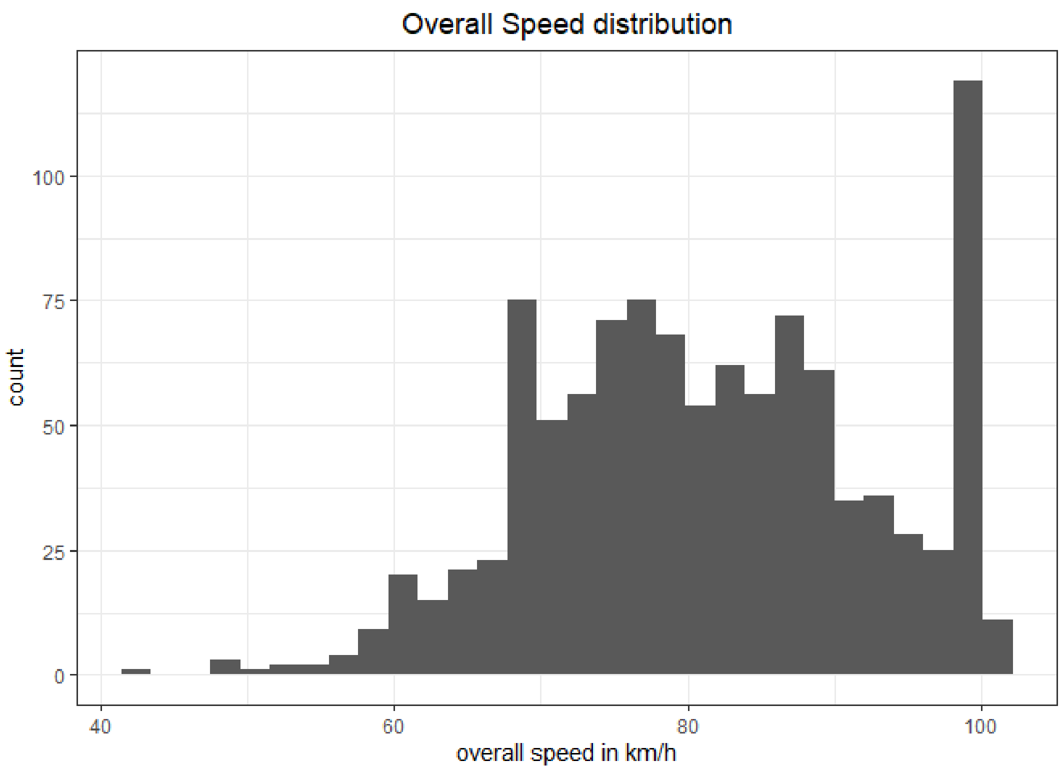

Figure 6: Overall speed distribution

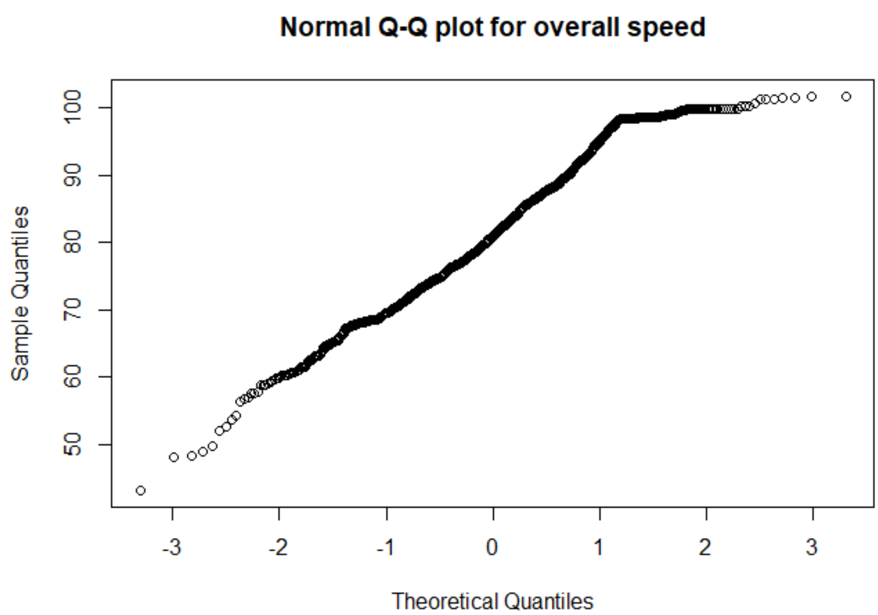

Figure 7: Overall speed QQ plot

For the stopping difference, most participants stopped near the stop bar on the safer side (> 0), with some being overly cautious and others disregarding safety. The distributions shown at this point include the same participants on all intersections and we have not yet differentiated them by introducing the intersection variables and their effect.

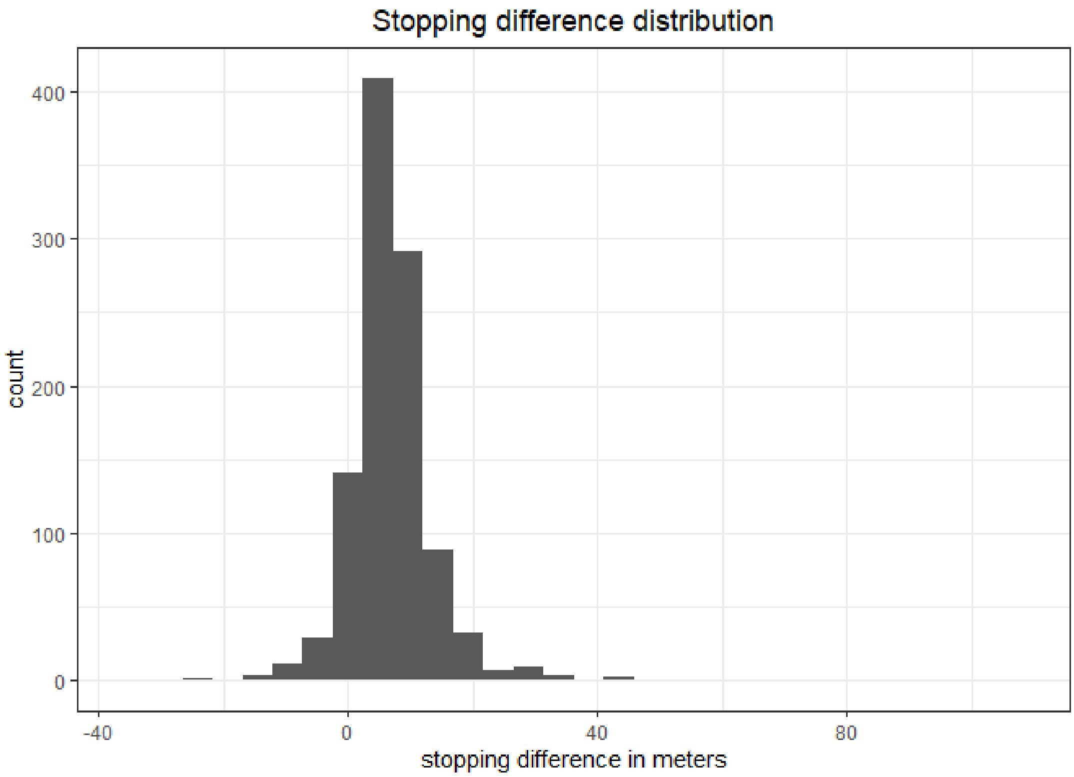

Figure 8: Stopping difference distribution

For participants who came to a full stop before accelerating at the green light, the mean acceleration is equal to 2.25 m/s^2. The maximum is 3.5 m/s^2 while the minimum is 0.24 m/s^2 and this significant difference between the two extremes highlights a difference in behavior.

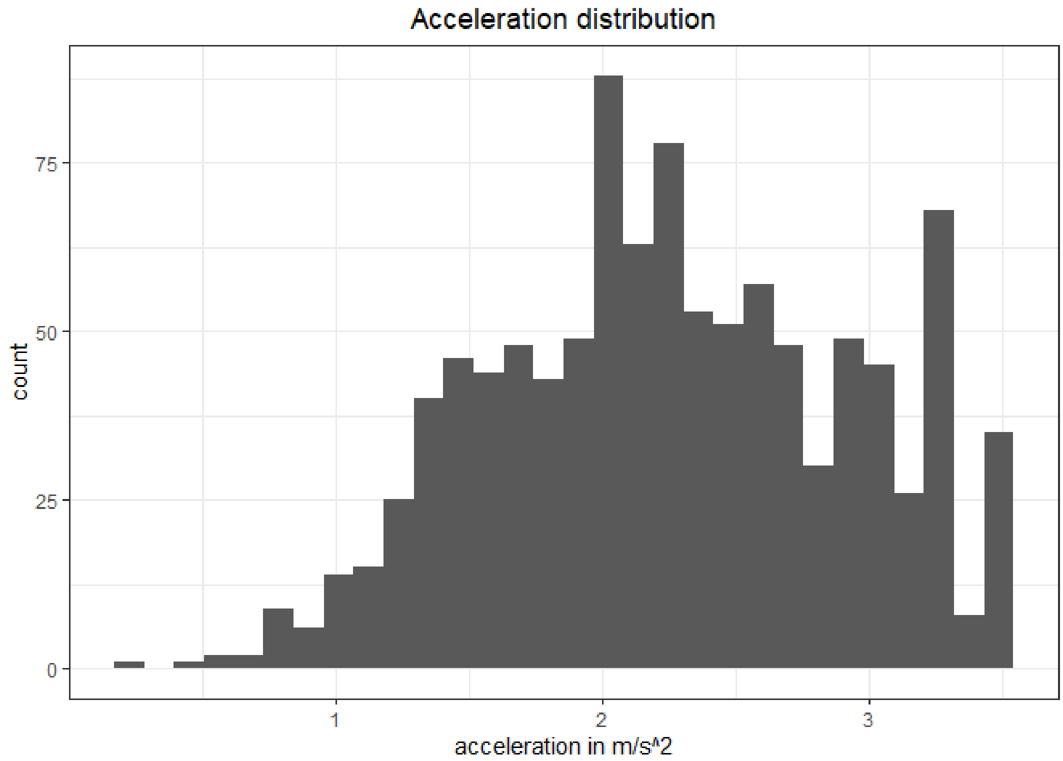

Figure 9: Acceleration distribution

The reaction time which is both the perception and reaction time together are frequently used in transportation engineering for design purposes. According to AASHTO (2011), a conservative total reaction time is 2.5 seconds. This value has been determined from empirical and theoretical data as it varies depending on the person and situation. For comparison, the average driver has a total reaction time of around 1.0 to 1.5 seconds. This number includes the time for the driver to perceive the obstacle and initiate brake application by getting his foot off the gas pedal and on the brake pedal. In our study, it includes the perception for the drivers to see the change in traffic light in addition to the time it takes them to get their foot off the gas pedal but not on the brake pedal. In addition, the majority of the participants are young which is a factor that lowers the reaction time. The distribution is centered around the mean which turned out to be 0.80 seconds.

