# Effects of depressed mood and alcohol use and misuse on risky driving

Nevicia F. Case, Department of Psychiatry

McGill University, Montréal

June 2022

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Doctor of Philosophy.

Dedicated to Jehovah Nissi

## Table of Contents

## Abstract

Introduction: Male drivers and first-time driving while impaired (DWI) offenders are two at-risk populations for risky driving. However, it is still unclear how depressed mood below the clinical threshold impacts driving outcomes in these populations when combined with 1) alcohol use at 0.05% blood alcohol concentration (BAC), i.e., below the *per se* criminal legal threshold of 0.08%, or 2) alcohol misuse characterised by hazardous or harmful alcohol use that is below the clinical threshold for alcohol use disorder. The roles of decision-making and sensation-seeking in predicting these outcomes are also uncertain. In response, this dissertation conducts two separate, but complementary studies.

Manuscript 1: This manuscript examines the effects of depressed mood and 0.05% BAC on two outcomes in health adult male drivers: 1) the decision to drive, and 2) risky driving. Participants were assigned to one of four conditions according to their depressed or non-depressed mood and randomisation to receive either an alcohol or placebo beverage. All participants then completed the Iowa Gambling Task (IGT), a measure of decision-making. Participants then responded to a decision-to-drive scenario and drove in a simulator. One-way ANOVA revealed that conditions did not significantly differ in risky driving. However medium effect sizes between conditions in mean highway acceleration and mean highway speed were observed. Regression analyses showed that depressed mood and 0.05% BAC did not significantly predict IGT scores, the decision to drive, and risky driving.

Manuscript 2: This manuscript examines the predictive potential of depressed mood and alcohol misuse on risky driving. Male DWI offenders were recruited. At baseline, participants completed the Millon Clinical Multiaxial Inventory III (MCMI-III) to measure depressed mood, the Alcohol Use Disorders Identification Test (AUDIT) to measure alcohol misuse, and the Sensation Seeking Scale-V (SSS-V) to measure sensation-seeking. A follow-up 3 years later measured self-reported risky driving using the Analyse des comportements

routiers (ACR3). Risky driving offence data (RDO9) from participants' driving records were collected up to 9 years after baseline. Hierarchical regressions showed that the AUDIT significantly predicted ACR3. The SSS-V did not significantly moderate this relationship. MCMI-III scores were non-significant in predicting ACR3 and no baseline measures were significant predictors of RDO9.

Discussion: Both manuscripts aimed to identify factors contributing to risky driving outcomes in males. The primary significant result was that alcohol misuse significantly predicted risky driving 3 years later in DWI offenders. This extends the focus of the literature beyond the acute effects of alcohol on risky driving. The non-significant findings related to depressed mood in both manuscripts may stem from the potential mediation of emotional intelligence, and the limited validity of the depressed mood questionnaires in males who display externalising behaviours. Through replication, the results of this research may reduce injury risk by informing targeted interventions, driver education, and relicensing policies for DWI offenders.

## Résumé

Introduction : Les conducteurs masculins et les primo-délinquants pour conduite en état d'ivresse sont deux populations susceptibles à la conduite à risque. Cependant, on ne sait toujours pas comment l'humeur dépressive, en dessous du seuil clinique, influe sur les résultats de la conduite dans ces populations lorsqu'elle est associée à 1) une consommation d'alcool à 0,05 % d'alcoolémie, c'est-à-dire en dessous du seuil légal pénal de 0,08 %, ou 2) un mauvais usage de l'alcool caractérisé par une consommation dangereuse ou nocive, en dessous du seuil clinique du trouble de l'alcoolisation. Les rôles de la prise de décision et de la recherche de sensations dans la prédiction de ces résultats sont également incertains. En réponse, cette thèse mène deux études distinctes, mais complémentaires.

Manuscrit 1 : Ce manuscrit examine les effets de l'humeur dépressive et d'un taux d'alcoolémie de 0,05% sur deux résultats chez les conducteurs adultes masculins en bonne santé : 1) la décision de conduire, et 2) la conduite à risque. Les participants ont été soumis à l'une des quatre conditions en fonction de leur humeur, dépressive ou non, et de la randomisation pour recevoir une boisson alcoolisée ou un placebo. Tous les participants ont ensuite rempli l'Iowa Gambling Task (IGT), une mesure de la prise de décision. Les participants ont ensuite répondu à un scénario de décision de conduire et ont conduit dans un simulateur. L'ANOVA à sens unique a révélé que les conditions ne différaient pas significativement en matière de conduite à risque. Cependant, des effets moyens ont été observés entre les conditions lors de l'accélération moyenne et la vitesse moyenne sur autoroute. Les analyses de régression ont montré que l'humeur dépressive et le taux d'alcoolémie de 0,05 % ne prédisaient pas de manière significative les scores IGT, la décision de conduire et la conduite à risque.

