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Analyzing Drivers' Passing Decision on Two-Lane Two-Way Highways: Interplay of Psychological Traits and Traffic

By

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This thesis is dedicated to my precious family..

My Mother, Sister, and Late Father

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Analyzing Drivers' Passing Decision on Two-Lane Two-Way Highways: Interplay of Psychological Traits and Traffic

Bahaa Sharif Sabek

Abstract

Passing maneuvers on rural two-lane highways have significant implications on safety, highway performance, and traffic operations. This research seeks to better understand drivers' passing behavior by examining the interplay between drivers' psychological traits and traffic variables influencing this decision. A driving simulator session followed by a self-report questionnaire were used to understand drivers' decision to pass a lead vehicle or continue following it. A total of 160 licensed drivers were exposed to four randomized passing situations associated with different levels of risk. The lead vehicle was set to be a truck in all four scenarios, but its speed and the passing gap size were altered. The full-scale driving simulator captured observed driving behavior through performance metrics such as speed, lateral deviation, and travelled distance. The demographics and psychological factors including impulsiveness, mindfulness, and depression were collected through the self-report questionnaire. Results revealed that, irrespective of the passing situation and risk involved, the propensity to overtake lead vehicles is associated with lower attitude towards rule violations and speeding. With riskier overtaking situations, effects of impulsiveness and mindfulness become more significant. Concerning a driver's current state and feeling, motorists who have been depressed lately are more likely to perform overtaking in specific situations. Such findings can be incorporated to enhance driving educational campaigns and curricula aiming to promote safe mobility and lessen the social and economic burdens of high-impact crashes.

Keywords: Driving simulator, Two-lane highways, Passing maneuvers, Passing gap, Lead vehicle, Impulsivity, Mindfulness, Psychological traits.

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List of Abbreviations and/or Symbols

i.e.: That is

LAU: Lebanese American University

VR: Virtual reality

PSD: Passing Sight Distance

LR: Low risk

MR: Medium risk

HR: High risk

M50R: Medium risk involving a lead truck's speed of 50 km/hr

M70R: Medium risk involving a lead truck's speed of 70 km/hr

FG: Following gap

TTC: Time to Collision

Chapter One

Introduction

Two-way two-lane highways or simply, two-lane highways are common in road networks around the world. These roadways are considered to be a key element within highway systems whereby they are situated in various geographical areas, mostly rural, to provide extensive transportation-related services for all vehicular traffic (Transportation Research Board, 2010). On a two-lane road, drivers are constantly faced with slower vehicles in front of them. As a reaction, a driver may tolerate the slowing down imposed by the slower lead-vehicle, and continue to follow behind it, or he/she may perform a passing maneuver. Such overtaking maneuvers characterize the unique interactive relationship that exists between traffic on the two opposing travel directions as drivers are required to perform lane changes and use the opposing lane. These behaviors have serious implications on safety, highway performance, and traffic operations (Abdul-Mawjoud & G. Sofia, 2014; Farah et al., 2009a; Polus et al., 2000; Transportation Research Board, 2010). Specifically, a reduction in passing opportunities can lead to vehicle platoons and thus, lowering the highway's level of service, increasing fuel consumption and emissions, as well as increasing the possibility of performing risky passing maneuvers. The decision to overtake a lead vehicle is dependent on different road/traffic variables, and driver personality differences.

Consequently, researchers have been interested in assessing the effects of these variables on the driver's decision to engage in passing movements. The most prominent influencing ones include speed differential, lead vehicle size, and passing gap size. Speed differential is the difference in speed between the subject vehicle and the leading vehicle. Compared to a regular passenger car, whenever the leading vehicle is a truck, minimal visibility for the driver behind it is available. Also, prior to overtaking, drivers have to assess the distance between the opposing vehicles to decide if they can pass safely. This distance is the passing gap. Based on Farah et al. (2009b), a passing gap is the distance or time headway between two vehicles in the opposing traffic at the instant that the subject vehicle becomes right next to the opposing lead vehicle as illustrated in Figure 1.

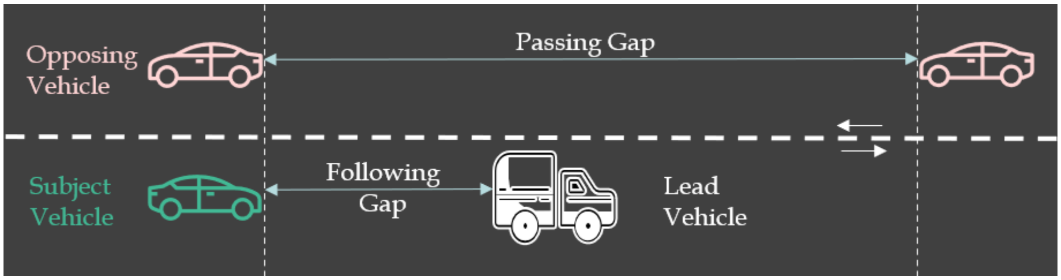


Figure 1: Illustration of Passing and Following Gaps.

Overtaking a lead vehicle must be completed carefully as this action involves the risk of head-on collisions with the approaching vehicles. According to Muslim & Itoh (2019), drivers executing passing maneuvers, especially at high speeds, are responsible for a significant proportion of roadway accidents. Head-on collisions are the most common type of accidents on two-lane highways (Tang et al., 2007). Moreover, passing maneuvers are significantly associated with potential head-on crashes especially under risky situations (Bar-Gera & Shinar, 2005; Farah et al., 2012). Passing behavior is not only affected by situational road conditions, but by the drivers' personality traits also. Drivers who are cautious and comply with driving rules and regulations drive more safely than those who are risk-takers and aggressive.

With regards to the Eastern Mediterranean Region, road traffic injuries are considered to be an important cause of fatalities and disabilities (Chandran et al., 2010; Khalil et al., 2017). In Lebanon, it is believed that road traffic injuries are a growing burden (Ghandour & Hammoud, 2020; Ghoubaira et al., 2021). Moreover, the increasing frequency of car crashes has become one of the most worrying concerns today within the Lebanese context with half of these road crashes occurring on undivided two-lane roads (Choueiri et al., 2010). In 2018, car accidents surpassed 4,500 with 6,085 injuries and 500 fatalities (Lebanese Internal Security Forces, 2019). However, Akl (2010) asserts that that Lebanese Internal Security Forces' statistics record only instant roadway deaths and do not apply the recognized international definition with respect to fatal accidents (within 30 days of the accident). This suggests that the recorded roadway deaths on Lebanon's highways are underreported.

To date, several countermeasures have been employed to attempt and reduce the number of recorded road fatalities. These countermeasures included mainly the partial implementation of the new Highway Code and the effective acting of the Internal Security Forces against roadway violations and insecurity (Kobeissy & Carnis, 2021). However, considerable highway violations and aggressive driving behaviors are still happening. With the aim of reducing injuries, fatalities, economic losses, and providing a safe environment for the Lebanese road users, it is vital to study the passing behavior of Lebanese drivers when faced with several situations associated with different levels of risk. In fact, such investigations enhance the thorough understanding of the driving population's psychological and behavioral profiles. Accordingly, viable and sustainable countermeasures that would be based on this comprehensive knowledge can be developed to improve the Lebanese driving environment, enhance the traffic culture, and promote sage mobility.

In this thesis, motorists' driving behavior and a variety of demographic and psychological factors considered relevant were analyzed and assessed to predict the drivers' decision to pass a lead vehicle or continue following it. A laboratory study consisting of a full-scale driving simulator session followed by a questionnaire to be filled by 160 participants was prepared. The driving simulator was utilized to capture observed driving behavior through performance metrics including speed, lateral deviation, distance traveled, and collision with other vehicles. Demographic and psychological factors were collected through a self-report questionnaire. To further understand the human behavior, this study focused on personality constructs that affect drivers' decisions including normlessness, impulsivity, and mindfulness. Aiming to reduce crashes on two-lane highways, head-on collisions because of improper risky passing in specific, the results of this research capture the influence of traffic variables as well as demographic and psychological traits on the decision of whether to engage in a passing maneuver or continue following the lead vehicle.

Chapter Two

Literature Review

Two-lane highways are the most critical roadways where passing is associated with a high crash risk due to the need to drive on the opposing traffic lane to complete the maneuver (Bar-Gera & Shinar, 2005; Farah et al., 2012; Muslim & Itoh, 2019). In addition, overtaking lead vehicles is a driving task that is considered to be complex and mentally complicated (Cantin et al., 2009; Hoban, 1983). Therefore, passing on two-lane highways should be meticulously studied to gain a better understanding of this phenomenon. Previous literature has discussed the impact of various traffic and psychological conditions on drivers' passing behavior.

2.1 Traffic conditions and risky passing behavior

The effects of road infrastructure on driving behavior were investigated by Farah et al. (2012) who determined that the degree of risky behavior increased with better road conditions (adequate roads, lower traffic volumes, lower speeds).

As opposing traffic volumes decreased reflecting an increase in the passing gap size, the probability of drivers accepting the gap and passing increased (Farah & Toledo, 2010; Bella, 2011). In fact, after developing four scenarios, each with higher oncoming traffic volume than the previous, Bella (2011) observed that while the number of completed passes decreases as traffic increases, the number of displacements increases with traffic which provides an indication of driver's discomfort because of traffic conditions that prevent him/her from overtaking. Moreover, Emo et al. (2016) defined passing risk as the time between the driver and oncoming vehicle before crashing; high risk was six seconds and moderate risk was 12 seconds. It was found that drivers pass more frequently in the moderate-risk condition characterized by lower oncoming traffic volume than in the high-risk condition. In fact, only 27 out of 112 participants executed passes in the high-risk condition.

Farah and Toledo (2010) studied the effects of different traffic variables on passing behavior using a driving simulator. The experiment included four engineering factors, of which, passing gaps in the opposing lane and speed of lead vehicle are of our interest.

Results showed a higher likelihood to attempt a pass when the lead vehicle is slower relative to the driver's desired speed. In fact, even when the lead vehicle speed equaled the wanted one, passing desire was not negligible. This is in accordance with results of a study conducted by Bar-Gera and Shinar (2005). In their simulator study, the leading vehicle was assigned varying speeds (same speed as the driver, slightly higher or slightly lower). In all cases, drivers passed vehicles which were slower than theirs. In 64% of the cases, they passed the drivers that were faster by three km/hr and in 47% of the cases, they passed the vehicles faster by 3-6 km/hr. This study also predicted that drivers prefer to drive within a certain speed range, making any vehicle traveling at a speed in that preferred range an obstacle. This leads them to pass the vehicle.

Kinnear et al. (2015) tested similar engineering variables on 183 participants who exhibited more frequent passing maneuvers when there was no opposing traffic. Also, they concluded that lower lead vehicle speeds are associated with greater passing intentions. In fact, speed had a stronger effect on overtaking intentions when there was no oncoming traffic versus when there was oncoming traffic.

Furthermore, Figueira and Larocca (2020) concluded that passing is affected by impeding vehicle speed rather than its size after studying the following distance between the subject and lead vehicles in different driving conditions in a simulator. Leading vehicle size considerably affects driver's visibility. Thus, when a truck is the lead vehicle, drivers tend to maintain a larger following gap behind the truck, making it harder to overtake.

In accordance to that, Muslim and Itoh (2019) deduced that the type of leading vehicle affects overtaking intentions whereby large vehicles will obscure drivers' sight, increase risk feeling, and lengthen the passing maneuver duration. A vehicle takes more time to pass a truck than to pass a passenger car. This means that the larger the leading vehicle, the lower the tendency to overtake. This was also shown in Farah and Toledo's (2010) study. The type of front vehicle also affects the critical gaps, which are defined as the smallest gap that a driver is assumed to accept. When the leading vehicle is a truck, a larger critical gap is needed because it obscures the visibility and poses a higher safety risk, compared to passenger cars. Therefore, having a truck in front of the subject car may be a motive not to pass. This was determined by utilizing a driving simulator.

2.2 Driver’s psychology and risky passing behavior

These results indicate that drivers may initiate overtaking even when the road section is dangerous and overtaking sight is insufficient or impaired. Still, there exist additional factors influencing the engagement in risky behaviors. Variability in driving behaviors across motorists is a consequence of a variability in human factors. In fact, Eysenck (1952) previously asserted on how stable personality traits and constant thinking frameworks affect individuals’ reactions to their environment. Moreover, personality traits can influence individuals and lead them towards specific temporal psychological states which in return, alter their driving behavior. For instance, Zhang et al. (2016) observed in their study that drivers who were in a state of anger drove at higher speeds and maintained shorter headways from vehicles upfront. Many noteworthy studies support and provide evidence in regards to an existing relationship between a driver’s certain psychological traits, aggressiveness and hostility, and risky driving behavior.

2.2.1 Impulsivity

Impulsivity is a major factor that has been associated with driving anger (Bıçaksız & Özkan, 2016; Demir et al., 2016) and was found to predict reckless (Sarma et al., 2013) or risky driving (Smorti et al., 2018). Berdoulat et al. (2013) asserted the existence of a positive association between impulsivity, driving anger, and aggressiveness with respect to driving behaviors like aggressive violations, errors, and concentration losses. Similarly, Čabarkapa et al. (2018) exhibited the significance of impulsivity as predictor of traffic accidents. Moreover, Hine et al. (2015) revealed that young impulsive males exhibited higher inclinations to perform risky driving actions when compared to females. Some researchers have specifically investigated the association between impulsivity and risky passing maneuvers. Farah et al. (2008) showed that the frequency of overtaking maneuvers on a driving simulator is associated with a faulty decision-making style or acting without thinking. They also found that these drivers drove faster and had fewer aborted overtaking maneuvers.

According to Emo et al. (2016), there is an association between drivers’ coping mechanisms when passing and the execution of a passing maneuver. They explain that different drivers adopt different coping mechanisms based on available road conditions.

However, these mechanisms may affect the passing maneuver negatively. To illustrate, being mindful and taking more time to assess the situation should supposedly enhance safety during a passing maneuver. However, the cost is that the oncoming vehicle is getting closer by the second. Thus, if the driver does choose to pass after assessing the situation, they are inclined to make a rapid, perhaps impulsive, pass to avoid crashing into the oncoming car that is now closer. Nevertheless, it was hypothesized for this experiment that impulsiveness will increase the likelihood of overtaking regardless of the passing situation and the level of risk associated with it.

2.2.2 Normlessness

Normlessness refers to the belief that violating social norms is sometimes necessary to achieve goals (Ulleberg & Rundmo, 2003). Wang et al. (2018) deduced that normlessness is associated with reckless and careless driving styles as well as angry and hostile driving. Farah et al. (2012) conducted a study in which they classified participants, after driving in a simulator, into three risky driver levels. They found that the riskiest drivers were the ones who drive with recklessness and carelessness and deliberately violate safe driving norms. Du et al. (2018) divided aggressive drivers into four categories, one of which included people "ignoring rules". Additional study performed by Disassa and Kebu (2019) revealed that normlessness has a substantial impact on drivers' unsafe driving behavior. To further illustrate, normless drivers who indulge in culturally unacceptable behaviors to achieve individual goals are more likely to participate in dangerous driving actions, given how normlessness can manifest itself in traffic settings as traffic rule violations or risky driving. In fact, normlessness has consistently been associated with driving anger (Demir et al., 2016), less positive attitudes regarding traffic safety (Lucidi et al., 2014; Lucidi et al., 2019), traffic violations (Lucidi et al., 2019), and risky driving (Ulleberg & Rundmo, 2003). Furthermore, normlessness was observed to be a significant predictor of the overall number of accidents experienced by drivers (Yang et al., 2013). Thus, it was expected that this trait would play a role in drivers' decisions to undertake risky passing maneuvers.