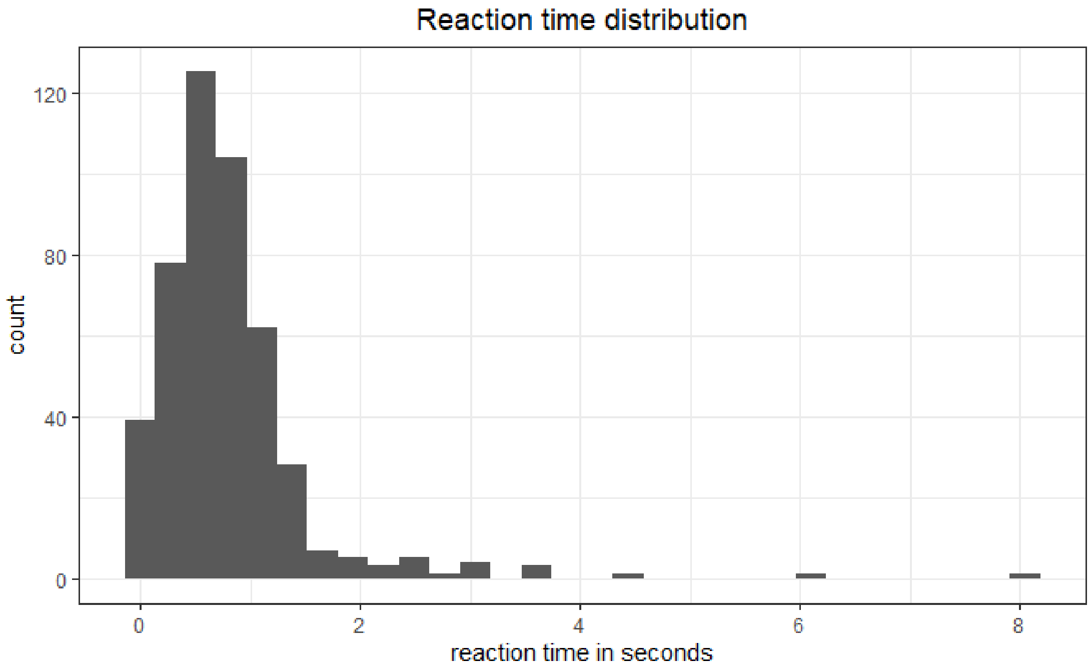

Figure 10: Reaction time distribution

4.3 Intersection variables

For the sake of determining whether the variables at the intersections affect the stopping location of a driver, Pearson's chi-squared test is used. The nominal variable is the violation versus non-violation of the stop bar at the red light. For a driver to be considered law-abiding, he should have a stopping location (in meters) inferior to the location of the stop bar or else he would be considered to have committed a violation. This variable is used in parallel with the intersection variables to get the relation between the two. The X-squared value obtained is 24.15 with a p-value of 0.0002027 (< 0.05) which proves that committing a violation with respect to the stopping location at the stop bar is affected by the variable placed at the intersections in the simulation.

Since drivers are passing through six scenarios, one after the other, they may experience a carry-over effect in their behavior. What is meant by that is that their reaction to an intersection variable might have been different, had the variable been placed on a more advanced intersection where the participant would have gained more comfort and experience in the simulator. As mentioned in the model development part of the study and in addition to having a training segment, participants will randomly be driving on one of three combinations of the simulation. Each combination will have a different order for the intersection variables and the order dependency will be tested to verify that the output data is independent of the order.

The simulator output variable to test for is the one related to the stopping location which can be categorized as: “before the stop bar”, “on the crosswalk”, “after the crosswalk” and “passed the red light”. This variable will be tested at each intersection with respect to the combination and will serve as a baseline to disprove the carry-over effect. Since this variable and the combination name are categorical, a chi-squared test is used. Pearson’s and Fisher’s chi-squared tests are used simultaneously as using Pearson’s test on data that has small sample sizes in some categories might give an incorrect approximation whereas Fisher’s chi-squared test is more flexible.

Table 3: Testing for carry-over effect in intersection variables

		Stopping location PI				
Combination	Content	Before the stop bar	On the crosswalk	After the crosswalk	Passed the red light	Total
1	Count	39	2	1	1	43
	Expected Values	37.9	2.4	1.2	1.5	
	Row Percent	90.7%	4.7%	2.3%	2.3%	24.4%
	Std Residual	0.184	-0.284	-0.200	-0.385	
2	Count	53	3	0	2	58
	Expected Values	51.1	3.3	1.6	2.0	
	Row Percent	91.4%	5.2%	0.0%	3.4%	33.0%
	Std Residual	0.269	-0.163	-1.284	0.016	
3	Count	63	5	4	3	75

	Expected Values	66.1	4.3	2.1	2.6	
	Row Percent	84.0%	6.7%	5.3%	4.0%	42.6%
	Std Residual	-0.375	0.358	1.281	0.277	
Total		155	10	5	6	176

The presented table is a sample showing the results for the stopping location at the intersection having a police officer (Pl). All standard residuals for all locations and combinations are withing the | 1.96 | range. In addition, the statistics for all table factors return a Pearson's X^2 of 4.03 with a p value of 0.672 and a Fisher's p value of 0.752. This proves that there is no carry-over effect depending on the order in which this intersection scenario was presented to the participant.

4.4 Predictive model

Mixed effects modeling is a statistical analysis that models complex interactions between predictors and outcome variables. It accounts for repeated measures as well as random variances in the components of the data. The two fundamental inputs for this type of modeling are the fixed and random effects. For the data used in this study, the fixed effects are the attributes that do not change for the same person within the timeframe of the study: the demographics and psychological traits. The six intersections are considered as unidentical repeated measures for each participant hence for the same driver, an intersection variable is a random effect. Using mixed effects models brings the analysis for the study to another level compared to traditional analyses. This model can adapt to missing data for driving outputs that could be non-applicable for some drivers at some intersections. Instead of having to remove participants if we were using ANOVA for example, the models present estimations using all the data points regardless of few cells being empty. Before proceeding to build a predictive model, the data was transformed into a longitudinal shape using the “reshape2” package (Wickham, 2007). This reshaping helps read every person’s occurrence at every intersection as a data point observation taken repeatedly. Mixed effects models collect patterns of change for an individual by making these separate examinations dependent. The R software version 4.0.3 is used with the “lme4” package (Bates et al., 2015) for linear mixed effect modeling. A model is built for every simulator driving output by first introducing all fixed effects to it. The results obtained guide the filtering process by removing the demographic and psychological variables that show no significance. The model is run at various stages with various effects each time until obtaining the final fixed effects that will be kept. Next, the random effect which is the scenario is added. The components of that effect will each exhibit a distinct importance hence the filtering again to reach the final model. The model possibilities can also be compared using indicators such as the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC) and the Pseudo-R^2 for fixed effects and for the total. The AIC is a measure used to compare the fit of a regression whereas the BIC estimates the likelihood of the model to be effectively predictive. Both metric values have no good or bad thresholds but are rather used for comparisons between models as the better alternative is the one with the lowest value. Similarly, the Pseudo-R^2 gives a higher value for the model with the relatively better goodness-of-fit in terms of variability. After the final model is chosen, its Intraclass Correlation Coefficient (ICC) is checked as it describes how strongly items in the same set relate to each other from 0 to 1. The higher the ICC, the stronger the relation, with an ICC lower than 0.50 indicating poor reliability.

4.4.1 Stopping difference

For the stopping difference model, the ICC is 0.57 which means that the reliability is moderate. The higher the stopping difference, the safer the behavior of the driver as he would be farther away from the intersection and a value less than 0 would mean he has passed the stop bar. On that note, parameters that have a positive estimate would promote a safer behavior. For this predictive model and the coming ones, the scenario that is being compared to (joined with the intercept) is the one with the predicted imitation behavior. That is, other cars that are stopping after the stop bar could influence the participant which would explain here the high significance and positive estimate of the Pd and PdPl scenarios since their effect is in a different direction. Regardless of the scenario, and starting with a negative intercept estimate, the higher the person scores on the indicated psychological scales, the more he is likely to have a safe stopping distance.

Table 4: Stopping difference predictive model

	Fixed effects					Random effects
Parameter	Estimate	SE	95% CI	t	p	SD
Intercept	-12.68	3.37	[-19.28, -6.07]	-3.76	< 0.001	4.63
Scenario Pd[1]	2.11	0.46	[1.21, 3.01]	4.58	< 0.001	2.12
Scenario PdPl	1.83	0.60	[0.67, 3.00]	3.08	< 0.001	5.46
Gender (Female)[2]	2.34	0.70	[0.97, 3.70]	3.36	< 0.001	
DBS Anxiety Based Performance Deficit	1.18	0.45	[0.31, 2.06]	2.66	0.01	
DBS Exaggerated Safety Behavior	1.51	0.39	[0.73, 2.28]	3.83	< 0.001	
Mindfulness	1.09	0.44	[0.22, 1.96]	2.46	0.01	
BFI Agreeableness	0.48	0.20	[0.09, 0.87]	2.39	0.02	

Mindfulness describes a person's consciousness and awareness in the present moment and how well they are focused on their behavior while in a specific scenario. The higher the score on the mindfulness scale, the higher the level of dispositional mindfulness. Furthermore, the higher that level of mindfulness, the higher the difference between the final position of the driver and the stop bar. This can be explained by the fact that people who are in control of themselves and their surroundings are highly responsive to change. A crash only needs a brief moment of

[1] Whenever a scenario is present, the factor for the estimate is 1. Only one scenario can be present at a time.
[2] To introduce the gender to the model, the factor for males is 0 and the factor for females is 1.

distraction to happen, but with mindful driving, more focus can be achieved leading to a safer driving environment. Reynaud and Navarro (2019), Koppel et al. (2018) and Chahine et al., (2022) reinforce this position as people who practice mindfulness exhibit safer driving behavior leading to less crashes. As shown in the following boxplots, the drivers are clustered depending on their score on the scale and with respect to the mean of that scale. Similarly, those with higher score on the DBS exaggerated safety behavior and BFI agreeableness tend to exhibit a safer behavior. An elevated score on the first scale mentioned corresponds to a person who can see the danger in a situation and stay cautious and in a safe position to prevent the worst-case scenario from happening. A person who is agreeable usually maintains a peaceful relationship with his surroundings. In contrast, this means that lower levels of agreeableness tend to predict higher driving risk (Anitei et al., 2014 and Alavi et al., 2017). These traits are predictors of non-aggressiveness which explains the relationship with a safer and calmer driving in both cases. Gender also affects the stopping difference as females are safer drivers who stay farther away from the stop bar. This result confirms the findings in many previous publications (Vardaki & Yannis, 2013; Parmet et al., 2015; Song et al., 2021). In all these boxplots, the scenarios significant in the model which are the Pd and PdPl have indeed a positive effect on that distance when compared with the imitation scenario I.