Manuscrit 2 : Ce manuscrit examine le potentiel prédictif de l'humeur dépressive et de l'abus d'alcool sur la conduite à risque. Des hommes ayant commis une CFA ont été recrutés.

Au départ, les participants ont rempli le Millon Clinical Multiaxial Inventory III (MCMI-III) pour mesurer l'humeur dépressive, l'Alcohol Use Disorders Identification Test (AUDIT) pour mesurer l'abus d'alcool, et le Sensation Seeking Scale-V (SSS-V) pour mesurer la recherche de sensations. Un suivi 3 ans plus tard a permis de mesurer la conduite à risque auto-déclarée à l'aide de l'Analyse des comportements routiers (ACR3). Les données sur les infractions de conduite à risque (RDO9) provenant des dossiers de conduite des participants ont été collectées jusqu'à 9 ans après la ligne de base. Les régressions hiérarchiques ont montré que l'AUDIT prédisait significativement l'ACR3. Le SSS-V n'a pas modéré significativement cette relation. Les scores MCMI-III n'étaient pas significatifs pour prédire l'ACR3 et aucune mesure de base n'était un prédicteur significatif du RDO9.

Discussion : Les deux manuscrits visaient à identifier les facteurs contribuant aux résultats de la conduite à risque chez les hommes. Le principal résultat significatif est que l'abus d'alcool prédit de manière accrue la conduite à risque 3 ans plus tard chez les contrevenants pour CFA. Cela élargit le champ d'intérêt de la littérature au-delà des effets aigus de l'alcool sur la conduite à risque. Les résultats non significatifs liés à l'humeur dépressive dans les deux manuscrits peuvent provenir de la médiation potentielle de l'intelligence émotionnelle et de la validité limitée des questionnaires sur l'humeur dépressive chez les hommes qui présentent des comportements externalisant. Grâce à la répétition, les résultats de cette recherche peuvent réduire le risque de blessures en informant les interventions ciblées, la formation des conducteurs et les politiques de renouvellement de permis pour les contrevenants de la CFA.

## Acknowledgements

The completion of this dissertation would not have been possible without Dr. Thomas G. Brown and Dr. Naguib Mechawar. I wish to thank my supervisor, Dr. Brown, for his guidance and generosity. I am grateful to my graduate program director, Dr. Mechawar, whose patience, support, and encouragement have been invaluable. Thanks to my committee members, Drs. Michel Perreault, David Dunkley, Reut Gruber, and Kevin Manaugh for their direction which was critical to the research process. Drs. Martin Lavallière and Danielle Groleau's insights added value. My dissertation and oral defence examination committee members, Drs. Naguib Mechawar, Ken Dewar, Thomas Raedler, Danielle Groleau, Bruno Debruille, and Joseph Rochford contributed their diverse clinical and research expertise. I am indebted to the many research participants who shared their data for the purposes of these studies. Manuscript 1 and Manuscript 2 were funded by grants from the Canadian Institutes of Health Research – [MOP-137065] and [MOP-86451], respectively – awarded to Dr. Brown. I'm honoured to have received external funding from Fonds de recherche du Québec – Santé and McGill University's Faculty of Medicine Max E. Binz Psychiatry Fellowship.

I also acknowledge the work that went into the preparation of an additional study which is not presented in this dissertation. This study was also under the tutelage of Dr. Brown, whereby I designed and began the execution of a mood induction study until its premature termination in response to the COVID-19 pandemic. I thank the volunteer research assistants, Camille Ramirez, Charlene Osei-Afrifa, Emilie Soria, Marianne Lau, Paul De Luca, Sze Pak Ng, and Tristan Malczewski, whose assistance with participant recruitment, experimental manipulations, and data collection allowed me my first opportunity to bring to life a study that I conceptualised. Throughout this process, discussions with Lysiane Robidoux-Leonard and my labmates, Dr. Manal Eldeb, Nathaniel Moxley-Kelly, and Dr. Derek Albert were invaluable.