2.2.3 Mindfulness

Mindfulness is most commonly defined as the state of being attentive and aware of the present moment (Brown & Ryan, 2003). In other words, it reflects the ability to be aware persistently of any current events and observing the experiences taking place. This variable has been studied previously and linked to risky driving actions as well. Studies that have examined mindfulness and self-reported driving behaviors have found negative associations between mindfulness and problematic driving behaviors such as errors, lapses, texting while driving, and other willful violations of rules (Feldman et al., 2011; Koppel et al., 2018; Murphy & Matvienko-Sikar, 2019). Mindfulness was also found to predict self-reported driving anger (Stephens et al., 2018). With regards to using a driving simulator, a study by Valero-Mora et al. (2015) found no significant relationship between mindfulness and two driving parameters assessed in the simulator. However, the authors highlighted the need for further exploration due to the limitations of sample size and the choice of driving parameters. Additionally, Kass el al. (2011) determined via the means of a driving simulator that mindfulness training significantly increases driving situational awareness, which in turn improves driving performance and the ability of drivers to identify hazards. Similar results concerning the positive correlation between mindfulness sessions and enhanced driver performance were observed by Reynaud and Navarro (2019). Consequently, a driver's mindfulness level was expected to play a key role in his/her choice to either pass or continue following the lead vehicle. For this experiment, it was hypothesized that mindfulness will decrease the likelihood of overtaking especially in regards to the passing situations involving medium and high levels of risk.

2.2.4 Hypermasculinity

The general consensus in the literature is that males are more likely to engage in risky driving than females (Cordellieri et al., 2016; Farah et al., 2012; Liu et al., 2022; Nævestad et al., 2022; Voogt et al., 2014; Wang et al., 2018). Researchers have attempted to explain the relationship between gender and unsafe driving by examining the role of gender roles and masculinity. Ozkan and Lajunen (2005) found that masculinity predicts the number of traffic offenses and violations, and Krahé and Fenske (2001) found that it was associated with driving aggression as well as decreased safety concerns. More recently, Krahé (2017) showed that some aspects of masculinity predict higher levels of aggressive expression of driving anger. Concerning differences in passing behaviors, Farah (2011) discovered via a driving simulator experiment that male drivers tend to overtake lead vehicles more frequently, maintain smaller following gaps prior to their initiation of the passing maneuver, as well as accept shorter passing gaps. Vlahogianni and Golias (2012) interpreted the reasons for such gender-based variability during passing maneuvers whereby this is mainly a consequence of prevailing differences in the process of scanning and evaluating available opportunities for passing. Thus, it was hypothesized that male drivers will tend to record more risky passing maneuvers in this experiment.

2.3 Data collection background

The utilized data collection methods to analyze driver behavior during passing maneuvers include naturalistic field observations as well as driving simulators. For instance, Polus et al. (2000) collected data through the means of videotaping traffic flows of 300 to 1,000 vehicles per hour and quantified the prominent elements of an overtaking maneuver. Carlson et al. (2006) as well as Harwood et al. (2008) are examples of another field studies performed on two-lane two-way highways in Texas and Missouri respectively which employed video recording techniques to collect data on passing maneuvers and calculate their corresponding average travel distance and travel time on the opposing lane, i.e. the left lane. Moreover, Llorca et al. (2015) developed a microsimulation model that assesses the effects of vehicles, road geometry, and specific human factors on passing maneuvers on rural two-lane highways through collecting field data from 1,752 maneuvers on ten two-lane roads. Although costly and time-consuming, collecting data through field surveillance on real highways guarantees capturing drivers' natural behaviors. Nevertheless, drivers remain unidentified preventing researchers from assessing the impacts of several variables including age, gender, and psychology (Gates et al., 2007).

An alternative tool which has been considerably exploited to explore driver behavior is driving simulators. The usage of a driving simulator to record observations and generate data is more feasible and affordable compared to field measurements. This is significant especially when investigating passing maneuvers as they can occur at any instant and location along the road. In fact, most observational studies have exhibited passing-related complications (Carlson et al, 2006; Harwood et al, 2010; Llorca et al. 2013a; Llorca et al, 2013b; Polus et al, 2000). Therefore, various studies adopted this alternative virtual reality simulation tool to investigate drivers' passing behaviors (Gray & Regan, 2005; Bar-Gera & Shinar, 2005; Farah et al., 2008; Farah et al., 2009b; Jenkins & Rilett, 2005; El-Bassiouni & Sayed, 2010; Toledo & Farah, 2011). In fact, a driving simulator has been shown to be a reliable alternative to observe driving behavior (Alicandri, 1994; Jenkins & Rilett, 2004; Lee, 2003; Llorca & Farah, 2016). Jenkins and Rilett (2004) emphasize that using a driving simulator is the most practical and accurate method of driver assessment because of the drawbacks field tests present. Moreover, Bella (2008) completed a research using a driving simulator whose results coincided with real world experimentation. Similarly, Llorca and Farah's (2016) results showed similarities between reality and simulation regarding gap acceptance decisions, passing time and distance when occupying the opposing lane.

Additionally, and to further explore the existing relationship between behavior and psychology, other studies employed a combination of both driving simulator and questionnaires to collect observed driving behavioral data and psychological data respectively (Ābele et al., 2020; Danaf et al., 2015; Linkov et al., 2019; Qin et al., 2011; Riendeau et al., 2018; Zhang et al., 2016). The usage of driving simulators in research provides several advantages (Bella, 2009; Farah et al., 2008) whereby investigators have full control of the environment and can set the conditions as needed which is something field studies offer little control over. This reflects that the exact situation can be replicated as many times and on all participants. These attributes are significant when assessing passing behaviors whereby a driving simulator would provide flexibility and control in the identification of the pass or do not pass and continue following decision.

2.4 Aim and literature gap

Overtaking lead vehicles on two-lane highways is a complex driving task which causes the rise of considerable issues when observing a driver's passing behavior including the possibility that a passing action can happen anywhere within the permissible passing zone. Concerning drivers' characteristics, studies have proven that diverse drivers exhibit a variety of passing behaviors. For instance, it was revealed that gender and age significantly affect the overtaking behavior (Cordellieri et al., 2016; Farah, 2011; Llorca et al., 2013b; Liu et al., 2022; Wang et al., 2018). With respect to gender variability, Farah (2011) discovered via a driving simulator study that, compared to female motorists, male drivers pass more regularly, maintain lesser following gaps, as well as accept shorter passing gap sizes. As for differences in age, when compared to old drivers, younger drivers maintain lesser following gaps and have higher preferred driving speeds. This is in compliance with the outcomes attained by Llorca et al. (2013b) who opted to perform an observational experiment by means of an instrumented vehicle. Furthermore, these drivers' characteristics played a significant role in many established passing-related models in which they were considered as input variables. For example, and with respect to the driver's decision to accept or reject an available passing gap to pass a lead vehicle, Hassein et al. (2017) employed logistic regression to formulate a gap acceptance model incorporating variables including driver's age and gender, in addition to the gap size. Farah et al. (2009a) established also a passing gap acceptance model that encompasses variables related to the passing gap, infrastructure quality, and certain personality traits. These character traits included gender, age, monthly distance travelled (in kilometers), and the driver's accident record. Similar to our study's data sources, Farah et al (2009a) applied a combination of a driving simulator and a questionnaire to which participants revealed their socio-demographic and driving styles information. Moreover, Farah et al. (2007) tested the significance of including driving styles in the passing behavior model, and found that drivers who are characterized by an anxious driving style and/or patient and careful driving style have larger critical gaps.

Although prior research generally confirms that there exists a robust link between human factors and driving behavior, the impacts of personality traits and psychological states of motorists on various forms of their driving behavior remain to be the purpose of continuous research studies, especially in regards to drivers' passing behavior. Nevertheless, the majority of research aims to explore the overall effect of personality traits and states on common driving behavior within the general sense without focusing in particular on the passing behavior. Furthermore, the limited studies which targeted passing behavior focused exclusively on traditional human characteristics including mainly gender, age, and general driving style. On the contrary, this present study explores drivers passing behavior highlighting the effects of specific psychological traits including impulsivity, normlessness, depression, and less explored constructs like mindfulness. Also, this study examines the interplay between a driver's observed behavior on the road, personality latent constructs including impulsiveness, mindfulness, safe as well as aggressive driving, in an attempt to predict the driver's decision to pass a leading vehicle or continue following it across various passing situations. The concerned passing situations involve varying passing gap size and speed of the impeding vehicle upfront. In all examined passing situations, the size of the lead vehicle was fixed to be a truck to provide minimal visibility and provoke frustration for the following drivers. With such devised research structure, this study offers insights regarding the effects of these altered passing situations on the motorist's behavior and their relation to the concerned psychological factors.

Chapter Three

Methodology

3.1 Research Program

The primary steps followed throughout this research are summarized in Figure 2:

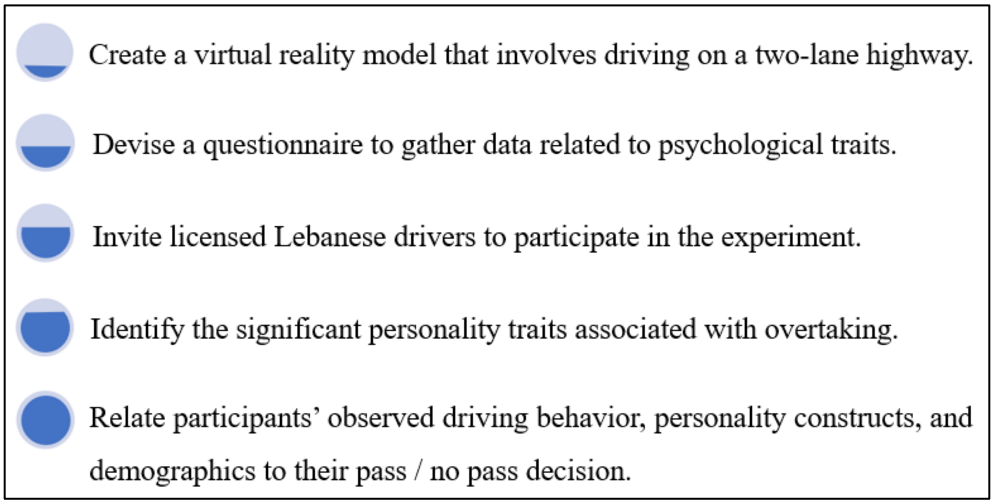


Figure 2: Visualization of the Study Steps.

The proper trainings related to human subject research offered by the Collaborative Institutional Training Initiative (CITI) program were completed. This is a requirement set by the Lebanese American University (LAU) to ensure that all research, involving human participants, would be conducted with integrity and professionalism. Also, this research was granted approval from LAU's Institutional Review Board (IRB) assuring protection of the human participants in this study. Throughout the study, participants' data remained confidential and were not shared with anyone outside the scope of this research. For further anonymity, personal information that could identify the participants such as their names were not collected.

Prior to initiation of the data collection process, the required sample size was calculated on the basis of estimating a single continuous value for a mean. Given that the psychological scales adopted are the main pillars of this research and its outcomes, their expected mean and deviations were the basis of this calculation. In fact, 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 were assumed. These provide a sample size for questions of the mean of 97 (see eg Zikmund et al, 2013).

The experiment included two parts: a driving simulator session followed by an electronic survey fill-out. While the simulator collected performance measures including speed, position, and lateral movement, the survey comprised several sections capturing demographics as well as the psychological characteristics of the participants.

The participants recruitment process comprised sending personal invitations as well as an email to the full LAU community. Yet, the study was restricted only to licensed Lebanese drivers above the age of 18. The email explained briefly the study and clarified its importance for improving roadway safety. Also, the email included a link to an online appointment scheduling platform where participants booked an appointment to participate as per their convenience. Such initiative was crucial because of the COVID-19 pandemic that was still prevalent. In fact, thirty minutes time-slots were made available which provided enough time for disinfecting the simulator between successive trials and maintaining proper distancing between the participants. Moreover, people from outside the LAU community were recruited via a snowball sampling technique and personal invitations. All recruited drivers were accustomed to the Lebanese driving environment characterized by congestion, improper serviceability, and considerable violations.

A total of 160 motorists participated in this study. All of them were volunteers as no compensations were offered for participation. One participant started the driving session but was unable to continue and withdrew from the experiment because of motion sickness and dizziness. Another participant completed the driving session but had to urgently stop and leave while responding to the survey with more than 50% of the questions left unanswered. Also, 25 participants were excluded from the analysis as they portrayed what is referred to in this study as “chaotic driving behavior” (see Section 3.5 for further explanation). Thus, the final sample size consisted of 133 participants (men = 84, women = 49). The original goal of the sampling was to represent the population in terms of age and gender. Younger age groups and males, on the other hand, were overrepresented. This was due to the fact that the driving simulator is located on campus, making it mostly accessible to students. Another possible reason is that the overall experiment necessitates a considerable time commitment (about 30 minutes). Table 1 summarizes participants' socio-demographic information in regards to gender, age, marital status, having children, driving experience (in years), and previous involvement in a roadway accident.

Table 1: Socio-demographics of the Participants.

	Men	Women
Total 18+	84	49
Age		
18-29	70	41
30-49	8	6
50+	6	2
Marital Status		
Married	12	7
Single	72	42
Children		
Yes	9	8
No	75	41
Driving Years		
Less than 1 year	4	5
1-10	64	34
11-20	7	3
21+	9	7
Road Crash Involvement		
No	44	28
Minor accident	32	19
Major accident	8	2

3.2 Self-report measures

The self-report questionnaire consisted of eight independent sections. The English version is presented in appendix A while the Arabic version is included in appendix B. In regards to the Arabic version, the survey package was first assembled in English and then forward translated to Arabic then back-translated to English by the author. The back-translation was compared with the original assembled English version and the necessary revisions were made. In the first section, each participant had to input a unique code that was assigned to them at the beginning of the experiment following their agreement to participate. This technique permitted linking the simulator driving data with the reported survey data. The second section consisted of seven sociodemographic questions that captured primarily the participants' gender, age, marital status, whether they have children, and additional driving-related questions including accident history and driving experience. The remaining six sections included six standard psychological scales that measured impulsiveness, mindfulness, depression and anxiety, driving behavior, attitudes toward traffic safety, and the big five personality traits. Each section was dedicated to a certain scale:

3.2.1 Short UPPS-P Impulsive Behavior scale

The original UPPS model was developed by Whiteside and Lynam (2001). This model of impulsivity considers this trait to be a multi-dimensional construct that is comprised of several impulsive personality traits. Cyders et al. (2014) developed the short version of this model. It is a 20-item scale that measures five dimensions of impulsivity: positive urgency, negative urgency, (lack of) premeditation, (lack of) perseverance and sensation seeking on a 4-point Likert scale. The short version generally replicated the inter-scale correlations as well as the internal consistency of the full UPPS-P with a range of Cronbach α between 0.74 – 0.88 across the subscales deeming it a reliable replacement for the full UPPS-P inventory (Cyders et al. 2014). Furthermore, in another study by Dugré et al. (2019) the same short UPPS-P version also showed good reliability with Cronbach alpha ranging from 0.61 to 0.88 among psychiatric patients. This short version of the UPPS-P scale has been translated into several languages including Arabic (Bteich et al., 2017), French (Billieux et al., 2012), German (Keye et al., 2009), Italian (D'Orta et al., 2015), and Spanish (Cándido et al., 2012).