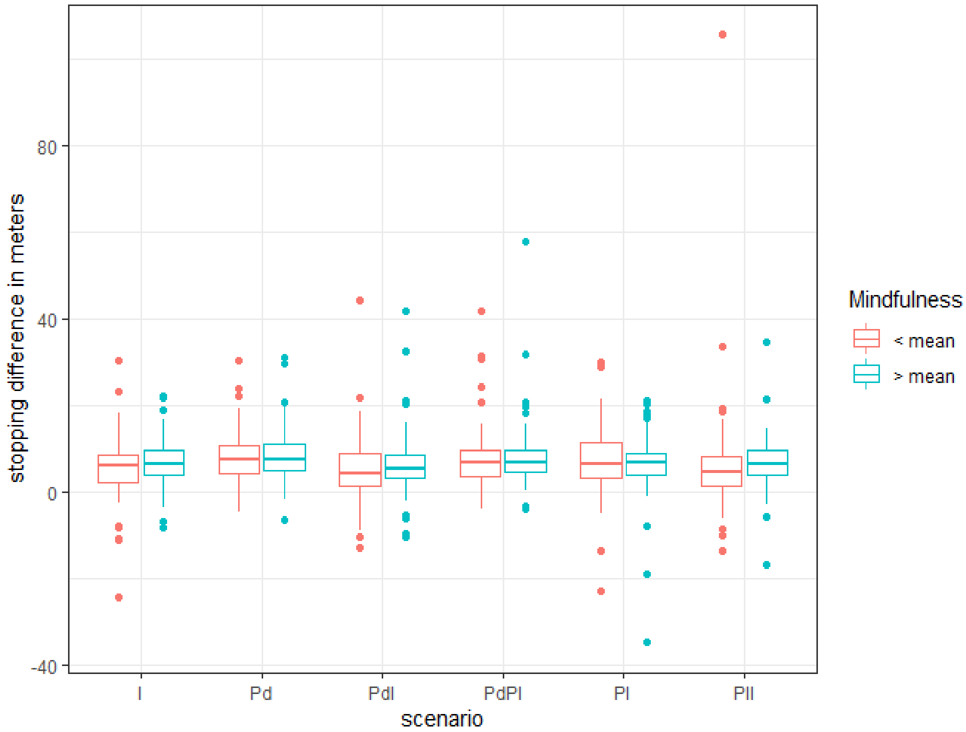

Figure 11: Stopping difference versus mindfulness

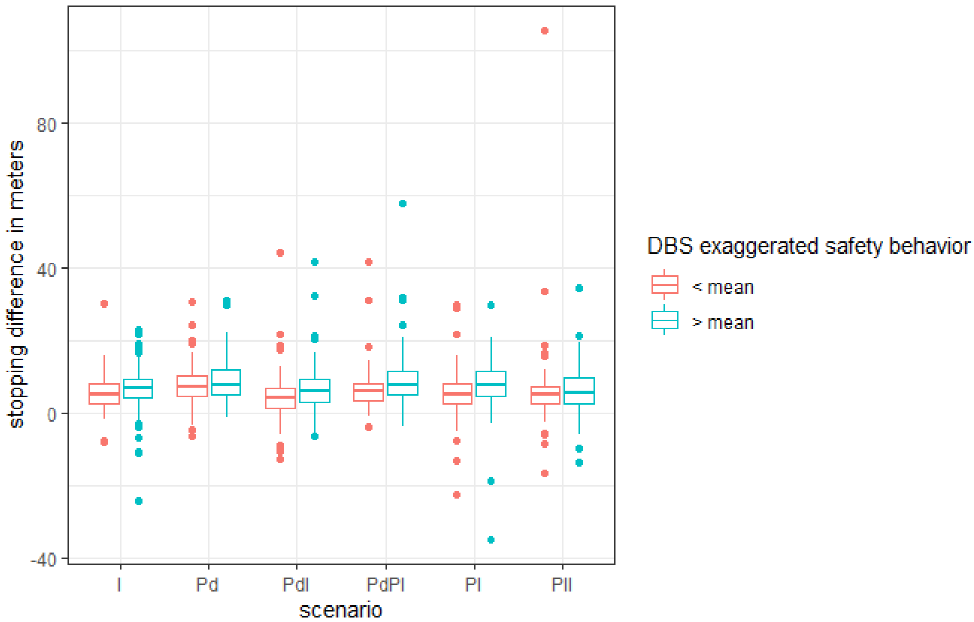

Figure 12: Stopping difference versus DBS exaggerated safety behavior

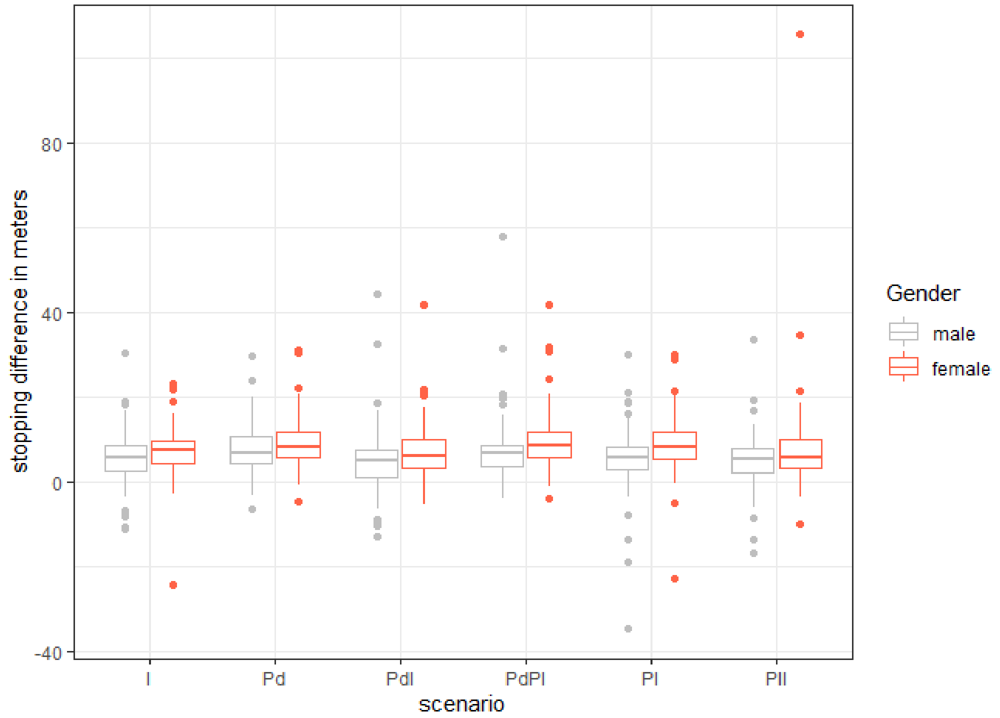

Figure 13: Stopping difference versus gender

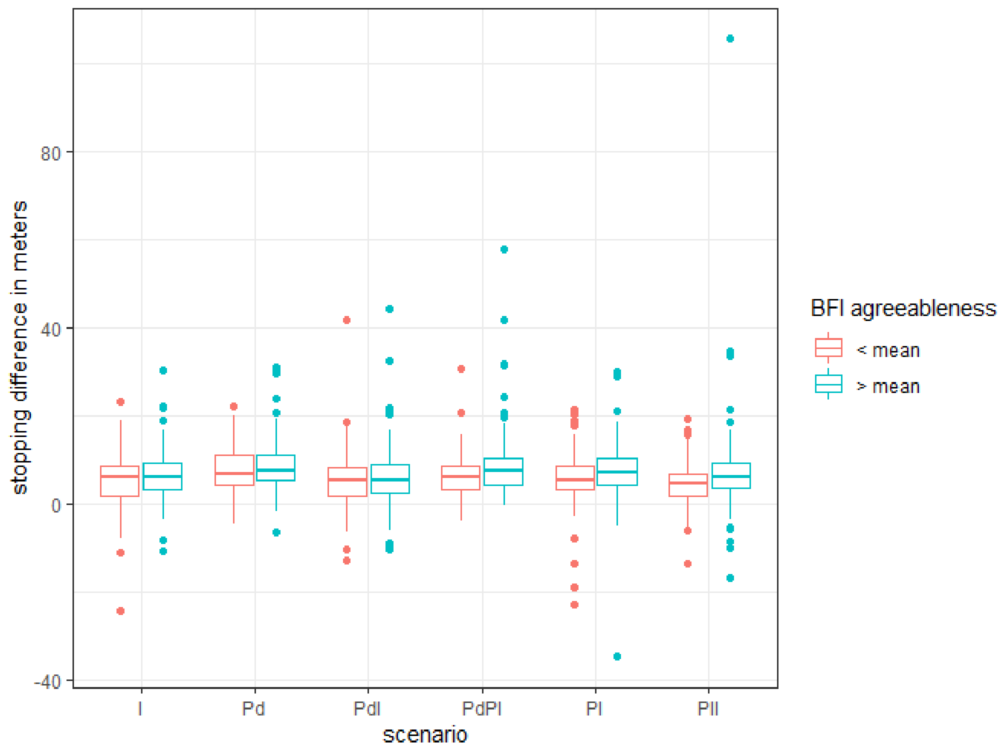

Figure 14: Stopping difference versus BFI agreeableness

4.4.2 Final rolling length

The final rolling length model has an ICC of 0.64 and is a measure in meters for the distance rolled, if any, in the last 5 seconds of the red light. This does not indicate the last placement of the driver and whether or not a violation was made but can rather be related to their impatience and inattention. Indeed, those who score higher on the mindfulness scale tend to have a higher rolling length. This can be explained by the fact that people who are in control of themselves and their surroundings might perceive the obstacle in front of them and calmly approach it. It is important to note that the estimate for this parameter is the highest and the scale is over 6, which is a high range compared to other scales. Subsequently, this high increase in rolling length means that the rolling towards the intersection is starting from a farther distance and should not be related to impatience. In the contrary, it means that the person is choosing to take his time approaching since he will be waiting for the same amount of time either way.

On the other hand, other participants whose mental health is affected by depression are more impatient to get through the intersection as depression is known to make people more nervous and irritable. This difference in behavior is mainly highlighted in the Pd scenario where the pedestrians are crossing but then the participant would still be waiting for the green light. This impatience in relatively depressed people who are waiting for the pedestrians to pass one after the other could be making them roll more once the space in front of them is cleared. On the contrary, it is obvious with all variables that the presence of a police figure always lowers the rolling length and hence is more likely to make people doubt coming closer into the intersection as there is a person standing in its middle. It can be deducted that the willingness of a driver to drive into the intersection is mostly affected positively by the presence of pedestrians after they pass and negatively by the presence of a fixed police officer. The same impatience trait can also be applied for people above 40 years old at the pedestrian scenario. This behavior can be reinforced by the fact that older adults are used to being in a rush due to their busier lifestyles and family commitments.

Table 5: Final rolling length predictive model

	Fixed effects					Random effects
Parameter	Estimate	SE	95% CI	t	p	SD
Intercept	-2.17	1.19	[-4.50, 0.16]	-1.83	0.07	3.18
Scenario Pl	-0.70	0.27	[-1.23, -0.16]	-2.56	0.01	0.81
Age	0.10	0.02	[0.06, 0.15]	4.30	< 0.001	
Mindfulness	0.58	0.27	[0.05, 1.11]	2.13	0.03	
PHQ Depression	0.24	0.12	[0.00, 0.50]	1.90	0.06	