I am grateful for the insights, encouragement, and support of Dr. A. Flynn, Dr. Morteza HajiHosseini, Dr. Ignacio Nazif-Muñoz, Dr. Lina Forcier, Angela Zwiers, Sukanya Biswabharati, Dr. Arpan Sharma, Dr. Angela Haffenden, Daniel Almeida, Dr. Kimberley Gauthier, Dr. Arturo Santisteban, Dr. Teresa Joseph, Amanda Chalupa, and Sara Guiza. Finally, I'm ever blessed for having the unwavering support of my friends, especially Dario (Donatella) Gomez, and my parents, Drs. Patricia and Neville Case, as I navigated both the triumphs and challenges of the years of work that have gone into preparing this dissertation.

## Contribution to Original Knowledge

This dissertation adds to the body of research on risky driving that has explored human factors, such as depressed mood and alcohol use/misuse. It does so by presenting two novel studies which are the first to investigate the combined effects of these human factors. Among a sample of first-time driving while impaired (DWI) offenders, alcohol misuse was found to predict engaging in self-reported non-DWI risky driving behaviours 3 years later. While much of the existing literature has focused on predicting first-time DWI offenders who become DWI recidivists, this research brings to the foreground the overlooked importance of predicting first-time DWI offenders who subsequently engage in non-DWI risky driving. The discussion provides a theoretical framework for the relationship between depressed mood and risky driving, proposing that it may in fact be the suppression of depressed mood that contributes to externalising behaviours, such as risky driving. Together, the research findings and arising discussion provide a springboard for future research aimed at preventing road traffic crashes by better predicting the human factors that contribute to them.

## Contribution of Authors

As first author, Nevicia Case led the design of research questions and reviewed the literature for each study. Independently, Nevicia Case conducted the statistical analyses; prepared the results, tables, and figures; and wrote the discussions for both Manuscript 1 and Manuscript 2, and the general discussion. Nevicia Case also contributed to participant randomisation, alcohol administration, and data collection for Manuscript 1.

As the principal investigator of the parent studies from which each of the studies in this dissertation was derived, Dr. Thomas G. Brown oversaw the design and execution of each study; provided feedback on the general introduction, introductions and methods for Manuscript 1 and Manuscript 2; and approved the general design of the statistical analyses.

## List of Abbreviations

| | |
|---|---|
| ACR | Analyse des comportements routiers (Analysis of Road Behaviours) |
| ACR3 | Risky driving scores on the Analyse des comportements routiers (Analysis of Road Behaviours) at Visit 3 |
| ANOVA | analysis of variance |
| AUDIT | Alcohol Use Disorders Identification Test |
| BAC | blood alcohol concentration |
| BAS | behavioural activation system |
| BIS | behavioural inhibition system |
| BDI-II | Beck Depression Inventory-II |
| CI | confidence interval |
| DUDIT | Drug Use Disorders Identification Test |
| DWI | driving while impaired |
| GABA | gamma aminobutyric acid |
| IGT | Iowa Gambling Task |
| OR | odds ratio |
| MAST | Michigan Alcoholism Screening Test |
| MCAR | missing completely at random |
| MCMI-III | Millon Clinical Multiaxial Inventory-III |
| PFC | prefrontal cortex |
| RDO9 | Number of risky driving offences at Year 9 |
| SAAQ | Société de l'assurance automobile du Québec |
| SDLP | standard deviation of lane position |
| SSS-V | Sensation Seeking Scale-V |

## List of Tables

## List of Figures

# Chapter 1: General Introduction

## Statement of the Problem

Road traffic crashes were responsible for 1.35 million fatalities globally in 2016 and were the leading cause of death among individuals aged 5-29 (World Health Organization, 2018b). In 2019, injuries as a result of road traffic crashes accounted for 1026 disability-adjusted life years per capita, the sixth highest cause worldwide (World Health Organization, 2020). The impact of road traffic crashes extends beyond the victims themselves, to also include economic and social impacts on the victims' families and societies (Bachani et al., 2017). In addition to the estimated $1-8 trillion in costs worldwide that are attributed to road traffic crashes, the psychological and socioeconomic impacts of road traffic crashes on individual victims and their families are extensive (Bachani et al., 2017; Chen et al., 2019). Consequently, the breadth and depth of these impacts highlight the urgent need to prevent road traffic crashes.