3.2.2 Mindful Attention Awareness Scale (MAAS)

Developed by Brown and Rayan (2003), the Mindfulness Attention Awareness Scale (MAAS) is a 15-item measure (e.g. "I find myself doing things without paying attention") rated on a six-point Likert Scale, ranging from 1 (almost always) to 6 (almost never). Higher scores on the MAAS portray better mindfulness capabilities. Several studies have confirmed the convergent and discriminant validity of the MAAS (Brown & Ryan, 2007; Black et al., 2011) and its high internal consistency (e.g., $\alpha = 0.89$ in MacKillop & Anderson, 2007; $\alpha = 0.87$ in Rayan & Ahmad, 2016; $\alpha = 0.92$ in Ruiz et al., 2016).

Moreover, the MAAS has been translated and validated in many countries (e.g. Jermann et al., 2009 for French; Johnson et al., 2013 for Spanish; Rayan & Ahmad, 2016 for Arabic). Recently, the MAAS has shown high internal consistency in a Lebanese sample of drivers (α = 0.78, Chahine et. Al, 2022). Such robust evidence verifies the reliability of the MAAS in assessing mindfulness.

3.2.3 Attitudes Toward Traffic Safety (ATTS)

Established by Iversen (2004), this scale investigates road safety attitudes whereby it is divided into three dimensions measuring attitude towards rule violation and speeding (in 11 items), attitude towards the careless driving of others (in 3 items), and attitude towards drinking and driving (in 2 items). Answers are rated on a five-point Likert Scale, ranging from 1 (strongly disagree) to 5 (strongly agree). In a recent study conducted by Trógolo et al. (2019), the ATTS scale was utilized to assess risky driving attitudes among five hundred and fifty-eight drivers from Argentina. The internal consistency (α) measured at two time points was as follows: 0.82 – 0.81 for attitude towards rule violations and speeding; 0.70 – 0.68 for attitude towards the careless driving of others; and 0.85 – 0.86 for attitude towards drinking and driving. Overall, such internal consistency values provided evidence for the scale's reliability in measuring driving attitudes especially since the reliability for the full scale showed a Cronbach alpha of 0.81 (Trógolo et al., 2019). The ATTS has been used in several countries including Italy (Lucidi et al., 2010), Turkey (Şimşekoğlu et al., 2012), South Africa (Bachoo et al., 2013), and China (Ma et al., 2010).

3.2.4 Driving Behavior Survey (DBS)

Clapp et al. (2011) developed the DBS to be a 21-item scale that assesses anxiety-based performance deficits, exaggerated safety/caution behavior and hostile/aggressive behavior (in 7 items each). Based on a 7-point Likert Scale, responses range from 1 (never) to 7 (always). Frequent anxious driving behavior is reflected by higher mean scores. An example item included in the Exaggerated Safety/Caution Behavior subscale is "I maintain a large distance between myself and the driver in front of me". In the original study performed by Clapp et al. (2011), internal consistencies for anxiety-based performance deficit, safety/caution, and hostile/aggressive subscales were 0.80, 0.75, and 0.87 respectively. High internal consistency was reported also by Baker et al. (2014) with

Cronbach's alpha (α) values ranging between 0.85-0.93. Furthermore, the DBS has been validated in several countries including Iran (Khanipour et al., 2015).

3.2.5 Patient Health Questionnaire-4 (PHQ-4)

To affirm the fact that anxiety and depression are dominant illnesses, Kroenke et al. (2009) developed and validated the PHQ-4, a four-item questionnaire answered on a four-point Likert-type scale. Its permits rapid and precise measurement of core symptoms of depression and anxiety via combining the two-item measure (PHQ–2), consisting of core criteria for depression, as well as the two-item measure for anxiety (GAD–2). Formulating this scale to be brief and short is key given that depression and anxiety are two state comorbid disorders. Moreover, as individual scales, the GAD-2 and PHQ-2 have construct and criterion validity. The PHQ-4 has been reported to have a Cronbach's alpha exceeding the 0.75 value for all scales deeming it a reliable scale (Stanhope, 2016). Another study by Materu et al. (2020) confirmed the validity of the scale as it showed a Cronbach alpha of 0.81.

3.2.6 Brief Big Five Inventory (Brief BFI)

The original Big Five Inventory (John et al., 1991; see John et al., 2008) was designed to measure the five comprehensive factors of personality traits: Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to Experience. Each of the Big Five dimensions includes a range of specific traits (Srivastava, 2022). Given that the BFI is a 44-item self-reporting scale, Rammstedt and John (2007) established a brief 10-item version that encompasses descriptive phrases which respondents rate on a five-point Likert scale similar to the original 44-item scale. The validity of this scale was found through mean intercorrelations as no Cronbach's alpha was calculated mainly because of the low number of items in the subscales whereby each includes only two items (Rammstedt & John, 2007). In this study, the Brief BFI-10 itemed scale was exploited primarily for time constraints. Including the full BFI-44 itemed scale was not optimal. Nonetheless, all BFI-related responses were later dropped from the analysis as this scale displayed low internal reliability (see section 3.2.7 below).

3.2.7 Scales Reliability and Validation for the Study's Sample

Reliability analysis was performed on the study's sample responses. A noteworthy measure of a scale's internal reliability and consistency is the Cronbach's alpha. Denoted sometimes as coefficient alpha, this metric describes the extent a set of items in a scale contribute in measuring, as a group, a single latent construct (Cronbach, 1951). The psych package in R (Revelle, 2022) was used to calculate all the alpha coefficients for the study's corresponding sample. The results of this analysis are summarized in Table 2. As illustrated in Table 2, only the Brief BFI scale and its corresponding subscales had significantly low internal consistency values. For that, all BFI-related responses were dropped from subsequent analyses. All remaining scales and their corresponding subscales registered adequate to high alpha values. Furthermore, a confirmatory factor analysis supported the adopted factor-structure for each scale.

Table 2: Cronbach Alpha for Psychological Scales and Subscales Used in This Study.

Scale/Subscale	Number of items	Alpha
ATTS	**16**	**0.8**
Attitude towards Rule Violation and Speeding	11	0.77
Attitude towards the Careless Driving of Others	3	0.71
Attitude towards Drinking and Driving	2	0.85
Short UPPS-P	**20**	**0.73**
Negative Urgency	4	0.69
Lack of Perseverance	4	0.7
Lack of Premeditation	4	0.62
Sensation Seeking	4	0.67
Positive Urgency	4	0.69
DBS	**21**	**0.76**
Anxiety-based performance deficits	7	0.69
Exaggerated safety/caution behavior	7	0.7
Hostile/aggressive behaviors	7	0.83
MAAS	**15**	**0.89**
PHQ-4	**4**	**0.86**
Anxiety	2	0.89
Depression	2	0.78
Brief BFI	**10**	**0.31**
Extraversion	2	0.52
Agreeableness	2	0.22
Conscientiousness	2	0.39

Neuroticism	2	0.55
Openness to Experience	2	0.061

3.3 Driving simulator

The experiment was conducted using the Forum8 3D virtual reality (VR) driving simulator found in LAU's Engineering Lab and Research Center (ELRC). Portrayed in Figure 3, this simulator consists of a full-scale Mercedes Smart car with its dashboard, two seats, and seatbelts. It has the same aspects as a regular car; accelerator and braking pedals, hand brake, dashboard with speedometer and tachometer, windshield and wipers, adjustable driver seat and a full stereo/CD player and audio system. Specifically, it is equipped with a full 500 W RMS 5.1 digital sound system and a force feedback steering rack providing actual car driving sounds and also tactile feedback. Equipped with four D-Box actuators mounted on a skid under the car, this automobile has three seven-inches LCD screens to mimic rearview and side mirrors. The car faces a 180-degree wrap-around display system onto which three synchronized overhead projectors project the 6.1 m wide by 1.5 m high simulation video.

In regards to the software used, the simulator is linked to Forum8's 3D real-time VR software (UC-win/Road) which was used to create and design the needed 3D driving environment with the desired scenarios and events, access the FORUM8 VR data library, and export all generated datafiles. UC-win/Road version 15.1.2 was used.

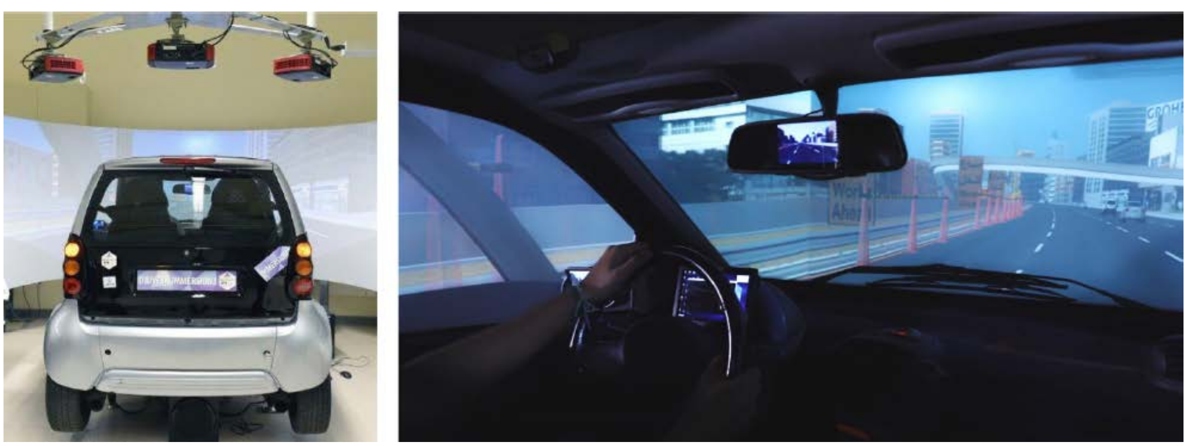


Figure 3: Full-Scale Driving Simulator – LAU ELRC.

3.3.1 Simulator experiment design and model development

Time of driving was chosen to be during daytime with good and sunny weather conditions to allow for better driver visibility and smoother driving. The alignment of the road built inside the VR environment consisted of a four-kilometer straight and level two-lane highway with a lane width of five meters. The reason for adopting a five-meter lane width rather than the standard 3.6 meters is because the lanes are perceived to be narrower than usual in the driving simulator. Appropriate lane markings have been provided as per the Manual on Uniform Traffic Control Devices for Streets and Highways, MUTCD (Federal Highway Administration, 2009). The posted speed limit (assumed also the road's design speed) considered was 80 km/hr all throughout the road section with posted speed signs put at different locations. Making the simulated road look real and vivid is key to let the driver behavior be real. Accordingly, the driving environment was designed to demonstrate a rural area given that most two-lane highways are found in such zones. Figure 4 includes snapshots from inside the modelled 3D simulator environment.

Figure 4: Simulator Environment - UC-win/Road 15.1.2.

The independent traffic variables were chosen based on their significance in affecting passing behavior on two-lane highways when tested in previous research. Independent variables being controlled include passing gap size (direct indicator of traffic flow density in the opposing lane), speed of leading vehicle with respect to the subject vehicle and the size of this impeding vehicle. Changing available passing gap size has a significant role in determining riskiness of passing maneuvers, studied independently by Bella (2011). Speed and type of the leading vehicle were also studied in several studies like Figueira and Larocca (2020) and Emo et al. (2016), where they were given significant importance in affecting driver behavior.

In this study, the lead vehicle was considered to be a single unit truck always which provided minimal visibility. Moreover, a small single unit truck would most likely provoke frustration for motorists driving behind it. In return, drivers might become impatient and willing to overtake the truck when given the opportunity to move into the opposing lane. In fact, in a study conducted by Yan et al. (2019), 95% of the participants exhibited overtaking intentions when the impeding vehicle was a truck. However, when the lead vehicle was a passenger car, only 36% of the participants were willing to overtake it. Furthermore, Farah (2016) reported that the probability of drivers completing a passing maneuver increases when the lead vehicle is a truck. For the other two traffic variables (passing gap size and lead vehicle's speed), each variable was assigned two values, one slightly higher than the standard value, and another value slightly lower. Table 3 provides a summary of the adopted values. The rationale behind these assumed figures is explained next in Section 3.3.2.

Table 3: Adopted Values for the Tested Traffic Variables.

Value	Truck Speed (km/hr)	Passing Gap (m)
1	50	125
2	70	378

3.3.2 Theory behind simulator experiment

Both tested measures, passing gap size and lead vehicle speed, are dependent on the road's design speed. For a design speed of 80 km/hr (adopted in this study):

The minimum passing sight distance (PSD) which reflects the minimum size of a passing gap for passing to be safe and adequate is 245 m based on AASHTO's Green Book "A Policy on the Geometric Design of Highways and Streets" (AASHTO, 2011). This is in accordance to the PSD value adopted in FHWA's MUTCD (FHWA, 2009). Prior to the 2011 edition of AASHTO's Green Book, inconsistencies existed for the minimal PSD value to be adopted between the Green Book and the MUTCD – under similar conditions (i.e. similar design speed). According to El Khoury and Hobeika (2007), this previous discrepancy for a similar condition can be explained by the fact that the Green Book overestimated PSD values by adopting a very conservative model. Abdulhafedh (2020) believes that the different requirements in design and marking (i.e. traffic operations) made it justifiable to have this previous application of separate PSD measures. Not only this, but researchers agree that restricting MUTCD PSD criteria is not recommended as this would encourage illegal passes at the positions where overtaking is currently permitted (Glennon, 1988; Harwood et al., 2008; Hassan et al., 1996). Nevertheless, this discrepancy between the two criteria was meticulously examined through research and was the basis of significant studies aiming to provide consistent standards – in which is attained now. Some of the alternative PSD models which have been proposed and published in the literature include Lieberman (1982), Saito (1984), Glennon (1988) (whose work is of our interest in this study), Forbes (1990), and Hassan et al. (1996). A comprehensive analysis of these alternative PSD models, in addition to others, has been carried out and included in the NCHRP Report 605 (Harwood et al., 2008).