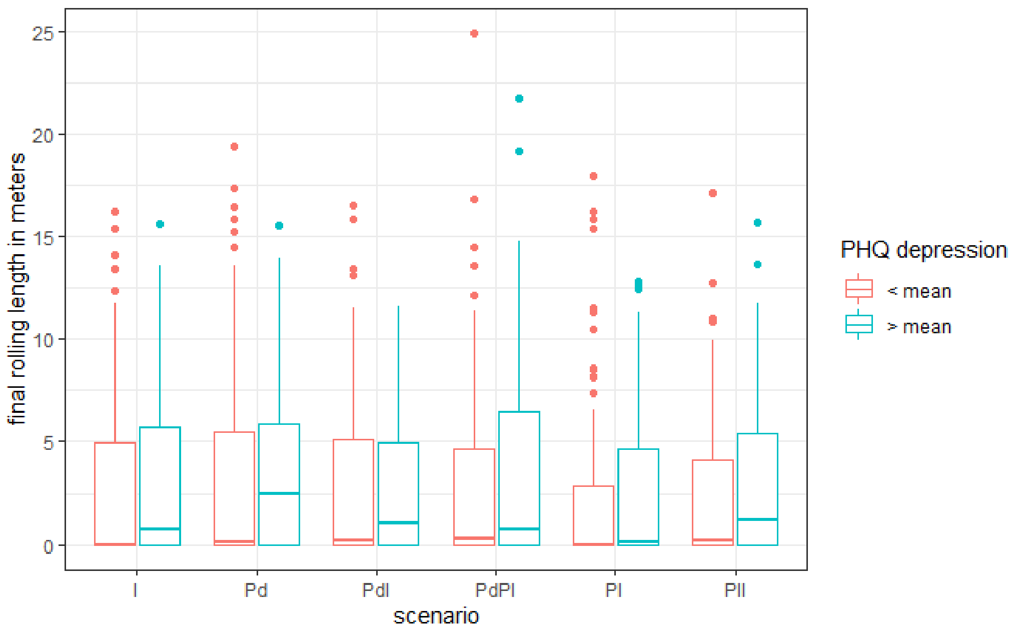

Figure 15: Final rolling length versus PHQ depression

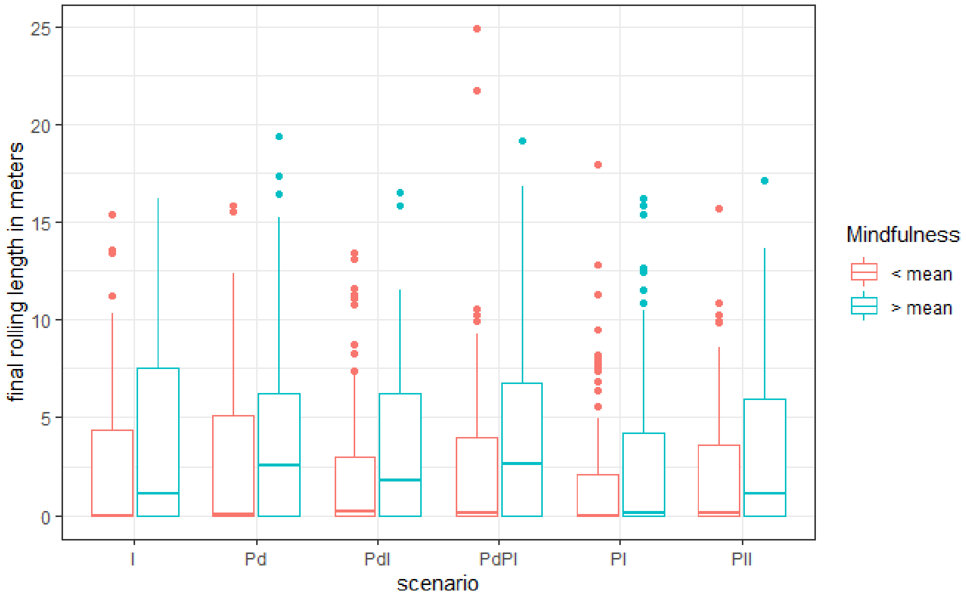

Figure 16: Final rolling length versus mindfulness

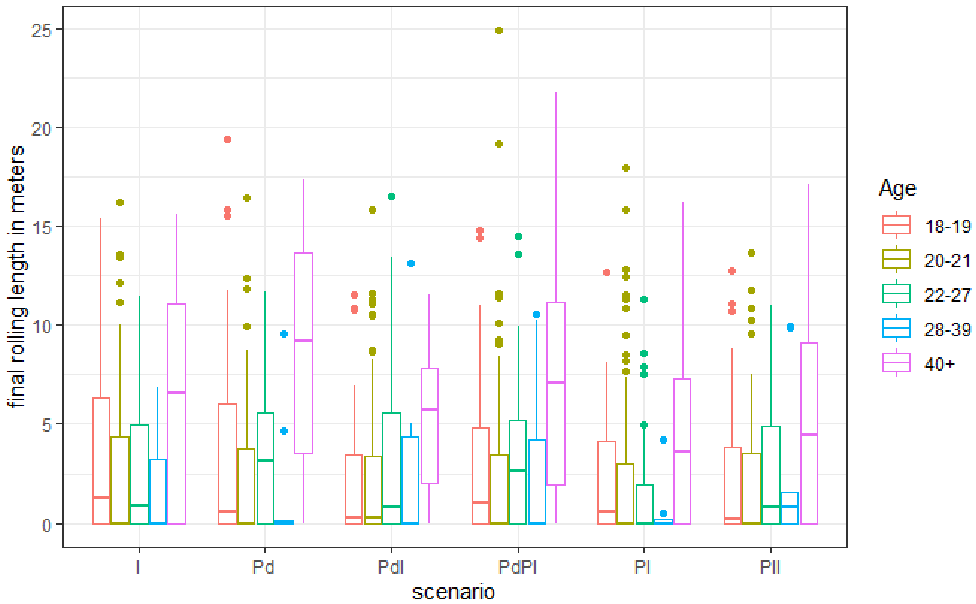

Figure 17: Final rolling length versus age

4.4.3 Acceleration

The acceleration in m/s^2 after stopping at the red and perceiving the green light can be a measure of aggressiveness and impatience in a driver. Drivers with a high acceleration rate are those who pressed quicker and with more force on the gas pedal in order to reach their cruising speed faster. On the contrary, those with lower accelerations were more peaceful and careful in their new departure and are considered safer drivers. Pearson's correlation test was performed for the acceleration and the overall speed using all data points from all scenarios. The two measures showed a significant positive relation with a p-value less than 2.2e-16. This means that drivers who usually drive at higher speeds, including those who go over the speed limit, have a high acceleration rate at the green light onset and are considered as aggressive drivers.

Table 6: Acceleration predictive model

	Fixed effects					Random effects
Parameter	Estimate	SE	95% CI	t	p	SD
Intercept	2.42	0.20	[2.02, 2.82]	11.81	< 0.001	0.52
Scenario PdPl	0.13	0.05	[0.03, 0.23]	2.48	0.01	0.41
Gender (Female)	-0.18	0.07	[-0.32, -0.04]	-2.44	0.02	
Have you been in an accident before[3]	0.15	0.05	[0.05, 0.26]	2.86	< 0.001	
ATTS Towards Careless Driving of Others	-0.13	0.04	[-0.21, -0.05]	-3.05	< 0.001	
BFI Neuroticism	0.05	0.02	[0.01, 0.09]	2.62	0.01	

For this model, the ICC is 0.63. Since the acceleration rate is relatively low, the intercept estimate starts at 2.42 m/s^2 and increases in function of the presence of pedestrians with police, the driver's accident history and scoring high on the neuroticism scale. People who have been in a major accident before are more likely

[3] The factors for being in an accident before are: 0 for never been in an accident, 1 for being in a minor accident and 2 for being in a major accident.

to keep being aggressive relatively to those who never had any accident. This difference is clearer for males who in general reach higher acceleration rates than females regardless of their accident history. The results regarding both the accident history and gender of a driver are explored by Terum and Svartdal (2019). According to this study exploring the lessons learned from accidents and near-accidents, and although experience with accidents may demand increased caution, it is not the case in either of the studies.

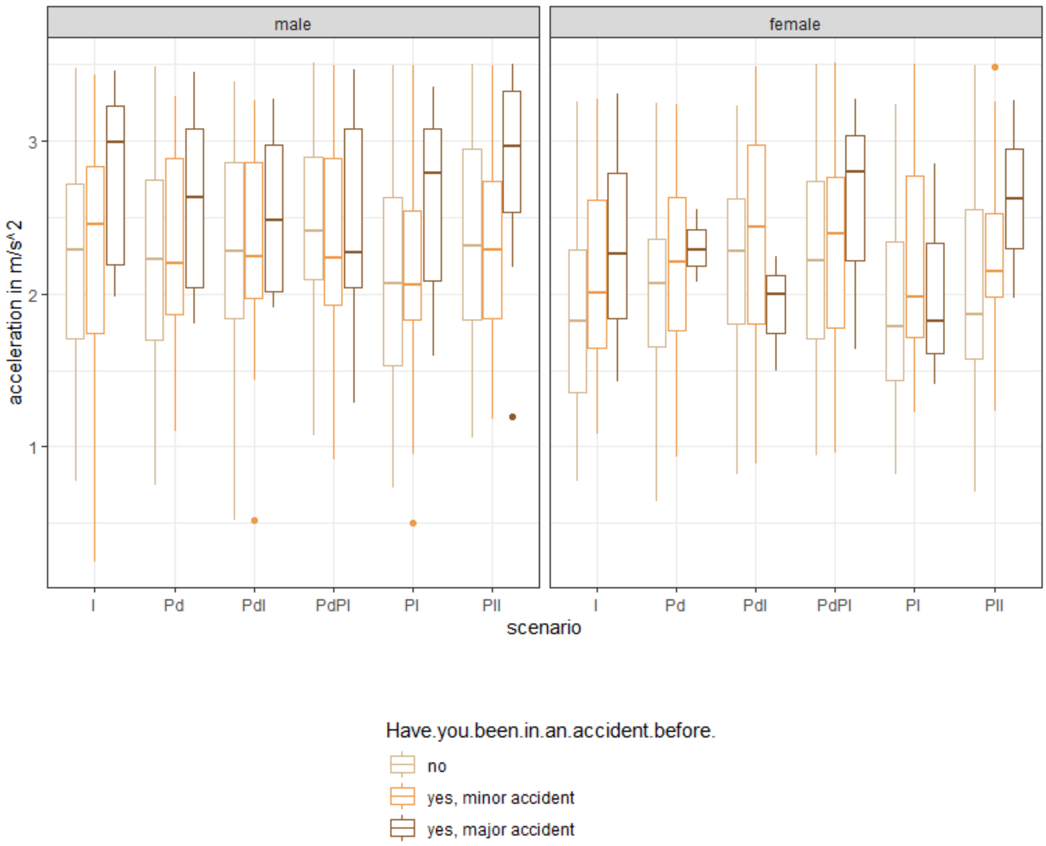

Figure 18: Acceleration versus gender and accident history

The ATTS scale deals with attitudes towards safe driving and gives a higher score for safer drivers. Participants scoring high on the subscale regarding the driving of others are those concerned with riding with an irresponsible driver regardless of the situation they are facing. Since those participants are reaching lower acceleration rates, then the latter is inversely related to safe driving.

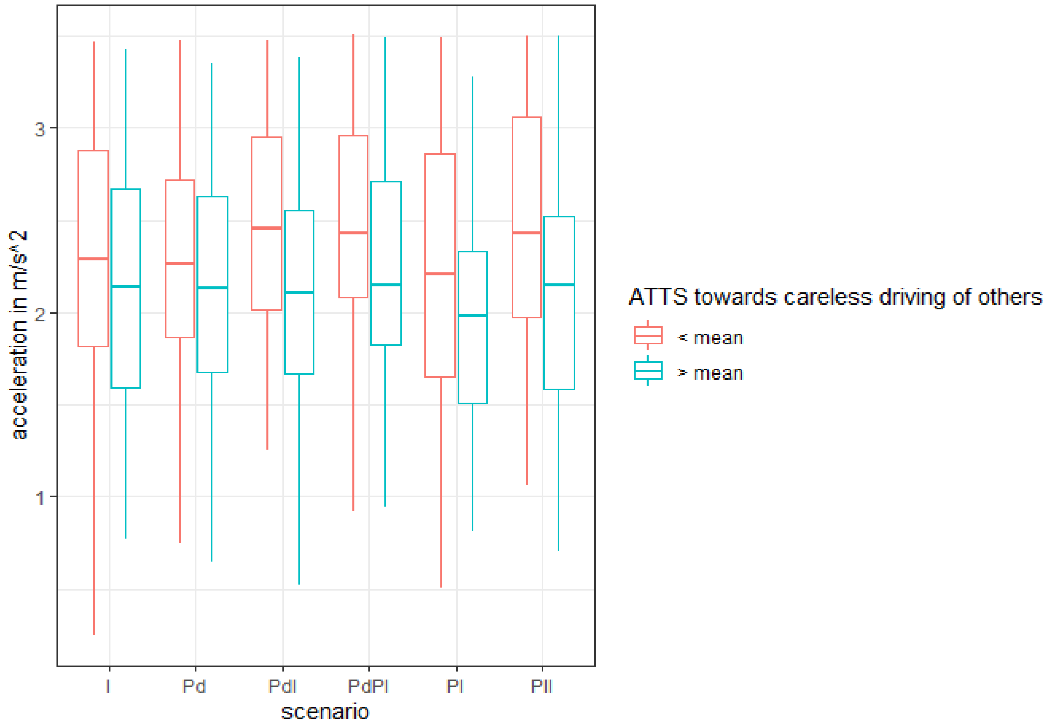

Figure 19: Acceleration versus ATTS towards careless driving of others

Neuroticism is a personality trait describing a person's tendency to go through negative emotions including anger and anxiety. The association between being an aggressive driver and having a high score on neuroticism is because having this personality trait makes drivers easily frustrated and they tend to respond more impulsively to stimuli. This result aligns with the findings in the recent research by Liu et al. (2022) in which this personality trait is associated with aggressive driving.