Road traffic crashes are thought to result from complex interactions among environmental, vehicular, and human factors (Jafarpour & Rahimi-Movaghar, 2014). While many middle- and high-income countries, including Canada, have significantly reduced the contribution of environmental (e.g., road design and lighting) and vehicular (e.g., safety features and maintenance) factors in road traffic crashes, human factors have been much more challenging to address (Jafarpour & Rahimi-Movaghar, 2014; World Health Organization, 2018b). Human factors include risky driving and the decision to drive, both of which can stem from driver characteristics, such as mood, substance use, and personality traits (Adanu & Jones, 2017; T. G. Brown et al., 2016). Among these characteristics, depressed mood and alcohol emerge as important contributors to risky driving. This dissertation explores how the effects of depressed mood and alcohol use/misuse may be amplified when they co-occur.

While clinical levels of depression and blood alcohol concentrations (BACs) exceeding the *per se* criminal legal threshold of 0.08% BAC are rightfully the subject of much research, this dissertation focuses on the overlooked, but also important phenomenon of depressed mood in the general population and 0.05% BAC. Depressed mood is estimated to be experienced by 2.8% of men each year (Topuzoğlu et al., 2015) and may increase the propensity for risky driving behaviours, such as increased standard deviation of lane position (SDLP; i.e., swerving; Chan & Singhal, 2015; Scott-Parker et al., 2012). Results of a path analysis indicate that the presence of clinical depression may predict an increased frequency in the decision to drive when there is less use of a designated driver (Zhang & Sloan, 2014). However, no such studies have been conducted using participants with symptoms below the clinical threshold. At doses up to and including 0.05% BAC, alcohol promotes risky driving by increasing SDLP and mean speed (Martin et al., 2013; Meda et al., 2009). Furthermore, acute tolerance to alcohol has been observed to increase frequencies in the decision to drive (Amlung et al., 2014; Marczinski & Fillmore, 2009; Starkey & Charlton, 2014; Weafer & Fillmore, 2012). Conducting research on lower thresholds of depressed mood and alcohol use will help to identify the point at which they begin to significantly contribute to risky driving and the decision to drive.

Research suggests that in the presence of a depressed mood, alcohol is often used as a coping mechanism to alleviate psychiatric symptoms (Hogarth, 2020; Hogarth et al., 2018). However, alcohol may, in fact, worsen some of the neuropsychological effects of depressed mood. Depressed mood is characterised by functional changes in the brain, including a marked decrease in co-activation both within the cortex, including the prefrontal cortex, and between cortical and subcortical networks (Wager et al., 2015). Importantly, these areas are also critical for decision-making which, in turn, is required for safe driving (Graefe, 2013). Acutely, alcohol's effects on the brain include dysfunction of the prefrontal cortex and

orbitofrontal cortex (Van Skike et al., 2019). Chronic patterns of alcohol misuse are correlated with the dysregulation of prefrontal and reward pathways – pathways which are also associated with high sensation-seeking (Shakra et al., 2018; Wan et al., 2020). To our knowledge, the combined effects of depressed mood in the general population with either acute alcohol at 0.05% BAC or alcohol misuse on risky driving have not been studied.

Through exploring these factors which may affect risky driving, we may gain a better understanding of how, despite law enforcement efforts, risky driving continues to pose a significant and persistent safety risk on the road by contributing to road traffic crashes (Jonah & Boase, 2017; Perreault, 2016). These factors may provide insight into risky driving, particularly among populations which present important opportunities for intervention, such as male drivers and male driving while impaired (DWI) offenders (T. G. Brown et al., 2015; Graefe, 2013). A comprehensive understanding of whether and under what conditions a combination of depressed mood and alcohol use/misuse contribute to risky driving represents a critical gap in the research, particularly given the greater tendency of males to drink alcohol as a means of coping with the symptoms of depressed mood (Mezquita et al., 2014) and the higher prevalence of male drivers and male DWI offenders who engage in risky driving (McDonald et al., 2014; Roidl et al., 2013; World Health Organization, 2018b).