Glennon (1988) formulated a new logical PSD model based on the kinematics relationships between the passing, passed, and opposing vehicles. However, Glennon adopted many assumptions that failed to portray actual road conditions. To make better use of this model, El Khoury and Hobeika (2007) presented a version of Glennon's model where four assumptions were not adopted anymore. The results of this new model exhibited that for a design speed of 80 km/hr and a 99% confidence interval, the mean PSD was 215 m. This is the average minimum distance needed for the passing maneuver to be safe in terms of not colliding with the opposing vehicle. It should be noted that for a design speed of 80 km/hr and a 95% confidence interval, the model provides a mean PSD of 213 m which is approximately similar. Therefore, for our research model, a gap value higher than 215 m would represent safer conditions and thus a low risk situation. Similarly, a gap value lower than 215 m would represent a situation where passing is risky as the distance is lower than the average distance needed to complete a safe passing maneuver. The results of El Khoury and Hobeika's (2007) model distribution showed a maximum PSD value of 378 m and a minimum value of 125 m. These boundary values were adopted in this study – as depicted in Table 3.

Regarding the leading vehicle speed and given a design speed of 80 km/hr, the assumed passed vehicle speed based on AASHTO's Green Book is 61 km/hr (AASHTO, 2011). In other words, when a vehicle is driving at 61 km/hr on a road with 80 km/hr speed limit, most probably it will be passed. Thus, the values for the leading vehicle speed that were adopted in this study are 50 km/hr and 70 km/hr – as depicted in Table 3.

Following such two by two matrix (two values for passing gap and lead vehicle speed each), this research project included four different driving situations with varying levels of risk whereby one independent variable was fixed in two situations while the other variable was modified. Table 4 shows a summary of the four considered passing events (referred to also in this thesis as passing scenarios or passing situations) with the level of risk associated to each.

Table 4: The Four Passing Events and Risk Levels Considered in This study.

Lead vehicle speed \ Gap size	378 m	125 m
50 km/hr	(50,378) LR[1]	(50,125) MR[2]
70 km/hr	(70,378) MR	(70,125) HR[3]

[1] LR: Low Risk [2] MR: Medium Risk [3] HR: High Risk

One setup involved a relatively low-risk situation whereby the leading truck's speed was 50 km/hr, and a 378 m passing gap was made available. Two setups were of moderate-risk, one with high lead vehicle speed (70 km/hr) and large passing gaps (378 m), another with low lead speed (50 km/hr) and relatively small gaps (125 m). And lastly, a setup involving high-risk passing situations with high lead vehicle speed (70 km/hr) and small passing gaps (125 m). From this point forward, and to distinguish between the two medium-risk events, the one involving a 50 km/hr truck speed will be referred to as M50R, while that with a truck's speed of 70 km/hr will be denoted as M70R. LR and HR will refer to the low-risk and high-risk events respectively.

The modelled continuous and straight highway was divided into four sections (shown in Figure 5) and in each, a different passing scenario took place. Every participant drove through the four sections and thus got involved in the four passing situations. The scenarios were modelled such that during each scenario, the participant was given four passing opportunities. If he/she decided not to pass and continue driving behind the truck, the latter did later leave through an off-ramp (to avoid platooning of the several trucks) and the participant continued driving onto the next scenario where a new truck merged first to the main road through an on-ramp and drove in front of the participant. This ensured that the simulated leading truck would not pop up or disappear suddenly in front of the drivers.

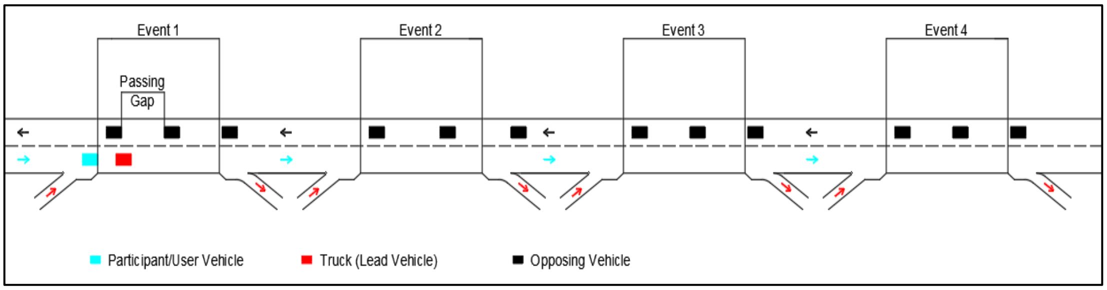


Figure 5: Illustration of the Modelled Highway and Events.

Two measures were adopted to account for and minimize the carryover effect:

First, drivers drove through a separate one-kilometer simulator training model prior to driving in the testing model (which included the experimented passing scenarios) to familiarize themselves with the simulator environment. Also, the testing model included at first a 500 m segment where participants drove freely (no lead vehicle obstructing their driving) to further enhance their control. Only after they surpassed this 500 m section, did the experimental successive passing scenarios start. This extensive simulator training course was provided based on the recommendations present in the literature. In fact, to enhance the simulator's validity, the general consensus in the literature is that more and/or longer adaptation training sessions with the driving simulator are recommended (Galante et al., 2018; Hill & Salzman, 2012; Klüver et al., 2016; Roenker et al., 2003). No data were collected from the training model.

Second, and in order to minimize the influences of repeating the same order of events, three distinct orders were made available. This was inspired by the observation of Chahine et. Al (2022). Participants do not drive through these four passing situations all at once, but rather go through them one by one. Given a total of four events, then 24 unique permutations are possible. Nevertheless, and because of time-related constraints, only three dissimilar sequences were set beforehand. Table 5 summarizes the three considered combinations and the order of events in each. There was no initial preference for choosing these three specific orders from the possible 24 arrangements.

Table 5: Considered Combinations of the Four Passing Events.

Combination	Event Order			
	1	**2**	**3**	**4**
1	M50R	LR	M70R	HR
2	LR	M70R	HR	M50R
3	M70R	HR	M50R	LR

As mentioned previously, a total of 160 volunteers participated in this study. One participant experienced dizziness while driving inside the driving simulator and had to withdraw from the experiment (no data were collected for this particular case). Another participant withdrew for urgent personal reasons while filling the survey leaving more than 50% of the questions unanswered. Their corresponding data were excluded also. The sum of participants who drove in each combination of events are included in Table 6.

Table 6: Participants Count in Each Combination.

Combination	Normal Drivers[1]	Chaotic Drivers[1]	Sample Size
1	45	7	52
2	42	11	53
3	46	7	53
Total	133	25	158[2]

[1] Difference between Normal and Chaotic Drivers is explained in Section 3.5.

[2] This total is excluding the two participants who withdrew.

3.4 Experiment procedure

The procedure with its chronological steps followed every time a participant arrives is visualized in Figure 6.

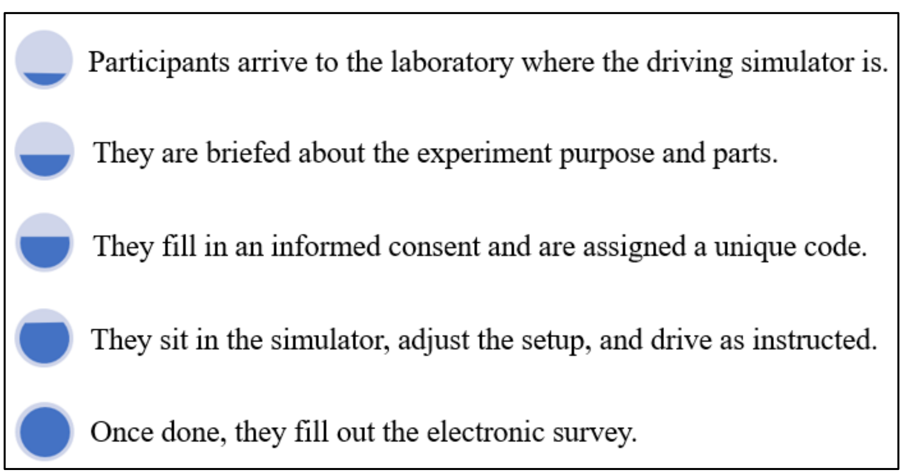


Figure 6: Visualization of the Experiment Procedure.

Upon their arrival to the laboratory, each participant was informed about the experiment, its parts as well as its aims. Next, they were requested to complete an informed consent form (English and Arabic versions were made available). Once agreed to participate in the experiment, each participant was assigned a unique code which was later used to link the simulator driving data with the reported survey data. After this, participants were asked to go inside the simulator where they were provided with general driving directions. In brief, they were asked to check the inside of the car and get a feel for it, adjust the interior setup including the seat as per their convenience. Since the road included ramps for the merging and diverging of the trucks, participants were instructed to drive straight at all times without exiting the main road. They were retold of their ability to withdraw from testing at any point, especially in the case of dizziness or fatigue. Yet, the most important reminder and instruction given is for them to drive normally as if they were driving in real life on the road.

The driving session in the simulator went as follows: First, participants drove through the one-kilometer training model to become familiar with the simulator environment. Once finished, they were asked if they felt comfortable and got an adequate handling and driving control. If that was the case, then the testing model which includes the passing scenarios was loaded. Otherwise, participants were asked to redrive through the training model. On average, each driving session was approximately five minutes long. Following its completion, participants were instructed to fill in the electronic survey using a computer present also in the laboratory and this required around 10 minutes per participant. The contents of the survey are thoroughly discussed in Section 3.2. Submitting their survey response was the final task the participants did in this study.

3.5 Experimental driving data (observed data)

While participants drove inside the simulator, information about the driver (participant), front vehicle (truck), and surrounding vehicles (opposing traffic) were being recorded. Specifically, data points were generated every 0.05 seconds. The collected information included time from simulation start (seconds), speed (km/h), distance along the road (m), offset from the road's centerline (m), and a binary variable with a true indicating collision with other vehicles and false indicating otherwise. It is important to mention that these data were collected only when the participants drove in the experimental highway model containing the four passing scenarios only. No data was generated nor recorded while driving the training road model. In addition to the survey responses, this was the only source of data reflecting observed driving behaviors. Participants were not video recorded. Figure 7 is a snapshot from inside the simulator software showing the impeding truck, an opposing vehicle, and the speedometer showing the speed at which the user vehicle (participant) is driving.

Figure 7: Impeding Truck in Front of the Driver – UC-win/Road 15.1.2.

The programming language R (R Core Team, 2022) and its integrated development environment RStudio (RStudio Team, 2022) were used to develop the needed statistical programs for this study. A specific program was developed to clean, manipulate, and extract the needed observed driving parameters from the simulator data files. Figure 8 displays a flowchart explaining the primary flow of logic within the developed script. In this flowchart, the names of the formulated functions are highlighted in yellow color. In brief, the written script loops over the available participants' records whereby it reads a single participant's data file, extracts the needed parameters, and stores them in a dedicated spreadsheet where each row in this spreadsheet represents a unique participant. This circulation of events and commands is repeated for every individual. Eventually, a structured dataset is obtained which is straightforward to analyze. In this structured dataset, each row denotes a particular driver while each column represents a certain attribute of these drivers (for instance: average speed per event).

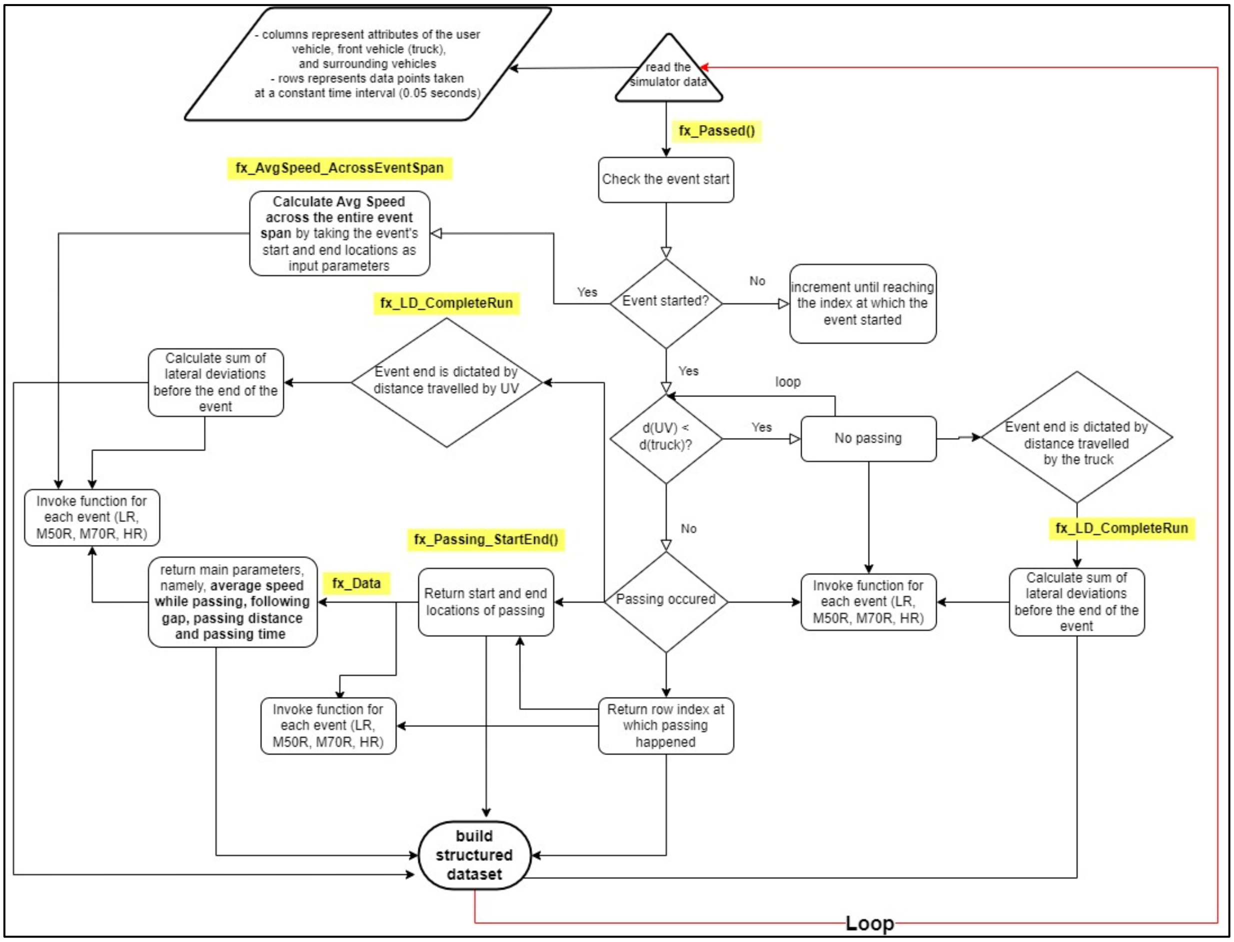


Figure 8: Flowchart for R Script Used to Extract Observed Driving Parameters.