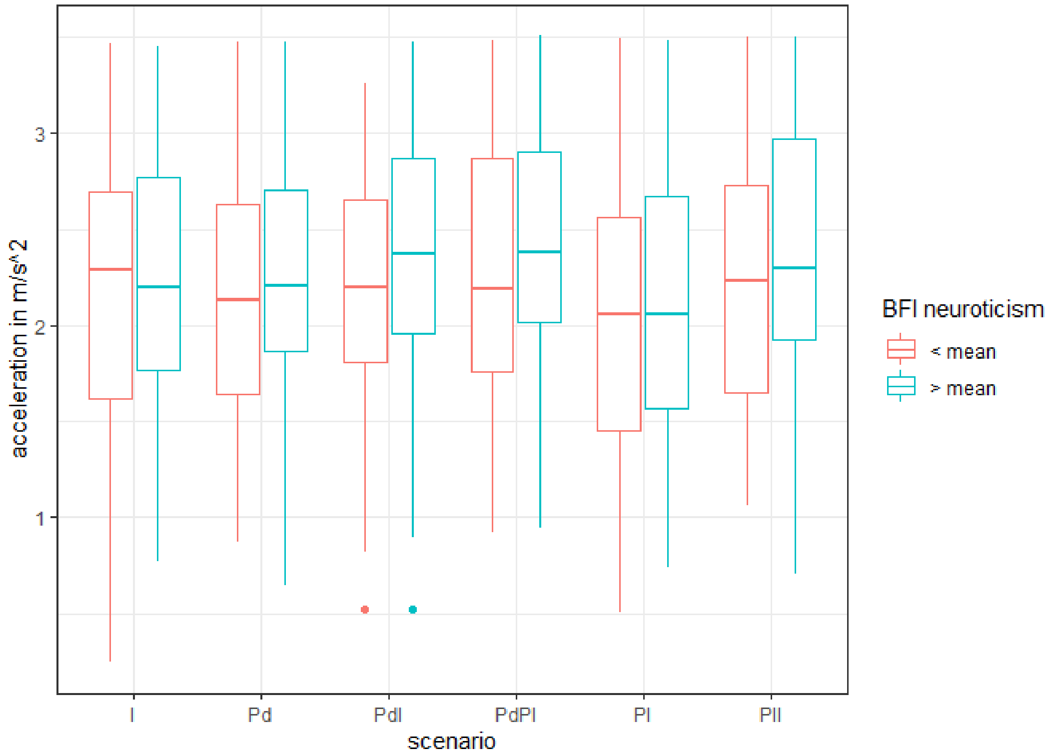

Figure 20: Acceleration versus BFI neuroticism

4.4.4 Overall speed

The overall speed model has an ICC of 0.61 and is not related to any scenario variable since this speed is freely taken away from intersections. Demographic and psychological variables are significant since they are predictors of aggressive driving behavior which in turn is closely related to speed. Age and gender in this model prove that younger males are more prone to speeding and taking risks. Females and older drivers, in contrast, have different cognition when it comes to driving and risk preferences. Gender and age combined support the conclusion by Song et al. (2021) that risky driving is less common in females. According to the latter study, this safe behavior develops faster with more years on the road for females, when compared with males.

Table 7: Overall speed predictive model

	Fixed effects					Random effects
Parameter	Estimate	SE	95% CI	t	p	SD
Intercept	107.64	4.71	[98.39, 116.88]	22.83	< 0.001	7.68
Age	-0.22	0.07	[-0.36, -0.09]	-3.23	< 0.001	
Gender (Female)	-3.02	1.29	[-5.54, -0.50]	-2.35	0.02	
ATTS Towards Rule Violations and Speeding	-4.31	1.02	[-6.30, -2.31]	-4.23	< 0.001	
DBS Exaggerated Safety Behavior	-2.46	0.75	[-3.94, -0.98]	-3.26	< 0.001	
BFI Extraversion	1.13	0.36	[0.43, 1.82]	3.17	< 0.001	

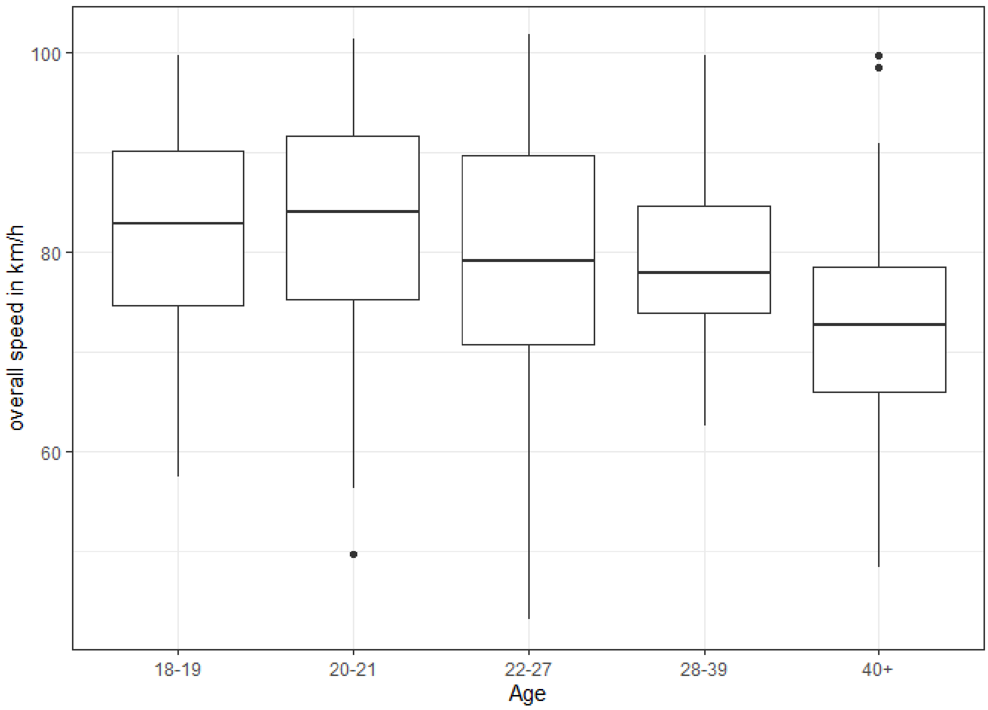

Figure 21: Overall speed versus age

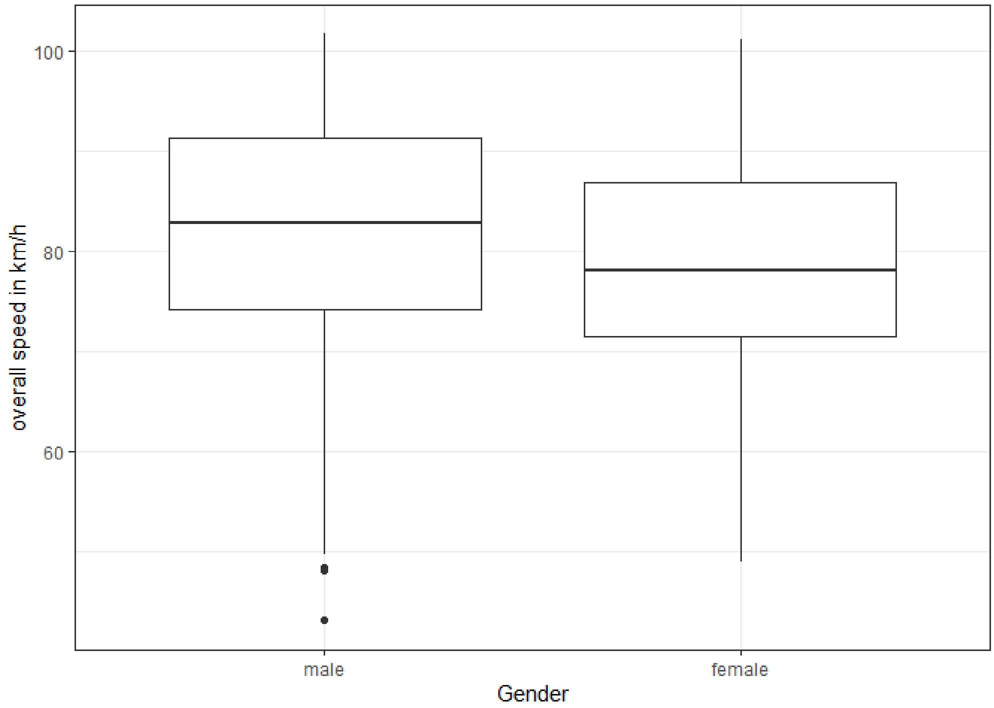

Figure 22: Overall speed versus gender

Extraversion is a measure of how energetic and sociable a person is. It is a personality trait associated with excitement-seeking, impulsivity, high activity level and positive emotions. Because of this level of excitement, extroverts are more likely to go over the posted speed limit (80km/h) thus taking more risks out of impulsivity. The results are consistent with the claim that extroverts are at higher risk of car crashes because of a lower level of attention while driving (Riendeau et al., 2018). On the contrary, participants scoring lower on the extraversion scale tend to worry more about what might happen in risky situation and thus are less likely to be speeding over the limit. The same applies for the exaggerated safety behavior and the ATTS scale which were also significant in previous models where high scorers were safer drivers. These participants usually drive under the speed limit as they are more cautious and aware of the risks of speeding.