### *The Current Dissertation*

In addressing these gaps in the literature, this dissertation begins by introducing the decision to drive in high-risk contexts (i.e., deciding to drive to and from a drinking establishment) and risky driving. It then reviews the relevant literature on depressed mood and alcohol use/misuse in relation to the decision to drive and risky driving. In further explaining these relationships: 1) decision-making is isolated as a potential mechanism through which depressed mood predicts risky driving, and 2) sensation seeking is isolated as a potential moderator of the effects of alcohol misuse on risky driving. Two complementary

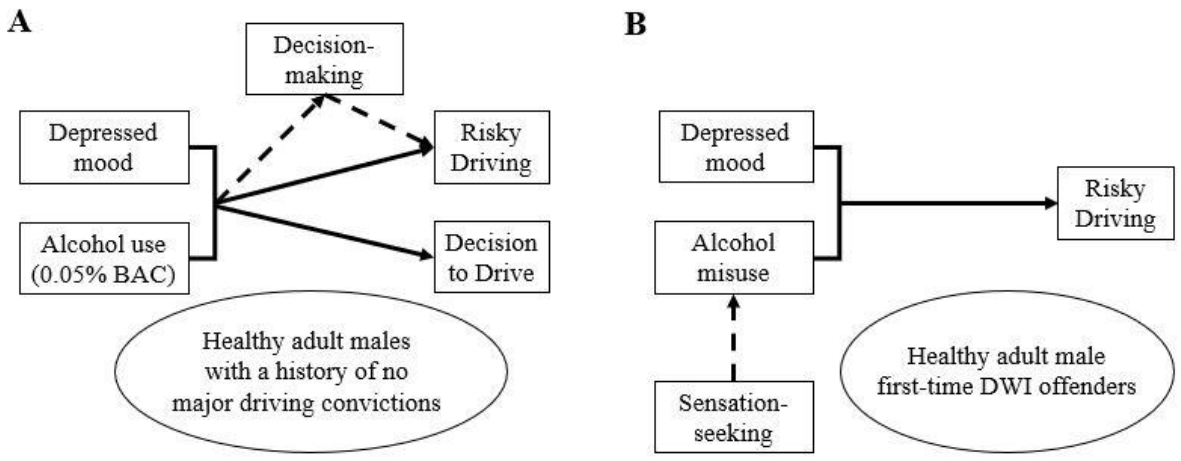
studies are then presented which explore the immediate (Manuscript 1) and long-term (Manuscript 2) effects of depressed mood and alcohol use/misuse on risky driving as follows:

1. a cross-sectional quasi-experimental study investigating the behavioural effects of acute alcohol and depressed mood on the decision to drive and risky driving in males with possible mediation of depressed mood by decision-making (see **Figure 1-1A**); and
2. a longitudinal observational study investigating the effects of alcohol misuse and depressed mood on future risky driving in male DWI offenders with possible moderation of alcohol misuse by sensation-seeking (see **Figure 1-1B**).

A summary of each manuscript's variables and their corresponding measures is presented in the Appendix (**Table A-1**). A general discussion of the findings from Manuscript 1 and Manuscript 2 situates them in the context of the existing literature and explores their implications for further research in this critical area of traffic safety.

**Figure 1-1.**

*Constructs and relationships explored and tested within the current dissertation.*




*Note.* (A) The decision to drive and risky driving are greater among individuals with a combination of depressed mood and alcohol use at 0.05% BAC. Depressed mood exerts its

effects through decision-making. (B) Greater depressed mood and alcohol misuse predict greater risky driving; the effects of alcohol misuse are modulated by sensation-seeking.

**Review of the Literature**

Society has become highly reliant on road transportation, but road traffic crashes remain a persistent problem and threat. Road traffic crashes are the leading cause of death among individuals aged 5-29 worldwide (World Health Organization, 2018b). For every death, there are an estimated 15-38 people injured as a result of road traffic crashes (World Health Organization, 2018b). In Canada, there were 114, 224 victims and their families who experienced the effects of road traffic crashes in 2018 (International Transport Forum, 2020). The health, psychosocial, and financial impacts of these fatalities and injuries are ongoing for many persons implicated in these crashes (Bachani et al., 2017). Road traffic crashes additionally burden healthcare systems, justice systems, and workplaces. They are also costly: in total, they accounted for $40.7 billion in costs to the Canadian economy in 2018 (International Transport Forum, 2020).