To determine when and if a passing maneuver happened, distance along the road data was exploited; whenever the distance of the participant along the road exceeded that of the truck at the same time instant, a passing maneuver was assumed to have taken place. Moreover, the beginning of the passing maneuver was considered to be at the last time instant where the participant was in his/her lane (right lane) prior their deviation onto the opposing lane. On the other hand, the first moment during which the driver returned to his/her lane was considered to be the end of the passing maneuver. Both of these occurrences were determined based on the offset from road centerline data and were used to compute several related driving measures that are commonly used to describe passing maneuvers. With respect to the driver's speed while passing, this was measured as the average between his/her speed when the passing maneuver started and ended. Moreover, it is at the start and end locations of the passing maneuver where the following gap (FG) and gap at re-entry were determined respectively. The following gap (illustrated in Figure

1) is the distance between the driver and lead vehicle when passing started. Drivers frequently shorten their headways, in preparation for passing, to the point that they are no longer keeping a safe and secure distance from the car upfront, increasing the likelihood of rear-end collisions (Rajalin et al., 1997). Several values have been determined for the following gap based on both field data (Hegeman, 2004; Llorca & Garcia, 2011; Polus et al., 2000) and simulator data (Bella, 2011, Jenkins & Rillet, 2004). In contrast, the gap at re-entry is also the distance between the two vehicles but at the end of the overtaking movement (i.e. when the driver passed the impeding vehicle and is now in front of it). In other words, the headway (expressed in meters or seconds) between the rear-end of the passing vehicle and the front-end of the passed vehicle is labeled as the gap at re-entry. Also, the time to collision (TTC) was computed. Introduced by Hayward (1972), the TTC notion reflects the remaining time in seconds between the passing and opposing vehicle following a successful completion of the passing maneuver. Similar to FG, TTC have been evaluated using field data (Llorca & Garcia, 2011; Polus et al., 2000) and simulator data (Bella, 2011; El-Bassiouni & Sayed, 2010; Farah et al., 2009b; Jenkins & Rilett, 2005). Common metrics between the drivers who performed a passing maneuver and the ones who chose to follow the leading truck were also extracted. In fact, the average speed per event for each driver was determined by averaging all the recorded speed data points within the event. Moreover, a parameter reflecting the extent of lateral deviations performed by a driver was computed through summing up the absolute values of the lateral deviations made by a driver within the event. This permitted to capture a driver's lateral deviations in both directions, left and right, through a single-valued variable.

It is worth noting that the subsequent analysis did not include all of the participants' driving outcomes. Following the data collection process, plots showing the variation of the lateral position of the vehicle (described by the offset from road center) versus time (from the first instant when simulation started till the end of simulation) were generated for each participant. This permitted the inspection of the drivers' comfort and control while driving. Accordingly, drivers were categorized into two groups: a group which exhibited a normal driving behavior i.e. had a smooth driving experience and did not lose control nor deviate outside the carriageway. The other group exhibited a chaotic driving behavior i.e. lost driving control and drove off the road – at least once. Figure 9 illustrates two random drivers, one from each group. As a reminder, lanes in this study were designed having a five-meter width (for visualization purposes inside the simulator). Accordingly, a 2.5 m offset from the centerline of the road reflects that the driver is positioned at the centerline of his/her traveling lane. Twenty-five participants were observed to demonstrate a chaotic driving behavior and thus, were excluded from analysis reducing the final sample size to 133.

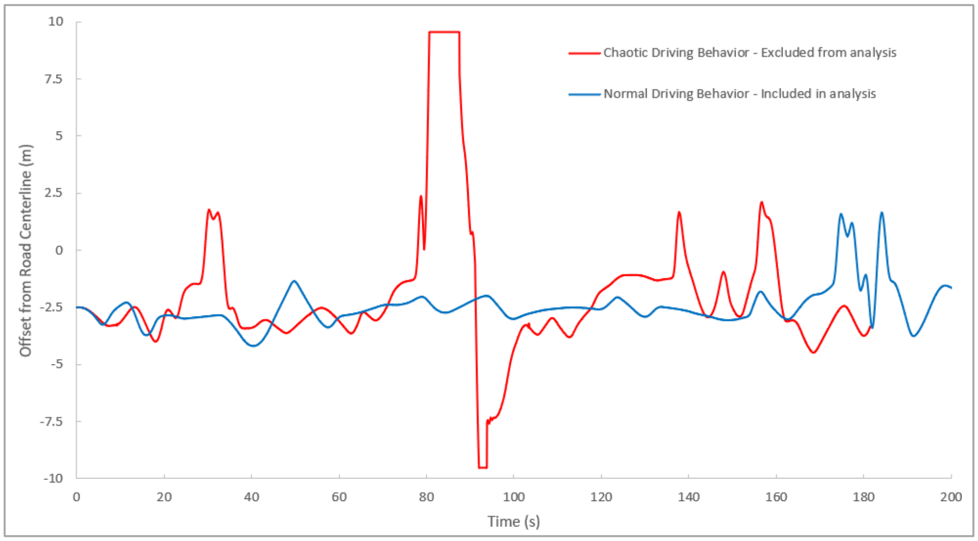


Figure 9: Offset from Road Center for Selected Drivers Versus Time.

Chapter Four

Analysis and Results

Descriptive statistics (mean, standard deviation, and range) regarding the scores of the considered demographic and psychological measures are reported in Table 7.

Table 7: Descriptive Statistics for the Demographic and Psychological Measures.

Variable	Mean Score	Standard Deviation	Range
Age	24.98	10.2	18 - 70
Gender	0.37	0.48	0 - 1
Previous involvement in accidents	0.53	0.63	0 - 2
ATTS-Attitude towards careless driving of others	4.03	0.83	1.67 - 5
ATTS-Attitude towards drinking and driving	1.86	1.09	01 - 05
ATTS-Attitude towards rule violations and speeding	3.52	0.63	1.91 - 5
DBS-Aggressive behavior	3.33	1.27	1.14 - 6.14
DBS-Anxiety based performance deficit	2.54	0.84	1 - 5.14
DBS-Exaggerated safety behavior	5.04	0.84	2.86 - 7
Mindfulness	3.87	0.9	1 - 5.8
PHQ-Anxiety	2.8	1.89	0 - 6
PHQ-Depression	2.31	1.84	0 - 6
UPPS-Lack of perseverance	1.9	0.47	1 - 3.5
UPPS-Lack of premeditation	1.85	0.39	1 - 3.12
UPPS-Negative urgency	2.37	0.59	1 - 4
UPPS-Positive urgency	2.17	0.52	1 - 3.75
UPPS-Sensation seeking	2.85	0.61	1.25 - 4

The primarily purpose of this study is to examine and analyze the pass / no pass decision per event. For that, the self-reported responses in regards to demographics and psychological traits were compared in pairwise tests relative to the observed pass / no pass decisions made in every passing event. This permitted the determination of the significant traits that impacted the passing decision in each event. Being the independent variable, the pass / no pass decision was analyzed as categorical with one indicating the occurrence of a passing maneuver and zero otherwise. A chi-squared test was performed to evaluate the existence of a significant statistical association between the passing decision and another categorical variable (for instance: gender). Only in the case of continuous variables, which is the case of all psychological traits, their relationship with the participants' passing decisions was analyzed using two-samples independent t-tests. Each one of the four passing situations was analyzed separately with respect to every demographic and psychological variable via chi-squared tests, t-tests and boxplots. Preliminary tests were performed as well to validate the needed assumptions; the normality and homogeneity of variance assumptions were assessed by means of the Shapiro-Wilk and Levene's tests respectively. For non-normal samples, a Mann Whitney U test was used instead of a t-test. In the case of an uncommon variance, the Welch's t-test was used instead of the standard Student t-test. Furthermore, if only few drivers passed during a certain overtaking scenario, their self-reported responses were compared to the sample mean and observations were made accordingly.

Table 8 summarizes the passing decisions in each scenario. It shows the number of people who passed the truck and those who chose to follow it throughout each event. Obviously, being the event with the lowest risk involved, LR had the highest number of passing maneuvers. The lowest number of passes were recorded in events M50R and HR characterized by their short passing gap. Moreover, Table 9 provides a summary of only the significant statistical tests (t-tests and chi-squared) results comparing those who passed to those who chose to continue following the lead truck in each considered event.

Table 8: Summary of the Passing Decisions Made in Each Event.

Event	No Pass	Pass	Total
LR	100	33	133
M70R	101	32	133
M50R	130	3	133
HR	129	4	133

Table 9: Two-samples Independent T-tests and Chi-squared Tests with Statistical Significance.

Event[A]	Driver's Measures	Mean (Std. Dev)		p-value
		Passed	Did not pass	
LR (33:100)	ATTS-Attitude towards rule violations and speeding	3.27 (0.60)	3.60 (0.63)	0.009**
	ATTS-Attitude towards careless driving of others	3.76 (0.86)	4.12 (0.80)	0.047*
	DBS-Exaggerated safety behavior	4.77 (0.84)	5.13 (0.83)	0.024*
	Mindfulness	3.59 (0.95)	3.96 (0.87)	0.040*
	Gender (M:F)	28:05	56:44	0.003**
M70R (32:101)	ATTS-Attitude towards rule violations and speeding	3.17 (0.52)	3.63 (0.63)	0.000***
	UPPS-Sensation seeking	3.10 (0.60)	2.77 (0.60)	0.008**
	Gender (M:F)	29:03	55:46	0.000***
M50R (3:130)	ATTS-Attitude towards rule violations and speeding	2.79 (0.67)	3.53 (0.63)	0.044*
	PHQ-Depression	4.67 (0.58)	2.25 (1.83)	0.028*
	Previous accident involvement (0:1:2)[B]	0:02:01	72:49:9	0.048*
HR (4:129)	Attitude towards rule violations and speeding	2.64 (0.44)	3.54 (0.62)	0.004**
	UPPS-Sensation seeking	3.41 (0.28)	2.83 (0.61)	0.043*

Note: *p < 0.05. **p < 0.01. *** p < 0.001.

[A] The ratio under each event's name represents the counts of the pass no pass decisions made in the event.

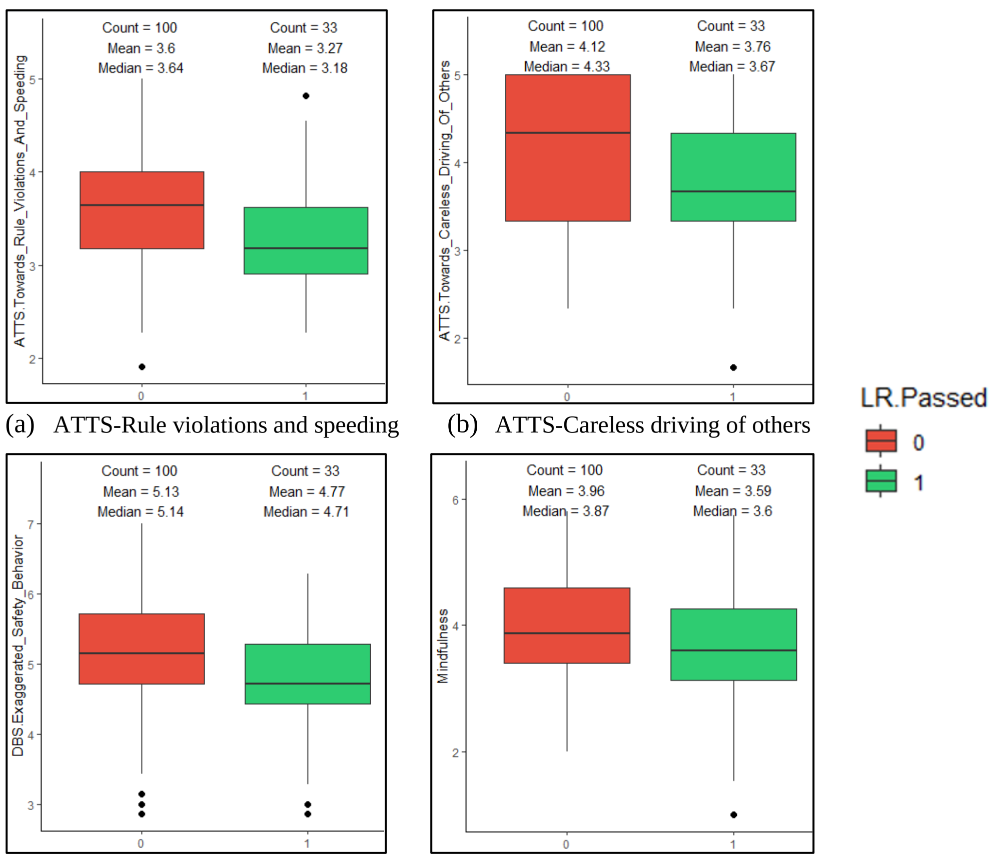
[B] 0 = None. 1 = Minor accident. 2 = Major accident.

The following sections present how the demographic and psychological traits relate to the pass / no pass decision in every considered event.

4.1 LR Event

Out of the 133 tested drivers, a total of 33 drivers (25%) passed in this low risk event. From Table 9, the significant traits affecting the pass / no pass decision in the LR event include a driver's attitude towards rule violations and speeding, attitude towards the careless driving of others, exaggerated safety behavior, mindfulness, and gender ($p<0.05$).

Aside from gender, Figure 10 presents a set of box-plots illustrating the scores for these significant psychological traits classified by those who chose to follow the lead truck throughout the event (left side of each figure and designated by the number zero) or pass it when provided the opportunity (right side of each figure and designated by the number one). The mean and median of all these four traits for drivers who passed in event LR (n = 33) were lesser than for those who did not pass and continued following the truck upfront (n = 100). Around 75% of the drivers who passed the truck had scores for attitude towards rule violations and speeding, attitude towards careless driving of others, and exaggerated safety behavior less than 3.64, 4.33, and 5.14 respectively. With respect to mindfulness, nearly 75% of those who did not pass the truck had scores higher than 3.6, which is the mean and median score for those who passed. On the other hand, mindfulness scores for those who passed were as low as one.



(a) ATTS-Rule violations and speeding (b) ATTS-Careless driving of others

(c) DBS-Exaggerated safety driving (d) Mindfulness

Figure 10: Box-plots of the Significant Psychological Traits in Event LR.

With respect to the gender variable, Figure 11 exhibit the variation of the passing decision with respect to gender of the participants. Around 33% of the male drivers chose to pass the truck. On the other hand, only 10% of the female drivers performed an overtaking maneuver in this event.

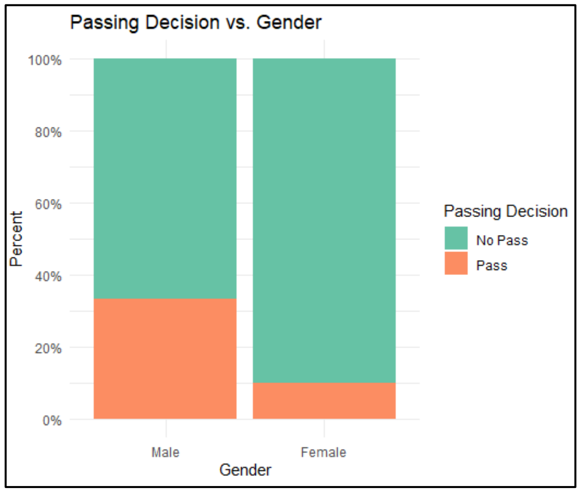
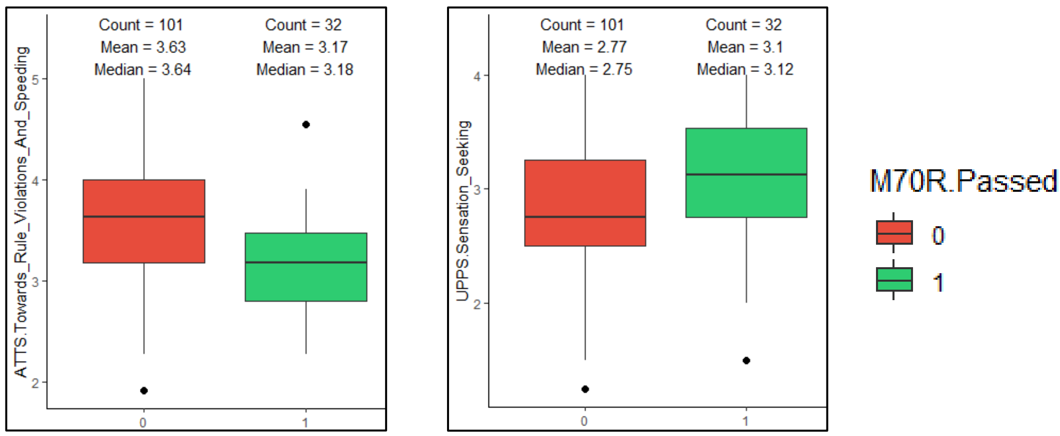


Figure 11: Passing Decision versus Gender in Event LR.