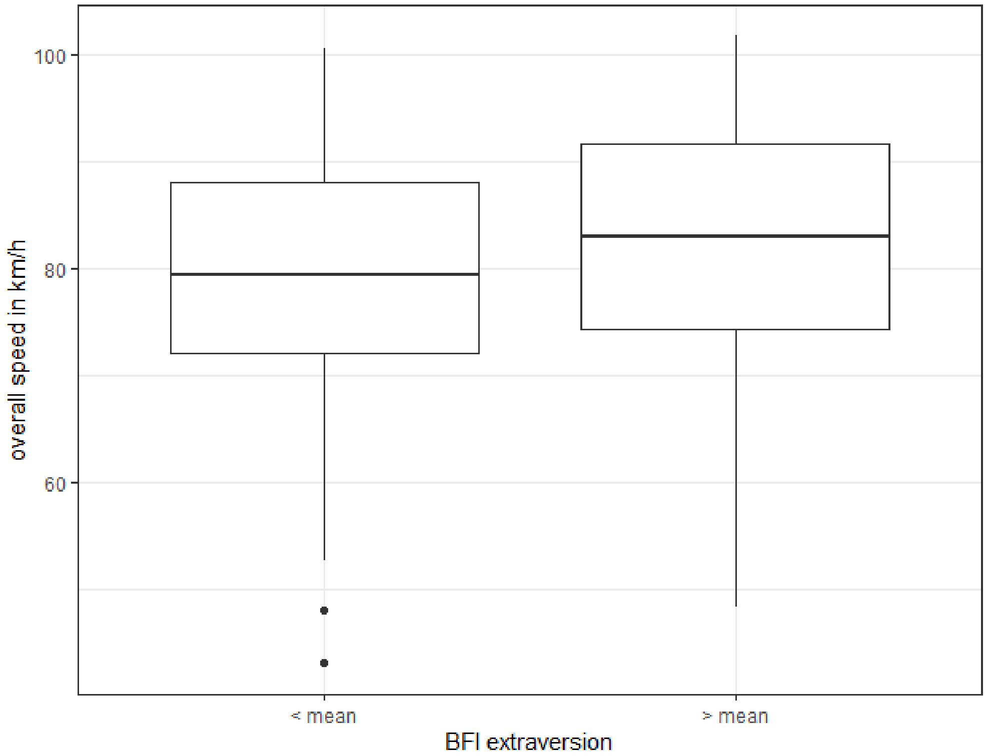

Figure 23: Overall speed versus BFI extraversion

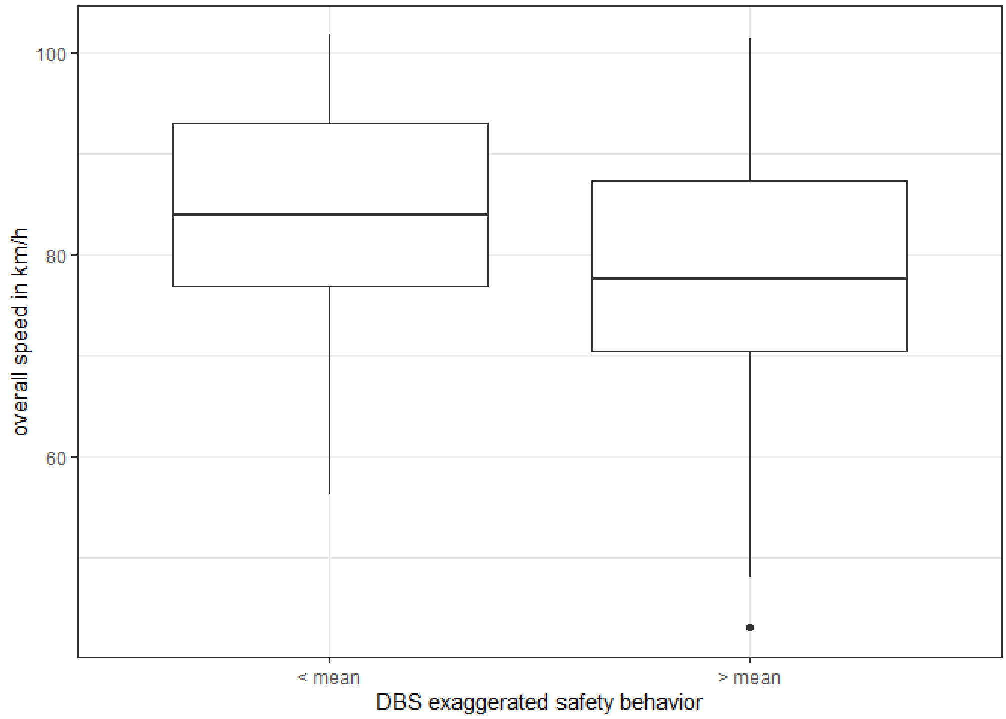

Figure 24: Overall speed versus DBS exaggerated safety behavior

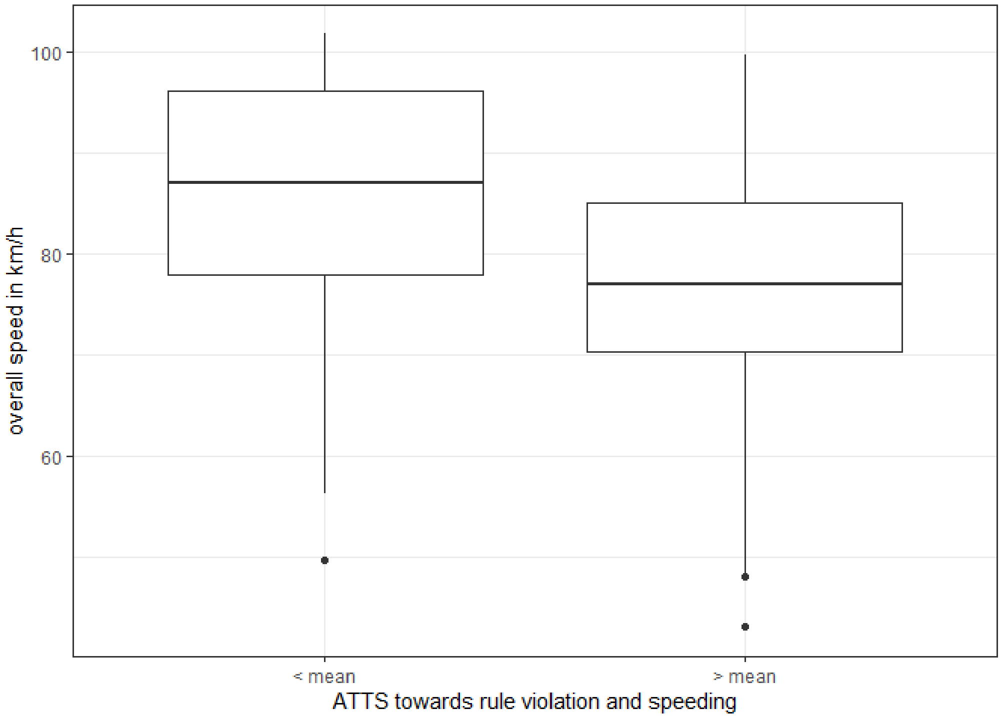

Figure 25: Overall speed versus ATTS towards rule violation and speeding

4.5 Field data and validation

4.5.1 Overview

Throughout this study, data was accumulated from the traffic management center (TMC) in Beirut to capture the behavior of Lebanese drivers in real-life trafficked intersections. The data recorded in video form shows three prime intersections in Jdeidet El Metn area from 9:45AM to 11:40AM on September 15, 2020. The data that is analyzed is only for the vehicles stopping first at the intersection’s red phase as we are not interested in the vehicles stopping behind them. The Figure below illustrates the three stopping locations referred to in this paper. With no violation, the first position is that of the first vehicle on the upper part of the figure where the stop is made before the stop bar. The second position where the vehicle surpasses the stop bar and takes from the space reserved for pedestrians is represented by the second, third and fourth cars. Finally, the black vehicle at the bottom of the figure fits in the violating category which stops beyond the stop bar and the crosswalk hence entering the dangerous middle zone of the intersection.

Figure 26: Violating and non-violating stopping positions (Source: TMC)

The Lebanese law protects pedestrian's right to cross and obliges the driver to halt at red lights. Such a law combined with driver's recklessness can lead to a dangerous number of accidents. This is illustrated by the pedestrians' reassurance for safety by the law when crossing the intersection while the drivers still show recklessness and lack of awareness to yield before the stop bar hence not allowing the pedestrian space and time to cross safely. In such cases the driver might be surprised by the pedestrians and crash into them due the latter's negligence to halt far away from the crosswalk. Therefore, it is crucial that the Lebanese driver be more mindful, and attentive toward pedestrians crossing the intersection, and allow them the space and safety to traverse peacefully without any accidents. The observations show that in cases where the vehicles stop on or after the crosswalk, the pedestrians, not having an exclusive space to walk, will have to cross in between the cars or even on paths in the middle of the intersection creating a sort of jaywalking (Figures 2 and 3).

Figure 27: Dangerous pedestrian crossing scenario 1 (Source: TMC)

Figure 28: Dangerous pedestrian crossing scenario 2 (Source: TMC)

The total sample collected consists of a total of 816 vehicles split as shown in the following datatable:

Table 8: TMC observations sample distribution by vehicle type

Datatable

Sample Considered	Number of vehicles	Percent of Total
Sample Size	816	100.0%
Motorcycles	100	12.3%
Passenger cars	668	81.9%
Trucks/buses	48	5.9%

The results (Figure X) show that 31% of the total number of vehicles were prone to stop before the stop bar while 44% stopped after the stop bar while covering the crosswalk, and the rest (25%) stopped after both the stop bar and the crosswalk hence parking at a dangerous location in the middle of the intersection. It was evident throughout all three intersections that the majority of drivers disregard the crosswalk and stop bar and choose to cross beyond these markings. According to the above statistics, approximately 70% of Lebanese drivers neglected the laws of safety that require drivers to halt before the stop bar present at each section. Such findings pose serious questions about pedestrians' safety while crossing the intersections and validates previous predictions about driver recklessness and ignorance for safety rules and regulations in Lebanon. An additional threat is present in the instances where the stopping cars achieve a full stop far after the stop bar and the crosswalk. These cases would not only cause danger to pedestrians but also to other vehicles moving from adjacent legs of the intersection. These statistics ascertain the need for adequate awareness campaigns, and firm law reinforcement regarding the safety rules and regulations around intersections to decrease hazardous accidents resulting from driver negligence.

4.5.2 Pedestrian Presence

It was initially predicted that once pedestrians are crossing at the terminal arm, drivers are expected to show restraint by yielding farther away from the crosswalk. Bearing in mind the safety of pedestrians, the drivers seeing pedestrians wanting on the sides of the road are anticipated to decrease their velocity before the crosswalk. This hypothesis would reduce any chance of pedestrian-vehicular interaction or accidents. According to our data (Figure x) and although the violation is still occurring, one must note that the percent of drivers stopping before the stop bar increases when there are pedestrians versus when they are absent. Such outcome though evident is not sufficient to guarantee the safety and wellness of pedestrians as the majority of drivers are still violating the stop bar.

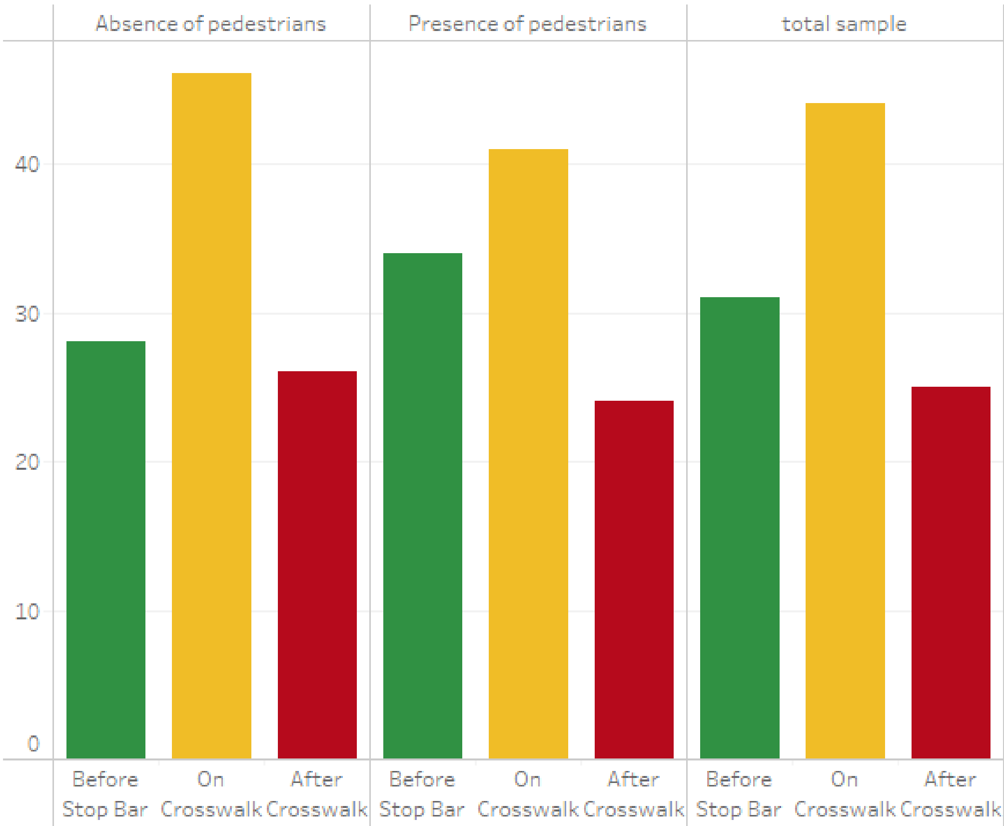

Figure 29: The influence of pedestrian presence on the stopping location of drivers

Indeed, the percentage of drivers stopping before the stop bar is around 27% with the absence of pedestrians compared to approximately 35% while pedestrians are present. As for the percentage stopping on the crosswalk the percentage decreased from 47% to 42% with the presence of pedestrians. Finally, the difference of percentages of drivers stopping after the crosswalk with the presence and absence of pedestrians is minimal. To conclude from this histogram, reckless drivers will most often stop after the crosswalk whether they see a pedestrian or not. However, many might be affected by the presence of the latter and would be inclined to stop before the stop bar instead.