Safety risks and the opportunity to manage them are present in both the strategic planning of a trip (e.g., the decision to drive) and the behavioural manoeuvring of the vehicle (e.g., risky driving; Michon, 1979). Both the decision to drive in high-risk contexts and risky driving are explored in this dissertation. The decision to drive in high-risk contexts may take into account the goals, routes, and the driver's perceived ability to drive safely. While alternatives to driving, such as walking or cycling may pose a lower safety risk than driving, pedestrians and cyclists are, instead, more likely to become victims as they represent over half of the fatalities in road traffic crashes (World Health Organization, 2018b). Risky driving refers to driving behaviours that increase the probability of road traffic crashes (Halpern-Felsher et al., 2017). The cognitive and behavioural interactions with the vehicle and the road environment are considered to be human factors. Addressing the decision to drive in high-risk

contexts and risky driving, therefore, represent important areas of focus for making roads safer for all road users. Understanding the many human factors that may contribute to the decision to drive in high-risk contexts (e.g., after alcohol intake) and engagement in risky driving (e.g., speeding, swerving) may be of particular importance among certain subpopulations of drivers, including male drivers and DWI offenders.

This review of the literature begins by introducing these at-risk subpopulations of male drivers and DWI offenders. It then examines existing research on the contributions of depressed mood and alcohol use/misuse to risky driving and the decision to drive in the context of male drivers and DWI offenders. Gaps in the literature are identified and establish the foundation for Manuscript 1 and Manuscript 2.

### *Male Drivers*

Male drivers represent a key subpopulation for research focused on mitigating risky driving. Compared to female drivers, male drivers are more likely to engage in risky driving behaviours (McDonald et al., 2014; World Health Organization, 2018b). These effects may be particularly strengthened when this relationship is mediated by depressed mood (Carroll & Rothe, 2014; McDonald et al., 2014). This may, in part, be related to patterns of alcohol use/misuse while experiencing a depressed mood.

Elevated alcohol use and misuse are likely contributing factors to male drivers' higher propensity for risky driving compared to females. In Canada, males are 28% and 16% more likely to exceed acute and chronic low-risk drinking guidelines, respectively (Canadian Centre on Substance Use and Addiction, 2019). Results from a randomised controlled trial showed that, compared to women, men are also more likely to drink when they are in a depressed mood (Cyders et al., 2016). This may be explained by longitudinal evidence demonstrating the use of alcohol as a maladaptive coping mechanism to alleviate symptoms of depressed mood (Mezquita et al., 2014). Interestingly, an exploratory factor analysis

revealed that harm avoidance was one of the strongest personality traits among individuals with negative emotionality (factor loading = 0.76) who, 5 years later, reported harmful or hazardous alcohol use as a coping mechanism for depressed mood (Mezquita et al., 2014). Despite links between depressed mood and alcohol use/misuse, a consolidated understanding of the risk of male drivers with both a depressed mood and alcohol use/misuse is missing from the literature. Therefore, these relationships are the focus of this dissertation.

### *DWI Offenders*

DWI offenders represent another subpopulation of focus for risky driving prevention. In addition to DWI recidivism, first-time DWI offenders are also at heightened risk for committing non-DWI risky driving offences, such as speeding and distracted driving (T. G. Brown et al., 2020; Perreault, 2016). Therefore, these drivers display a pattern of elevated risk that extends beyond acute alcohol intoxication. Furthermore, there are key characteristics that distinguish individuals with mixed convictions (convictions for both DWI and risky driving) from individuals with pure DWI convictions (multiple convictions for DWI and no convictions for risky driving; T. G. Brown et al., 2016). Compared to controls (no history of driving convictions), individuals with pure DWI convictions have greater alcohol misuse, impulsivity, cortisol stress responses, and a higher frequency of major driving convictions. In comparison to these same controls, however, drivers with mixed convictions exhibit lower agreeableness; greater alcohol misuse, sensation-seeking, sensitivity to reward, cortisol stress responses; a higher frequency of both risky driving and non-driving criminal convictions; and accelerate more when another car is trying to merge (T. G. Brown et al., 2016). Despite these comparisons having been primarily conducted in relation to a control group, the evidence suggests that individuals with pure DWI convictions and individuals with mixed convictions are two distinct groups. Therefore, with DWI recidivism having already been the subject of much research, these findings highlight the importance of also identifying characteristics

among first-time DWI offenders that may be critical for predicting those who are at high risk of mixed convictions – a current gap in the literature that is explored in Manuscript 2.