4.2 M70R Event

The number of drivers who passed in this event was 32 (24% of the sample). Following the results provided in Table 9 for the statistical tests performed to compare those who passed to those who chose to continue following the lead truck, the significant traits affecting this driving decision in the M70R event include a driver's attitude towards rule violations and speeding, impulsivity-sensation seeking, and gender ($p<0.05$).

Similar to Figure 10, Figure 12 presents a set of box-plots illustrating the scores for these significant psychological traits classified by those who chose to follow the lead truck throughout the event (left side of each figure and designated by the number zero) or pass it when provided the opportunity (right side of each figure and designated by the number one). From this figure, the mean and median of the attitude towards rule violations and speeding trait for the drivers who passed in the M70R event (n = 32) were lesser than for those who chose to follow the lead truck (n = 101). Also, more than 75% of the drivers who passed had scores lower than 3.64 for this trait. On the other hand, and concerning the sensation seeking measure, which is one dimension of the impulsivity construct, the mean and median of this trait for the drivers who passed (n = 32) were 3.1. This is higher than the 2.7 value for the mean and median for those who did not perform a passing maneuver (n = 101). In fact, nearly 75% of the drivers who passed the lead vehicle had scores for this trait greater than 2.7.



(a) ATTS-Rule violations and speeding (b) UPPS-Sensation seeking

Figure 12: Box-plots of the Significant Psychological Traits in Event M70R.

As mentioned, gender differences were also significant in this event across the passing decision made by drivers. Figure 13 exhibit the variation of the passing decision with respect to gender of the participants. The percentage of the female drivers who passed the truck was as low as 8% of the total females who participated in this study. More than 90% of the female drivers chose to follow the lead vehicle throughout this event. Whereas, around 35% of the male drivers decided to pass the truck upfront.

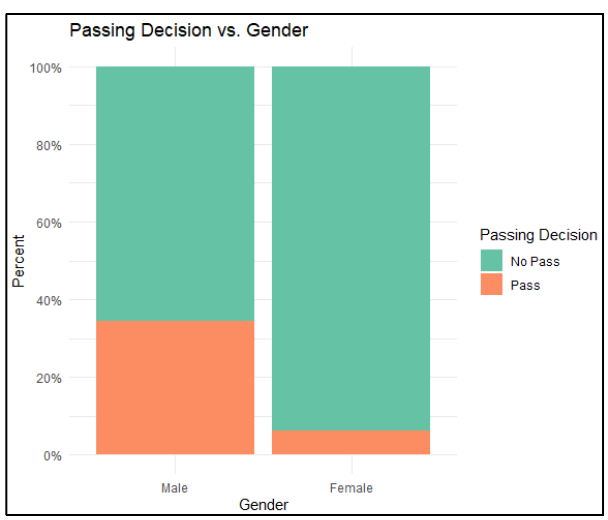


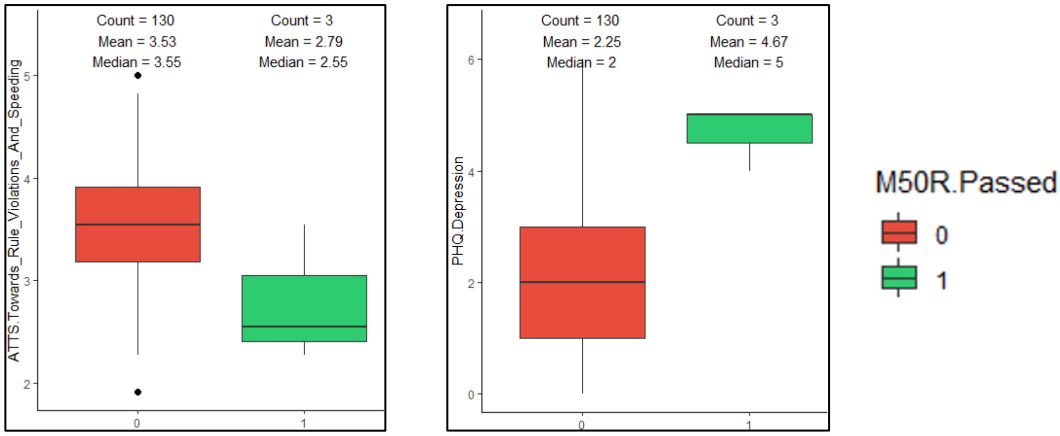
Figure 13: Passing Decision versus Gender in Event M70R.

4.3 M50R Event

Only three drivers (2.3% of the tested sample) recorded a successful passing maneuver in this medium risk event. Attitude towards rule violations and speeding, depression, and road accidents history were the driver's measures that registered significant statistical differences ($p<0.05$) in the M50R event across the binary passing decision, as shown in Table 9.

A set of box-plots illustrating the scores for attitude towards rule violations and speeding and depression traits are presented in Figure 14. Similarly, these plots are classified by those who chose to follow the lead truck throughout the event (left side of each figure and designated by the number zero) or pass it when provided the opportunity (right side of each figure and designated by the number one). From this figure, the mean and median of the attitude towards rule violations and speeding trait for the drivers who passed in the M50R event ($n = 3$) were lesser than for those who chose to follow the lead truck ($n = 130$). In fact, almost 100% of the participants who passed in this event had scores lower than 3.5 with nearly 50% of them even scoring below three. Regarding the second significant trait, depression, all three drivers who passed scored higher than four. On the contrary, the median of the depression variable for drivers who did not pass is only two. Moreover, about 75% of these drivers had depression scores lower than three and reaching a zero score.

With a p-value of 0.048 (as per Table 9), the road accident history variable is also a significant measure in this event. The variation of the passing decision with respect to this variable is illustrated in Figure 15. It can be observed that all drivers who passed the leading truck experienced at least one road accident previously (minor or major accident). None of the drivers who were never involved in a road crash performed an overtaking maneuver.



(a) ATTS-Rule violations and speeding (b) PHQ-Depression

Figure 14: Box-plots of the Significant Psychological Traits in Event M50R.

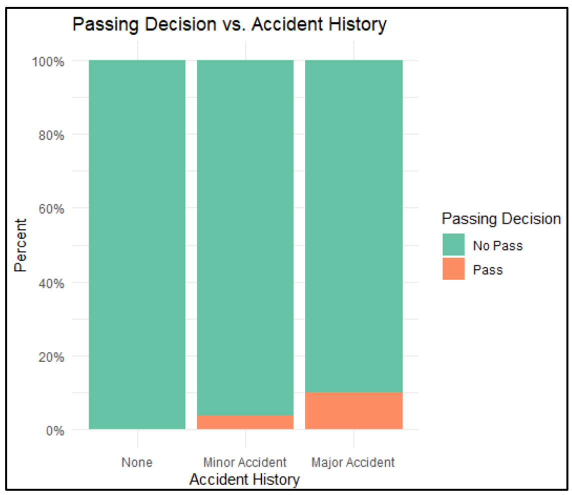


Figure 15: Passing Decision versus Road Accident History in Event M50R.

Figure 16 describes the magnitudes of the scores for specific psychological traits of the three participants who passed the leading truck in this event. These traits are the attitude towards careless driving of others, mindfulness, and impulsivity-sensation seeking. The last column in this figure represents mean scores of the sampled drivers (n = 133). Each of the remaining three columns refers to one of these three drivers. The labels on top of these columns denote the unique IDs which were assigned to the participants. In other words, the drivers who did an overtaking maneuver in the M50R event had the IDs P27, P100, and P80. Observing Figure 16, all of these three drivers had scores for attitude towards careless driving of others and mindfulness lesser than the mean scores of the sample. Moreover, two out of these three motorists (P100 and P80) had significantly higher scores for the impulsivity-sensation seeking trait than the mean score of the sample.

Only driver P27 registered a slightly lower score than the sample mean. It is noteworthy to mention also that these three drivers P27, P100, and P80 were all males with zero female participants performing a pass in this medium risk event characterized by a short passing gap and a slow leading truck up front.

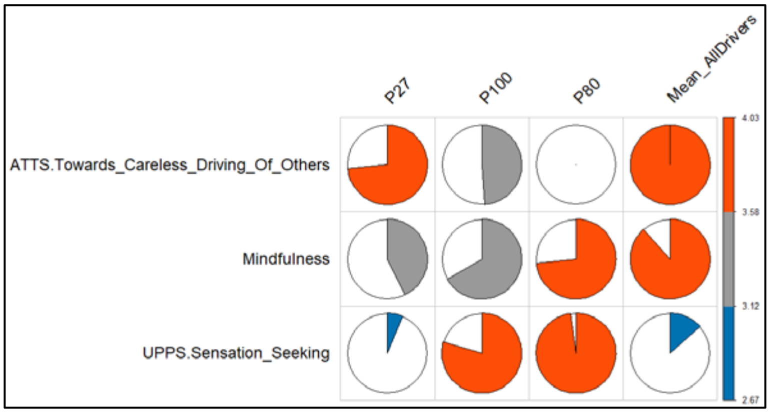
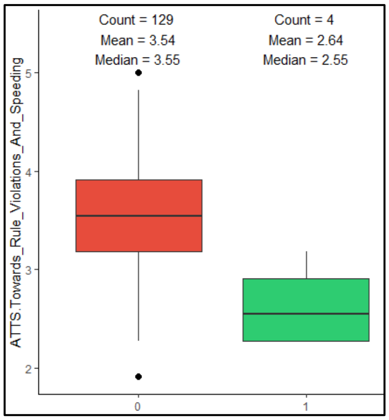


Figure 16: Scores for Certain Traits of Drivers Who Passed in Event M50R.

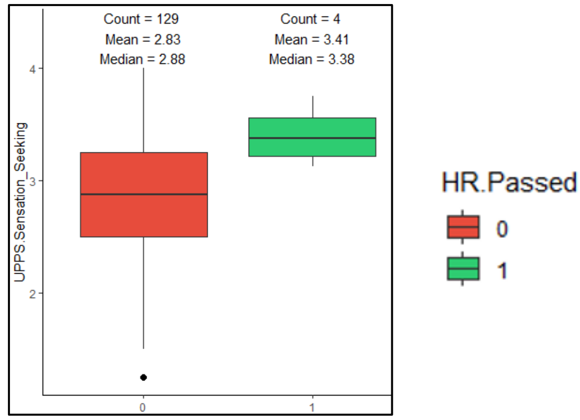
4.4 HR Event

This is the event with the highest risk involved when passing the lead truck. It is characterized by a short passing gap and a fast impeding truck. Out of the 133 sampled drivers who drove normally inside the simulator, only four drivers (3% of the sample) passed successfully in this event. All four drivers were males. The significant traits ($p<0.05$), as per Table 9, are the attitude towards rule violations and speeding and impulsivity-sensation seeking.

Like previous sets, the box-plots provided in Figure 17 demonstrate the scores for these two traits divided across the two groups; drivers who passed the truck and those who did not. Similar to the results in the other three events, it can be detected that the mean and median of the attitude towards rule violations and speeding trait for the drivers who passed in this event (n = 4) were lesser than for those who chose to follow the lead truck (n = 129). In fact, all four drivers who passed in the HR event had scores lower than 3.2. However, nearly 75% of those who did not pass had a score higher than 3.2 reaching a maximum of five. Concerning impulsivity (sensation seeking), the lowest score amongst these four drivers was 3.1 while 3.75 was the highest score. Conversely, around 75% of the participants who continued following the truck throughout this event had a score for this trait less than 3.1 reaching a minimum of 1.25.



(a) ATTS-Rule violations and speeding



(b) UPPS-Sensation seeking

Figure 17: Box-plots of the Significant Psychological Traits in Event HR.

The magnitudes of the scores for specific psychological traits of the four participants who passed the leading truck in this event are illustrated in Figure 18. These traits are the aggressive behavior, exaggerated safety behavior, and mindfulness. The last column in this figure represents mean scores of the sampled drivers (n = 133). Each of the remaining four columns refers to one of these four drivers. The labels on top of these columns represent the unique IDs which were assigned to the participants. Hence, drivers who performed an overtaking maneuver in the HR event had the IDs P100, P70, P81, and P98. Observing Figure 18, all of these four drivers had an exaggerated safety behavior score lesser than the mean score of the sample. Moreover, and except for driver P81, the remaining three drivers (P100, P70, and P98) had relatively similar scoring for the mindfulness and aggressive behavior traits. Compared the mean scores of the sample, these three drivers had lower mindfulness scores but higher aggressive behavior scores. However, driver P81 scored completely different for these two traits.

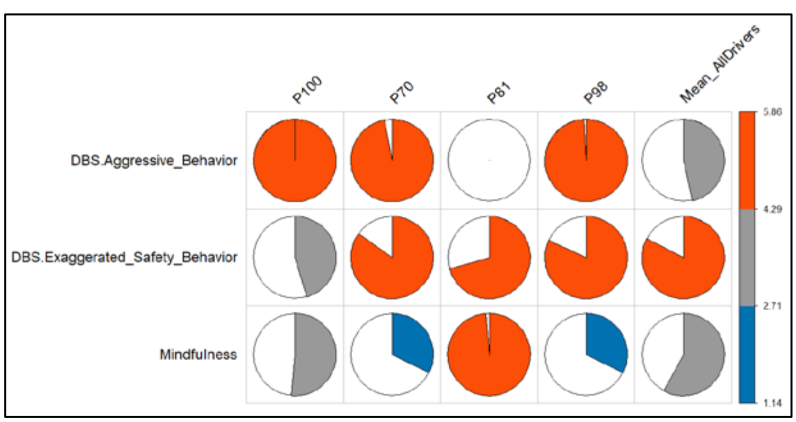


Figure 18: Scores for Certain Traits of Drivers Who Passed in Event HR.