4.5.3 Imitation Behavior

As human beings in a society, we are conditioned to fit into the standards and habits of those around us, sometimes disregarding whether they are right or wrong. This applies for behaviors related to driving as well. The observations from the recordings show a relation between the positions of adjacent cars stopping at the same red light. A general imitation behavior is present as the location categories of second and third cars closely match that of the first car stopping. This imitation is usually in groups of two to three. The overall stopping location of all the cars at one red light is often close and it is less common to have opposing extremes at the same instant. Figures 4, 5 and 6 are only a couple of minutes apart and show examples of general imitation behavior. We can note that as any stopping vehicle approaches more and more, the other vehicles get encouraged to do the same. They may not match the exact position of the main approaching car however they will try to match the position of the vehicles that are the closest to them. It is important to note that although the theory of imitation is obvious, it is not always present with all drivers or at all red light stops. The decision for the stopping location is subject to many factors and cannot be exclusively related to the imitation factor.

Figure 30: Imitation behavior at crosswalk limit (Source: TMC)

Figure 31: Imitation behavior beyond crosswalk (Source: TMC)

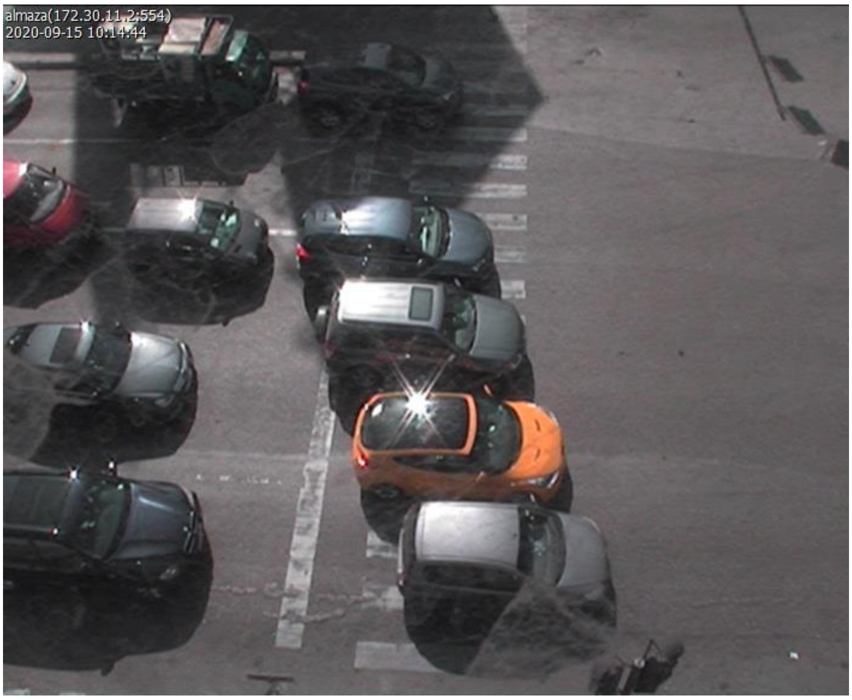

Figure 32: Imitation behavior gradually on crosswalk (Source: TMC)

4.5.4 General Observations

The use of motorcycles is very common in the Greater Beirut Area as commuters try finding a way to escape traffic. Many of those commuters put their lives at risk as they drive recklessly and with little to no personal protective devices (helmets etc.). Even at intersections, bikers manage to find their way through cars and in between lanes in order to stop at the front line. They do not stop with the regular traffic whenever they encounter a red light but keep going until they pass the first stopping car. These bikers are at a danger of collision with cars whenever the next departure takes place as they all these vehicles become fitted very closely with each other. In order for bikers to feel safer and move away from stopping cars to avoid a dilemma zone as the light turns green, they put themselves at an even greater risk: they approach even more to the center of the intersection. Stopping closer to the middle and hence further from the indicated stop location becomes dangerous as the incoming traffic from other directions might collide with them.

Indeed, Figure X compares the stopping location distribution per type of vehicle. While the most popular stopping location for passenger cars, trucks and buses is on the crosswalk, motorcycles are more likely to advance further beyond the crosswalk as only 7% of motorcycle drivers stop before the stop bar.

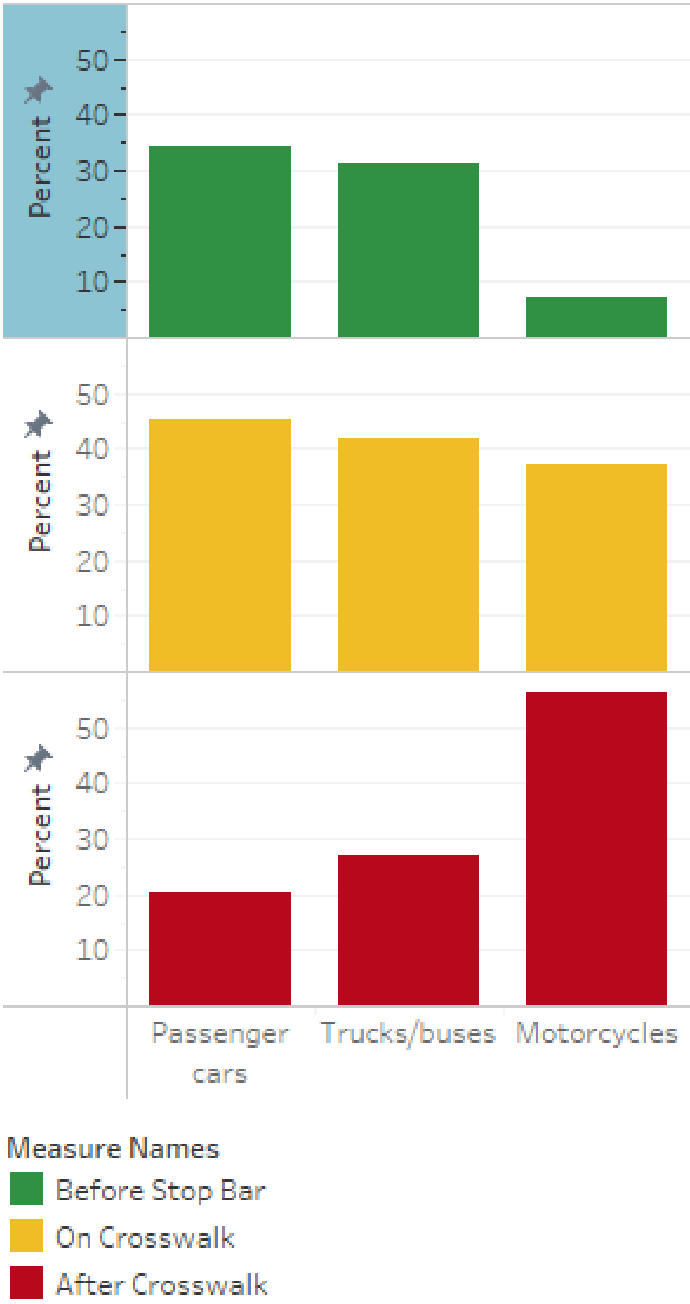

Figure 33: The relationship between vehicle type and stopping location of drivers

Lebanese drivers tend to waste a lot of their time during their day stuck in traffic. This might lead to them having less patience especially when waiting at a red light. As seen in the recordings, many cars that initially make a complete stop before the stop bar at the red light, and after waiting for a couple of seconds, tend to advance slowly until they eventually become parked on the crosswalk. This is even more common when these drivers are positioned next to vehicles who are already ahead of them. This behavior which reflects impatience is not rare among drivers and is present regardless of the initial complete-stop location. This behavior of trying to park among the firsts is obvious although no advantage is given to the vehicle that departs first at the green light since they each have his own lane. The slow advancement made with respect to their initial stopping position seems to be mainly due to impatience while waiting. This reaction may also be linked to an imitation behavior and pressure to match the position of the adjacent cars while keeping in mind that the queuing line behind is waiting for their next move.

CHAPTER 5

Conclusion

5.1 Intersection variables

Regarding scenario variables, drivers are mostly affected by the presence of humans on the intersection leg whether it is a pedestrian or a police officer. When it comes to the stopping difference and whether they are committing violations or not, then the presence of humans reinforces good safe behavior. However, when it comes to variables that depend on attention and patience such as rolling into the intersection or accelerating at the green light onset, then scenarios where pedestrians are present are the most encouraging followed by the imitation scenario and finally the police scenario. In other words, drivers are respecting the pedestrians passing but once they pass and the red light is still on, then their impatience makes them want to be done with the intersection, especially if other people around them are impatient as well. In terms of violations, scenarios affected by the imitation behavior experience more violations as drivers imitate, whether consciously or unconsciously, those violating the rules next to them. The least violations were recorded when the pedestrians and police were present simultaneously, with the pedestrian presence being the most effective between the two.

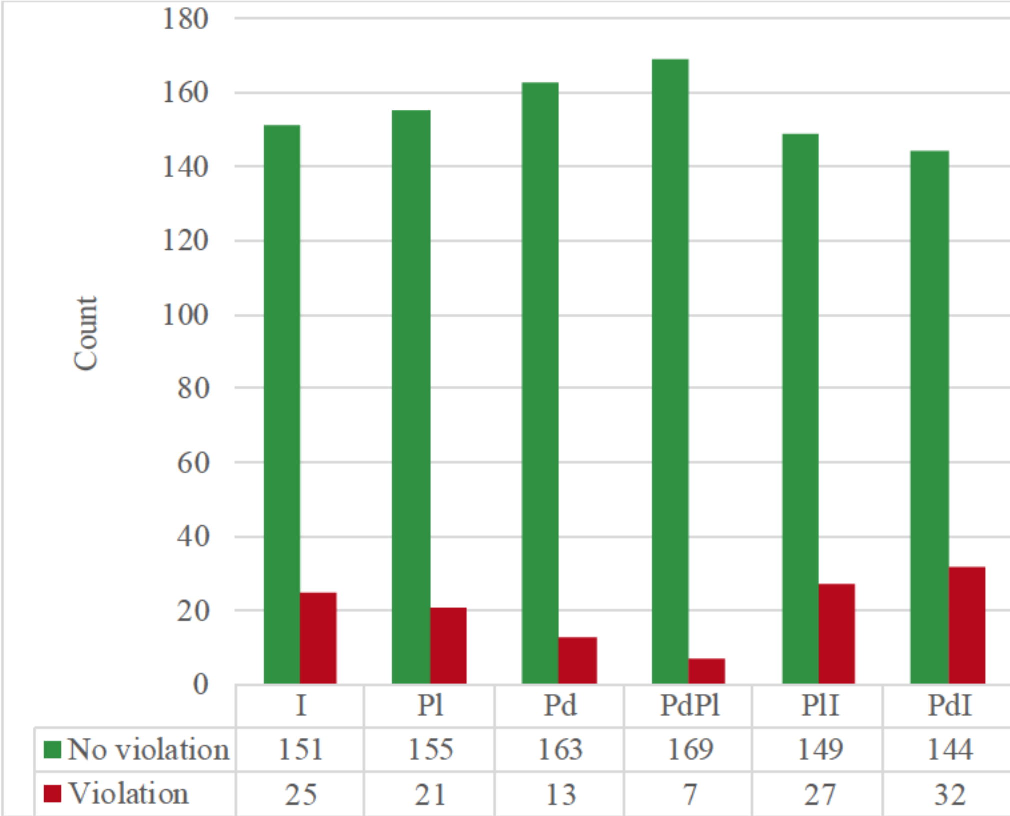

Figure 34: Number of violations versus intersection variables

5.2 Demographic variables

Age, gender and accident history are the three demographic variables that shape a person's aggressive versus safe driving. Males are risk-takers when it comes to the stopping difference and acceleration at the green light onset. Their aggressiveness is emphasized if they are younger by having higher speeds and being more likely to even exceed the speed limit. The young age of drivers, however, makes them more patient by rolling less into the intersection compared to older drivers. The past experience of a person who has been in a severe accident does a weak job at teaching him to drive more safely because personality traits predicting aggressiveness are more dominant. Those drivers are more inclined to have aggressive impulsive driving patterns such as a high acceleration rate.

5.3 Psychological variables

Psychological traits show dominance over intersection variables and are highly correlated with demographics. Drivers scoring high on the ATTS scale are concerned about traffic laws and thus have lower acceleration rates and overall speed. This score is the main one affecting the decision to commit a violation or not. The DBS scale is positively related to the stopping difference and negatively related to the increase in overall speed. Mindfulness plays an important role in increasing awareness about safety issues as mindful people place their car further away from the intersection stop bar. Personality traits from the BFI scale such as agreeableness, neuroticism and extraversion affect the drivers' behavior in various ways. People who score high on agreeableness thus having a peaceful connection with their environment stay further away from the intersection stop bar which leads to less violations and a safer environment for pedestrians to cross. Drivers who are impulsive and easily frustrated and angered score higher on neuroticism and reach higher acceleration rates. Extroverts are associated with impulsivity and high levels of excitement and energy which makes them more likely to go over speed limits. Mental health, especially depressive symptoms, affect drivers' connection with their environment as they would have a lower capacity to sustain attention. Consequently, rolling into an intersection is common as their focus drifts.

5.4 Recommendations

As proposed by other studies (Choueiri et al., 2010; Mayhew et al., 2017; Shell et al., 2015) and since Lebanon has a relatively weak driving education system, providing people with awareness about traffic laws and risks from collisions encourages abiding by the rules. The imitation behavior factor showed to be very influential, and hence the more informed the driver is, the less influenced he is by negative behavior. Simultaneously, with less people breaking the rules because of their traffic education, the potential presence of the imitation factor would be mitigated.

It is interesting to notice that people who were considered reckless drivers in this study, evaluated themselves as such when they scored lower on the ATTS scale. If drivers are aware of their behavior and do not see it as something that needs to change, then any way to convince them otherwise would lead to a safer driving environment. This can be successfully achieved through raising awareness in an effort to change the norm regarding how speeding and reckless driving are perceived. NGOs and media platforms can be influential in promoting this standard. After all, road safety is a shared responsibility.

To mediate for the aggressive behavior of people who have been in previous severe accidents, it is important to mediate for the psychological traits that make them aggressive. The dominance of the nature over the nurture can be overridden by mindfulness trainings, awareness and a more severe legal punishment. When more citations are given, citizens feel more responsible and less careless about the consequences.

Personality traits are hard to control and change however some psychological effects such as depression and mindfulness can be managed. In order to improve the quality of life of targeted individuals, awareness can be raised and techniques can be applied as therapy is not an easily accessible solution for all. Those recommended techniques includes stress management, mindfulness exercises (such as grounding) and interventions to reduce depression (such as breathing techniques).

5.5 Limitations

This research tackles driving behavior at intersections from two perspectives and with a representative number of vehicles. Nevertheless, the sample mostly consists of young drivers and does not include people from all educational backgrounds. Participants are mainly gathered from the university’s students, faculty, and staff.

Going through the results of the simulator variables, the effect of an intersection variable in the model is given in comparison to another fixed intersection variable. The number of violations as well is compared between scenarios but not to a base scenario serving as a reference with none of these variables.

Additionally, as the comparison between the simulator results and the real-life observations suggests, drivers in real-life seem to commit more violations. Although the variables that affect this behavior are found to have a very similar effect, there is a concern about the authenticity of participants’ behavior in the research versus in everyday life. As advanced and realistic as the simulator may be, it cannot certainly provide the same level of complexity and number of variables present in the real world.

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Appendix: Survey

Kindly input the code you were given at the beginning of the experiment:

____

Demographics

1. What is your gender?

○ Man.

○ Woman.

○ Other

2. What is your age? ____________

3. What is your marital status?

○ Single.

○ Married.

○ Widowed.

○ Divorced.

○ Separated.

○ ____________

4. Do you have children?

○ Yes.

○ No.

5. How many years of driving experience do you have? ____________

6. Have you been in an accident before?

○ No.

○ Yes, Major accident.

○ Yes, Minor accident.

7. Have you ever taken a formal driving education class?

○ No.

○ Yes. Please specify below:

____

Driving Safety

1. For each statement, please indicate how much you agree or disagree with the statement:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Many traffic rules must be ignored to ensure traffic flow.					
2. It makes sense to exceed speed limits to get ahead of "Sunday drivers".					
3. Traffic rules must be respected regardless of road and weather conditions.					
4. Speed limits are exceeded					

because they are too restrictive.					
5. It is acceptable to drive when traffic lights shifts from yellow to red.					
6. Taking chances and breaking a few rules does not necessarily make bad drivers.					
7. It is acceptable to take chances when no other people are involved.					
8. Traffic rules are often too complicated to be carried out in practice.					
9. If you are a good driver, it is acceptable to drive a little faster.					
10. When road conditions are good, and nobody is around, driving at 160 Km/hr is ok.					
11. Punishments for speeding should be more restrictive.					
12. I will ride with someone who speeds if that's the only					

way to get home at night.					
13. I will ride with someone who speeds if others do.					
14. I don't want to risk my life and health by riding with an irresponsible driver.					
15. I would never drive after drinking alcohol.					
16. I would never ride with someone I knew has been drinking alcohol.					

General Behavior

Below are a number of statements that describe ways in which people act and think. For each statement, please indicate how much you agree or disagree with the statement:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I generally like to see things through to the end.					
2. My thinking is usually careful and purposeful.					

3. When I am in great mood, I tend to get into situations that could cause me problems.					
4. Unfinished tasks really bother me.					
5. I like to stop and think things over before I do them.					
6. When I feel bad, I often do things I later regret in order to make myself feel better now.					
7. Once I get going on something, I hate to stop.					
8. Sometimes when I feel bad, I can't seem to stop what I am doing even though it is making me feel worse.					
9. I quite enjoy taking risks.					
10. I tend to lose control when I am in a great mood.					
11. I finish what I start.					

12. I tend to value and follow rational, "sensible" approach to things.					
13. When I am upset I often act without thinking.					
14. I welcome new and exciting experiences and sensations, even if they are a little frightening and unconventional.					
15. When I feel rejected, I will often say things that I later regret.					
16. I would like to learn to fly an airplane.					
17. Others are shocked or worried about the things I do when I am feeling very excited.					
18. I would enjoy the sensation of skiing very fast down a high mountain slope.					
19. I usually think carefully before doing anything.					

20. I tend to act without thinking when I am really excited.					

Driving Behavior

Often times, situations occur while people are driving which make them nervous (e.g., weather conditions, heavy traffic near accidents, etc.). Below is a list of behaviors that may or may not be relevant to you in these situations.

Based on your personal experience, please indicate how frequently you perform each of these items when a stressful driving situation occurs which makes you nervous, anxious, tense, or uncomfortable. Please indicate what you ***generally*** do, not what you think you should do:

	Never	Very Infrequently	Infrequently	Sometimes	Frequently	Very Frequently	Always
1. I lose track of where I am going.							
2. I yell at the driver/drivers who make me nervous.							
3. I slow down when approaching							

intersections, even when the light is green.							
4. I have trouble staying in the correct lane.							
5. I drift into other lanes.							
6. I forget to make appropriate adjustments in speed.							
7. I let the driver who made me nervous know that I am upset.							
8. I maintain a large distance between myself and the driver in front of me.							

9. I forget where I am driving to.							
10. I make gestures at the driver/drivers who made me nervous.							
11. I try to put distance between myself and other cars.							

Based on your personal experience, please indicate how frequently you perform each of these items when stressful driving situation occurs which makes you nervous, anxious, tense, or uncomfortable. Please indicate what you ***generally*** do, not what you think you should do:

	Never	Very Infrequently	Infrequently	Sometimes	Frequently	Very Frequently	Always
12. I maintain my							

speed in order to calm myself down.							
13. I try to stay away from other cars.							
14. I have trouble finding the correct lane.							
15. I pound on the steering wheel when I'm nervous.							
16. I decrease my speed until I feel comfortable.							
17. I honk my horn at the driver who made me nervous.							
18. I try to find ways to let other drivers know that they are making me nervous.							

19. During bad weather, I drive more cautiously than other vehicles on the road.							
20. I swear/use profanity while I am driving.							
21. I have difficulty merging into traffic.							

Daily Experiences

Below is a collection of statements about your everyday experience. Please indicate how frequently or infrequently you currently have each experience. Please answer according to what really reflects your experience rather than what you think your experience should be. Please treat each item separately from every other item:

	Almost Never	Very Infrequently	Somewhat Infrequently	Somewhat Frequently	Very Frequently	Almost Always
1. I could be experiencing some emotion and not be conscious of it						

until sometime later.						
2. I break or spill things because of carelessness, not paying attention, or thinking of something else.						
3. I find it difficult to stay focused on what’s happening in the present.						
4. I tend to walk quickly to get where I’m going without paying attention to what I experience along the way.						

5. I tend not to notice feelings of physical tension or discomfort until they really grab my attention.						
6. I forget a person's name almost as soon as I've been told it for the first time.						
7. It seems I am "running on automatic," without much awareness of what I'm doing.						
8. I rush through activities without being really attentive to them.						

9. I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.						
10. I do jobs or tasks automatically, without being aware of what I'm doing.						
11. I find myself listening to someone with one ear, doing something else at the same time.						
12. I drive places on 'automatic pilot' and then wonder						

why I went there.						
13. I find myself preoccupied with the future or the past.						
14. I find myself doing things without paying attention.						
15. I snack without being aware that I'm eating.						

General Mood

Over the last 2 weeks, how often have you been bothered by the following problems?

	Not at all	Several days	More than half the days	Nearly every day
1. Feeling nervous, anxious or on edge.				
2. Not being able to stop or control worrying.				
3. Little interest or pleasure in doing things.				
4. Feeling down, depressed, or hopeless.				

General Personality

For each statement, please indicate how much you agree or disagree with the statement:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I see myself as someone who is reserved.					

2. I see myself as someone who is generally trusting.					
3. I see myself as someone who tends to be lazy.					
4. I see myself as someone who is relaxed, handles stress well.					
5. I see myself as someone who has few artistic interests.					
6. I see myself as someone who is outgoing, sociable.					
7. I see myself as someone who tends to find fault with others.					
8. I see myself as someone who does a thorough job.					

9. I see myself as someone who gets nervous easily.					
10. I see myself as someone who has an active imagination.					

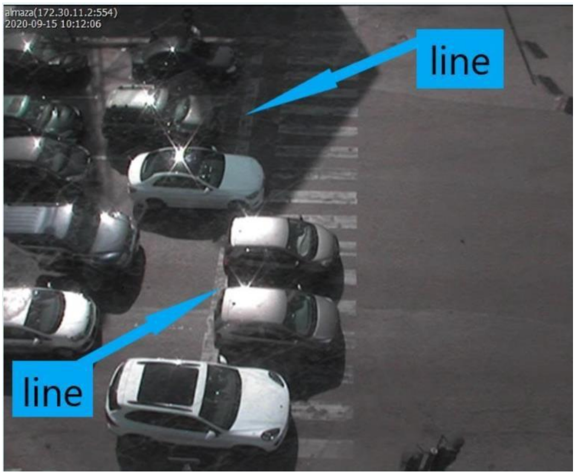
Post Simulation Feedback

1.How close do you think your driving behavior in the simulator was with respect to your driving behavior in general?

- Completely different.
- Very different.
- Very close.
- Completely the same.

2.Do you usually stop before or after the stop bar at intersections?

- Before.
- After.
- I am not sure.



3.Where do you think it is right to stop at intersections?

- Before the stop bar.
- After the stop bar.
- There is no right/wrong location.
- I am not sure.