Chapter Five

Discussion

This study investigated the interplay between traffic-related factors, drivers' demographic and psychological traits, and their corresponding decision to pass a leading truck or continue following it on a two-lane highway. A total of 160 licensed drivers were exposed inside a full-scale driving simulator to four randomized passing situations associated with different levels of risk. A self-report questionnaire was employed to collect data about their demographics and psychological traits. Using chi-squared tests, *t*-tests, and comparison of individual scorings to the sample mean scores, a significant relationship was found between the demographic and psychological factors, traffic-specific factors, and drivers observed passing behavior.

5.1 Significant Traits in All Events

Two considered driver's measures were significant across the four risky passing situations. These traits are attitude towards rule violations and speeding, and gender. Risky passing was associated with a lower attitude towards rule violations and speeding with males recording the highest counts of overtaking maneuvers in all risky situations. Such attained outcomes align with the literature.

With a lesser stance and advocacy towards driving rules, a normless driver would exhibit a reckless, hostile, and careless driving style to achieve a personal goal (Disassa & Kebu, 2019; Lucidi et al., 2019; Wang et al., 2018). In this study, drivers' personal goal was to pass the leading truck. Those who were committed to perform a passing maneuver had to exhibit a careless and unsafe overtaking action especially in the medium and high risky events that were characterized by a significantly short passing gap. Moreover, in regards to gender, males are more likely to engage in risky driving activities than females (Cordellieri et al., 2016; Farah et al., 2012; Liu et al., 2022; Nævestad et al., 2022; Voogt et al., 2014; Wang et al., 2018).

The following sections are divided based on the considered traffic variables (long passing gap, short passing gap, slow leading truck, fast leading truck) to better understand the interplay between these variables and the drivers' measures (demographics and psychological traits) which in return influences the passing decision. Each of the considered traffic variables was employed in two events.

5.2 Long Passing Gap (LR and M70R Events)

As per AASHTO's Green Book and MUTCD, the minimum PSD is 245 m. In this study, a higher value of 378 m was adopted (see Section 3.3.2). The two events that included this PSD value were the LR and M70R events which varied by the lead truck's speed. The LR event was characterized by a slow impeding truck moving at 50 km/hr while the M70R event had the truck driving at 70 km/hr. Figure 19 demonstrates a comparison between the significant traits in these two events. Traits that were significant in both passing scenarios are present on the left side of this figure. The right side includes the traits that were unique in a specific event. The common significant traits across the two passing situations including a conservative passing gap are only the attitude towards rule violations and speeding, and gender. These two traits, as mentioned previously, were significant in all passing scenarios. Hence, aside from the driver's measures that prevail irrespective of the passing situation, a large passing gap is not related to any unique trait. This is most probably because nearly all drivers who are likely to perform a passing maneuver in such relatively safe situations will overtake the lead vehicle.

However, it is the speed of the lead truck that dictates the psychological traits affecting the passing decision. As illustrated in Figure 19, in the case of a large passing gap and slow impeding truck (Event LR), in addition to gender and attitude towards rule violations and speeding, three traits become important. These are a driver's attitude towards the careless driving of others, exaggerated safety behavior, and mindfulness level. A significant portion of drivers who decided to pass in the LR event exhibited lower scores for all these three traits. Hence, drivers with minor mindfulness scores, minimal consideration about others driving style, and a lesser stance regarding safety are more likely to pass a slow leading vehicle when a large safe gap is available. On the hand, the impact of impulsivity (sensation seeking) on the passing decision becomes prominent in the case of a large passing gap and fast impeding truck (Event M70R), as per Figure 19. This comes in line with the literature. In fact, impulsivity and sensation seeking have been firmly linked to risky driving acts (Bachoo et al., 2013; Dahlen et al., 2005; Hine et al. 2015; Jonah, 1997; Smorti & Guarnieri, 2014; Smorti et al., 2018).

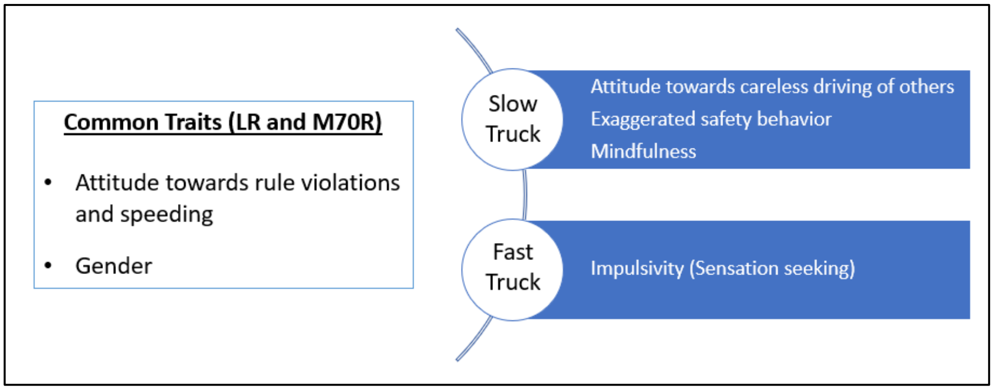


Figure 19: Comparison of Significant Traits Across Events with Large Passing Gap (LR and M70R).

5.3 Short Passing Gap (M50R and HR Events)

The two events that were characterized by a short passing gap (125 m) are M50R and HR. This adopted value for the PSD is about half the minimal PSD requirements (245 m) as per engineering standards (AASHTO and MUTCD). Event M50R included the slow impeding truck (50 km/hr) while event HR included the relatively fast lead truck (70 km/hr). Similar to Figure 19, Figure 20 includes the comparison between the significant traits in these two events. Common traits between the two passing scenarios are present on the left side of this figure. Dissimilar traits that were exclusive to a specific event are included on the right side of this figure. Besides the attitude towards rule violations and speeding and gender, mindfulness and impulsivity (sensation seeking) were additional traits that exhibited significance in both events. Compared to drivers who followed the leading vehicle, most participants who passed the leading vehicle during dense traffic (i.e short passing gap) scored lower on the mindfulness scale but higher on the impulsivity (sensation seeking) measure. Thus, drivers with high mindfulness and low impulsivity are more likely to keep driving behind the lead vehicle during high opposing traffic rather than passing it in such a risky situation. This confirms findings in the literature which presume a negative correlation between mindfulness and risky problematic driving actions (Koppel et al., 2018; Murphy & Matvienko-Sikar, 2019).

Taking the speed of the lead vehicle into consideration, additional traits would influence the passing decision – depending on the speed of this vehicle. As shown in

Figure 20, attitude towards the careless driving of others, depression, and previous accident involvement influence a motorist's passing decision when driving behind a slow truck during heavy opposing traffic (M50R event). All drivers who passed in the M50R event expressed lower attitude towards the careless driving of others and were feeling depressed lately which was reflected by their relatively high scores in regards to depression. This supports the findings of several studies which agree that depression is associated with risky and reckless driving behavior (Beratis et al., 2017; Li et al., 2021; McDonald et al., 2014; Vaughn et al., 2011). The remaining measure that was significant in the M50R event is previous accident involvement. Although only three drivers passed in this event, but all of them had been involved previously in at least one accident. All participants who had never experienced a road crash incident (54% of the sample) chose to continue driving behind the lead truck. Such risky passing behavior exhibited by these three drivers is most probably because of the Lebanese driving environment which is characterized by poor enforcement of driving rules and regulations and absence of accountability and firm punishments. Thus, drivers' aggressive and risky behaviors would remain persistent and not reduced, even if these motorists experience road crashes. On the other hand, when a passing situation involves a short passing gap but a fast-leading truck (HR event), driver's aggressive and exaggerated safety behaviors become significant (see Figure 20). In fact, only extremely aggressive drivers with minimal safety considerations for themselves and others' wellbeing would try to overtake a leading vehicle driving at a relatively high speed during dense traffic volumes. This was reflected by the scores of these risky motorists for such traits. Most participants who passed in this case exhibited high aggressiveness but relatively low exaggerated safety behavior.

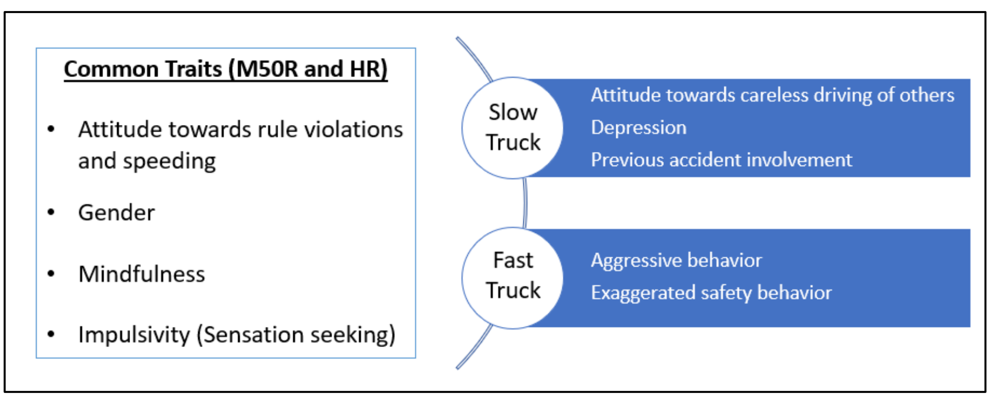


Figure 20: Comparison of Significant Traits Across Events with Small Passing Gap (M50R and HR).

5.4 Slow Leading Truck (LR and M50R)

The posted speed limit adopted in this study was 80 km/hr. For this speed value, AASHTO's Green Book assumes a 61 km/hr speed for the lead vehicle. The slow leading truck drove at a slightly lower value of 50 km/hr. LR and M50R events involved this setup. Yet, a long passing gap was made available in the LR event reflecting a low-risk passing situation. The passing gap in M50R event was designed rather short to involve a riskier passing condition. From Figure 21, the additional traits that were significant in the two events involving a slow impeding truck were a driver's attitude towards the careless driving of others and mindfulness. For both of these traits, most motorists who performed passing maneuvers displayed relatively low scorings. With respect to the attitude towards the careless driving of others measure, it is one of the three factors of the ATTS scale. This factor primarily investigates the extent of which a person finds it acceptable to take certain risks as a passenger. For instance, accepting a ride with a driver who speeds if others do or if this is the only possible way to reach home at night. Hence, people who are willing to take such risks as passengers will most likely overtake a leading truck driving at a slow speed and obstructing their driving corridor.

Specifically, for the LR case involving a slow lead vehicle and a long passing gap, driver's exaggerated safety behavior becomes significant whereby drivers who passed in this scenario showed relatively a low stance regarding safety. However, different traits were significant in the case of the M50R event which included a slow truck but a short passing gap (see Figure 21). In this scenario, depression, impulsivity (sensation seeking), and previous accident involvement were significant. This shows that the passing decision is influenced by the driver's behavior and his/her current psychological state.

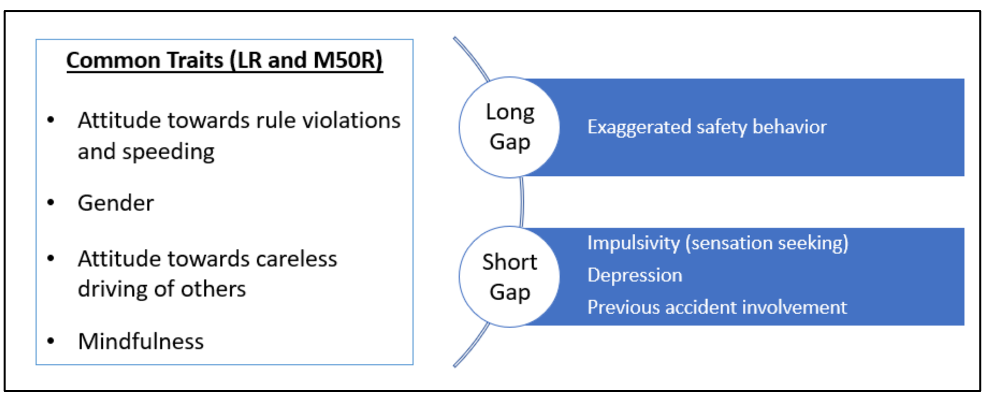


Figure 21: Comparison of Significant Traits Across Events with Small Passing Gap (LR and M50R).

5.5 Fast Leading Truck (M70R and HR)

The final traffic variable considered in this study is a leading truck driving fast at 70 km/hr. Events that included this variable were M70R and HR. M70R was characterized by a long passing gap while HR included a short passing gap. In addition to a driver's attitude towards rule violations and speeding and gender, impulsivity (sensation seeking) have a significant effect on the passing decision (Figure 22). Almost all participants who passed the fast impeding vehicle scored relatively high for this impulsivity measure. This shows that the decision to pass leading vehicles driving at high speeds is mainly influenced by the driver's tendency to act suddenly and rapidly without foresight and awareness. Drivers with the highest impulsiveness scores chose to pass the truck while those with lowest impulsiveness scores decided to continue following behind the truck irrespective of traffic density in the opposing direction. Only in the case of dense traffic (i.e short passing gap) where additional traits such as aggressive and exaggerated safety behaviors, and mindfulness appear to have substantial consequences on the passing decision.

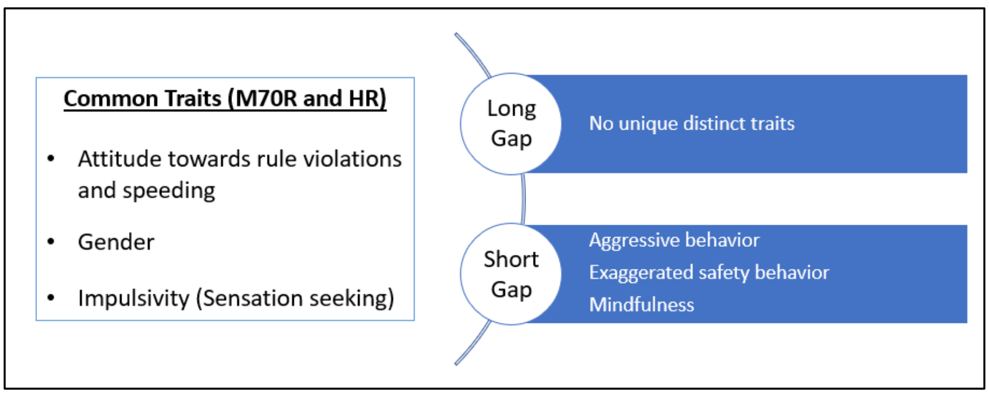


Figure 22: Comparison of Significant Traits Across Events with Small Passing Gap (M70R and HR).

Chapter Six

Limitations

This study attempts to explore drivers' passing decision on two-lane highways by discovering and analyzing the interplay that exist between certain traffic variables and demographic and psychological traits. Despite targeted recruitment, sample size was limited and fell short to properly represent the overall population especially in regards to gender and age. Also, it is possible that some participants deviated away from their typical driving behavior while driving inside the simulator because of social desirability. Such phenomenon could have biased the survey results also with participants underreporting and/or exaggerating in answering the questions. Moreover, besides being safe and effective, a driving simulator do not certainly ensure real-life complexities. Passing gap, lead vehicle speed and its size were the three engineering variables considered in this study with the latter fixed to be a truck. There are other uncontrollable conditions in real-life situations like road characteristics and geometry. Future research projects ought to ask drivers about why they passed or kept following the lead vehicle to understand and provide a cognitive assessment of their actions. Also, studies depending on naturalistic field observations may also be performed to validate the results of this research study as field data provide the best representation of drivers' characteristics.

6.1 Implications and recommendations for future research

The current study evaluates the interaction between several variables (traffic, demographic, and psychological traits) and their effects on drivers' passing behaviors. Several personality traits were highlighted and associated with risky passing behavior on two-lane highways with different available passing gaps and speed differentials. Findings are consistent with the hypothesis that motorists' psychological characteristics affect their decision to pass a lead vehicle or continue following it. In fact, results showed that male drivers with low attitude towards rule violations and speeding are more likely to overtake lead vehicles, irrespective of the passing situation they are involved in. It was found out also that impulsive and less mindful drivers were more likely to overtake lead vehicles when short passing gaps made available reflecting dense opposing traffic conditions. Results also reveal that the decision to pass a lead vehicle driving at a relatively high speed is primarily a purpose for sensation seeking whereby impulsive drivers decided to overtake the lead vehicle in such scenarios. In addition to personal attitudes and behaviors, findings showed that drivers' current feeling and state can significantly influence their passing decisions whereby drivers who have been showing depression symptoms lately decided to pass a slow impeding truck when provided a short passing gap. Passing maneuvers on two-lane highways are a complex action influenced by several parameters including psychological traits. It is difficult to determine how these characteristics relate to the passing decision. Nevertheless, results of this study represent a contribution and a step forward towards better understanding this complex relationship.

Globally, nearly 1.35 million people are killed per annum on the roads and between 20 to 50 million people are non-fatally injured (World Health Organization, 2018). However, there exist multiple measures that can be implemented to help lessen road fatalities and injuries counts (Elvik & Høye, 2020). A viable and sustainable initiative to improve road safety is enhancing the traffic culture (Obregón-Biosca et al., 2018). Changing drivers' attitudes towards unsafe driving must be the primary purpose of strategies aiming to promote road safety. Therefore, future plans should focus on incorporating these findings to enhance and update driving educational campaigns and curricula aiming to promote safe mobility and lessen the social and economic burdens of high-impact crashes. In specific, the outcomes of this study will permit to develop new educational material suited to each particular psychological factor. Furthermore, explicit and targeted roadside messages can be designed accordingly. Continuous interventions that focus on impeding the expression of impulsivity and sensation seeking are recommended. Thorough and specific educational trainings that aim to improve mindfulness and reduce impulsivity could be designed and implemented as part of drivers' training. Such trainings can specifically target the younger groups who will want to get their driver's license.

Moreover, this study exposed the necessity to continue investigating this research field, given its advantages for enhancing road safety and traffic operations. Examples of future research include exploring additional personality constructs and traits. This study aimed initially at exploring the Big Five traits (Extraversion, Neuroticism, Agreeableness, Conscientiousness, and Openness to Experience) using the brief BFI scale. Yet, the latter recorded significantly low internal reliability leading to the exclusion of all related data. Future studies are encouraged to employ the original BFI scale (44 items). Additional traits that could be investigated and have been related to risky and reckless driving include perceived hazard perception skills (Jiang et al., 2017; Sarma et al., 2013) and the Dark triad traits (Burtăverde et al., 2016; Endriulaitienė et al., 2018; Monteiro et al., 2018). Additionally, future studies that aim to develop a passing gap acceptance model are recommended to try and incorporate the mentioned psychological traits as parameters in their models.

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Appendices

Appendix A: Survey – English Version

Below are the questions included in the English version of the survey employed in this research project. Microsoft Forms was utilized to create the survey electronically.

I) Kindly input the code you were given at the beginning of the experiment: ………….

II) <u>Demographics</u>:

2.1 What is your gender?

- o Man.
- o Woman.
- o Other ……………..

2.2 What is your age? ……………..

2.3 What is your marital status?

o Single.	o Widowed.	o Separated.
o Married.	o Divorced.	o Other ……………..

2.4 Do you have children?

- o Yes.
- o No.

2.5 How many years of driving experience do you have? ……………..

2.6 Have you been in an accident before?

- o No.
- o Yes, minor accident.
- o Yes, major accident.

2.7 Have you ever taken a formal driving education class?

- o No.
- o Yes. Please specify ……………..

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

Attitudes Toward Traffic Safety (ATTS)	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.					

IV) 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 it:

Short UPPS-P Impulsive Behavior Scale	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.					

V) 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:

Driving Behavior Survey	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.							
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.							

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

The Patient Health Questionnaire-4 (PHQ-4)	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.				

VII) 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:

The Mindful Attention Awareness Scale (MAAS)	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.						

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

A Brief Version of the Big Five Personality Inventory.	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.					

Appendix B: Survey – Arabic Version

I) يرجى إدخال الرمز الذي أعطي لك في بداية التجربة:.................

II) معلومات عامّة:

1. ما هو جنسك؟
   - ذكر
   - انثى
   - آخر.................
2. ما هو عمرك؟.................
3. ما هو وضعك العائلي؟
   - اعزب
   - متزوج
   - ارمل
   - مطلق
   - منفصل
   - آخر.................
4. هل لديك اطفال؟
   - نعم
   - لا
5. كم عدد سنوات الخبرة في القيادة لديك؟.................
6. هل تعرضت لحادث سيارة من قبل؟
   - لا
   - نعم, حادث بسيط
   - نعم, حادث كبير
7. هل سبق لك أن أخذت درس تعليم قيادة رسمي؟
   - لا
   - نعم, يرجى التحديد.................

III) لكل بيان، يرجى توضيح مدى موافقتك أو عدم موافقتك على البيان:

	أعارض بشدة	أعارض	محايد	أوافق	أوافق بشدة
1. يجب تجاهل بعض قواعد المرور لضمان تدفق حركة المرور.					
2. من المنطقي تجاوز السرعة القصوى للتقدم على "سائقي الأحد".					
3. يجب احترام قواعد المرور بغض النظر عن حالة الطريق والطقس.					
4. يتمّ تجاوز السرعة القصوى لأنها شديدة التقييد.					
5. من المقبول القيادة عندما تتحول إشارات المرور من الأصفر إلى الأحمر.					
6. المخاطرة وخرق بعض القواعد لا يعني بالضرورة أنّ السائق سيئ.					
7. من المقبول المجازفة عندما لا يكون هناك أشخاص آخرين متورّطين.					
8. قواعد المرور معقدة في كثير من الأحيان بحيث لا يمكن تنفيذها في الممارسة العملية.					
9. إذا كنت سائقاً بارعاً فمن المقبول أن تقود أسرع.					
10. عندما تكون حالة الطريق جيدة ولا يوجد أحد في الجوار، فلا بأس من القيادة بسرعة 160 كم / ساعة.					
11. يجب أن تكون عقوبات السرعة أكثر صرامة.					
12. سأركب مع شخص يسرع إذا كانت هذه هي الطريقة الوحيدة للعودة إلى المنزل ليلاً.					
13. سأركب مع شخص يسرع إذا فعل الآخرون ذلك.					
14. لا أريد أن أخاطر بحياتي وصحتي بالرّكوب مع سائق غير مسؤول.					
15. لا أقود سيارتي أبدًا بعد شرب الكحول.					
16. لا أركب مع شخص أعرف أنه كان يشرب كحول.					

IV) فيما يلي عدد من العبارات التي تصف الطرق التي يتصرف ويفكر بها الناس. لكل بيان، يرجى توضيح مدى موافقتك أو عدم موافقتك على البيان:

	أعارض بشدة	أعارض	محايد	أوافق	أوافق بشدة
1. أحب عمومًا رؤية الأشياء حتى النهاية.					
2. عادة ما يكون تفكيري حريصًا وهادفًا.					
3. عندما أكون في مزاج جيّد، أميل إلى التّورّط بمواقف قد تسبب لي المشاكل.					
4. المهام غير المكتملة تزعجني حقًا.					
5. أحبّ أن أتوقف وأفكر في الأشياء قبل أن أفعلها.					
6. عندما أشعر بالسوء, أفعل غالبًا أشياء أندم عليها لاحقًا لأجعل نفسي أشعر بتحسّن الآن.					
7. بمجرد أن أبدأ شيء ما, أكره أن أتوقف.					
8. أحيانًا عندما أشعر بالسوء، لا يمكنني التوقف عما أفعله على الرغم من أنه يجعلني أشعر بسوء.					
9. أستمتع بالمجازفة.					
10. أميل إلى فقدان السيطرة عندما أكون في مزاج جيد.					
11. أنهي ما أبدأ.					
12. أميل إلى تقدير واتباع نهج عقلاني للأشياء.					
13. عندما أشعر بالضيق، غالبًا ما أتصرف بدون تفكير.					
14. أرحب بالتجارب والأحاسيس الجديدة والمثيرة، حتى لو كانت مخيفة بعض الشيء وغير تقليدية.					
15. عندما أشعر بالرفض، غالبًا ما أقول أشياء أندم عليها لاحقًا.					
16. أود أن أتعلّم قيادة طائرة.					
17. يشعر الآخرون بالصدمة أو القلق بشأن الأشياء التي أفعلها عندما أشعر بالحماس.					
18. أستمتع بإحساس التزلج بسرعة كبيرة أسفل منحدر جبلي مرتفع.					
19. أفكر مليا قبل أن أفعل أي شيء.					
20. أميل إلى التصرف دون تفكير عندما أكون متحمسًا حقًا.					

(V في كثير من الأحيان، تحدث مواقف أثناء القيادة مما يجعل السائقين يتوترون (على سبيل المثال: الظروف الجوية، وحركة المرور الكثيفة بالقرب من الحوادث، وما إلى ذلك). فيما يلي قائمة بالسلوكيات التي قد تكون أو لا تكون ذات صلة بك في هذه المواقف. الأسئلة التالية عن القيادة. اختر الجواب الذي يعكس قيادتك المعتادة في الحياة الواقعية لكل سؤال:

	أبداً	قليل الحدوث جداً	قليل الحدوث	أحياناً	غالباً ما يحدث	دائماً تقريباً	دائماً
1. أسهو عن وجهتي.							
2. أصرخ على السائق/السائقين الذين يسببون لي التوتّر.							
3. أخفف السرعة عند الاقتراب من التقاطع، حتى لو كانت الإشارة خضراء.							
4. أواجه صعوبة في البقاء في المسار الصحيح.							
5. أنحرف إلى المسارات الأخرى.							
6. أنسى أن أقوم بتعديلات مناسبة في السرعة.							
7. أعلم السائق الذي وتّرني أنني منزعج.							
8. أحافظ على مسافة كبيرة بيني وبين السائق الذي | أمامي.							
9. أنسى المكان الذي أقود إليه.							
10. أقوم بعمل إيماءات/إشارات يدوية إلى السائق/السائقين الذين يوتّرونني.							
11. أحاول أن أترك مسافة بيني وبين السيارات الأخرى.							
12. أحافظ على سرعتي لكي أهدأ.							
13. أحاول أن أبتعد عن السيارات الأخرى.							
14. أواجه صعوبة في العثور على المسار الصحيح.							
15. أضرب عجلة القيادة عندما أكون متوتر.							
16. أخفف السرعة إلى أن أشعر بالارتياح.							
17. أستعمل الزمور/البوق على السائق الذي يوترني.							
18. أحاول البحث عن طريقة لأخبر السائقين الأخرين أنهم يوترونني.							
19. خلال الأحوال الجوية السيئة، أقود بحذر أكثر من المركبات الأخرى على الطريق.							
20. أسب/أشتم عندما أقود.							
21. أواجه صعوبة في الانتقال الى مسار جديد والاندماج فيه.							

VI) يوجد أدناه مجموعة من العبارات حول تجربتك اليومية. بين مدى تكرار مواجهتك أو عدم مواجهتك لكل واحدة من التجارب الآتية. الرجاء الإجابة وفقًا لما يعكس تجربتك حقًا وليس وفقًا لما تعتقد أنه يجب أن تكون عليه تجربتك. يرجى التعامل مع كل سؤال على حدة وبشكل مستقل عن الآخر:

	تقريباً أبداً	نادراً جداً	نادر إلى حد ما	متكرر إلى حد ما	كثيراً جداً	تقريباً دائماً
1. يمكن أن أشعر بعاطفة ولا أكون واع بها حتى وقت لاحق.						
2. أدلق أو أكسر أشياء بسبب اللامبالاة، عدم الانتباه، أو التفكير بأمر أخر.						
3. أواجه صعوبة في التركيز في ما يحدث في الحاضر.						
4. عادة ما أمشي بسرعة إلى مقصدي غير منتبه إلى ما يحدث في الطريق.						
5. أميل إلى عدم ملاحظة التوتر الجسدي أو عدم الراحة حتى يخطف الأمر انتباهي بشكل جدي.						
6. أنسى اسم الشخص فور إخباري به للمرة الأولى.						
7. يبدو أنني أسير بحالة أوتوماتيكية أو تلقائية، بدون وعي كافٍ بماذا أفعل.						
8. أستعجل في إنجاز الأمور من غير إعطائها الانتباه الكافي.						
9. أركز بشكل كبير على الهدف الذي أريد أن أصل إليه لدرجة اني أفقد التركيز على ما أقوم به في الوقت الحاضر.						
10. أقوم بإنجاز الأعمال والمهام بشكل أوتوماتيكي بدون وعي بما أقوم به.						
11. أجد نفسي أستمع إلى شخص بأذن واحدة، وأفعل شيئاً آخر في نفس الوقت.						
12. أقود إلى أماكن "كطيار آلي" ثم أسأل نفسي لماذا ذهبت إلى هناك.						
13. أجد نفسي منشغلاً بالمستقبل أو الماضي.						
14. أجد نفسي أقوم بأشياء دون أن أنتبه.						
15. آكل وجبات خفيفة بدون أن أدرك أنني آكل.						

VII) على مدار الأسبوعين الماضيين، كم مرة تضايقت بسبب المشكلات التالية؟

	مطلقاً	عدة أيام	أكثر من نصف الأيام	تقريباً كل يوم
1. الشعور بالتوتر أو القلق.				
2. عدم القدرة على التوقف أو السيطرة على القلق.				
3. قلة الاهتمام أو المتعة في فعل الأشياء.				
4. الشعور بالاكتئاب أو اليأس.				

VIII) لكل عبارة، يرجى توضيح مدى موافقتك أو عدم موافقتك على العبارة:

	أعارض بشدة	أعارض	محايد	أوافق	أوافق بشدة
1. أرى نفسي كشخص محجوز.					
2. أرى نفسي كشخص يثق بشكل عام.					
3. أرى نفسي كشخص يميل إلى أن يكون كسول.					
4. أرى نفسي كشخص مرتاح، ويتعامل مع التوتر بشكل جيد.					
5. أرى نفسي كشخص لديه القليل من الاهتمامات الفنية.					
6. أرى نفسي كشخص خارجي، اجتماعي.					
7. أرى نفسي كشخص يميل لإيجاد خطأ في الآخرين.					
8. أرى نفسي كشخص يقوم بعمل شامل.					
9. أرى نفسي كشخص يتوتر بسهولة.					
10. أرى نفسي كشخص لديه خيال نشط.					