### *Risky Driving*

Risky driving refers to driving behaviours that increase the probability of crashes and injury (Joly & Bergeron, 1987). These behaviours cover a wide spectrum of manoeuvres including speeding, crossing intersections during a yellow light, following another vehicle too closely, not adjusting to atmospheric conditions, and using a cell phone while driving (Joly & Bergeron, 1987). Risky driving is commonly understood as a behaviour resulting from a combination of human factors (e.g., alcohol use, distraction, personality traits, mood), vehicular factors (e.g., safety maintenance), and environmental factors (e.g., weather conditions, visibility, road infrastructure; Michon, 1979; Reason et al., 1990). Human factors are considered to be the primary determinant of risky driving, accounting for an estimated 94% of all road traffic crashes (Jafarpour & Rahimi-Movaghar, 2014; Singh, 2018). Furthermore, driving is a dynamic activity involving the effective management of mood, cognition, and behaviour. A more holistic understanding of how these aspects of human factors function together may offer useful explanations supporting how the presence of depressed mood and alcohol use/misuse may disrupt cognitive processes and ultimately contribute to risky driving (Lheureux et al., 2016; Potard et al., 2018).

### *The Decision to Drive in High-risk Contexts*

An essential part of safe driving is determining the risk-level of a particular driving context. A driving context is considered high-risk when there is an elevated risk for road traffic crashes due to the presence of contributors, such as depressed mood and alcohol. Therefore, the decision to drive in a high-risk context represents an individual's decision about whether or not they will drive in a context that they should be perceiving as high-risk. This decision can be influenced by many factors, such as the availability and accessibility of

alternative transportation, convenience, social norms, as well as individual cognitive decision-making processes (Ouimet et al., 2020).

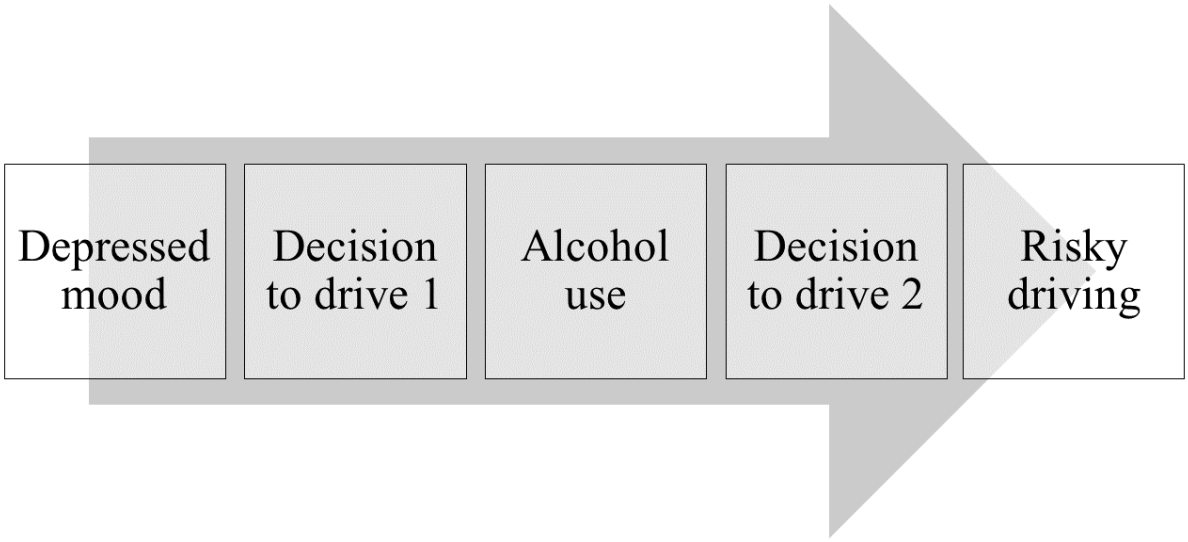
Making the decision of driving while impaired by alcohol is one of the most important decisions a driver can make. In this context, the decision to drive involves separate decisional processes which occur at two different timepoints: 1) often before drinking, the driver makes a decision about how to reach the drinking venue, such as a bar or friend's home (i.e., this decision is made while sober; Stephens et al., 2017); and 2) after the drinking episode has ended, the driver makes a decision about how to leave the drinking venue, for example, to go home (i.e., this decision is made while still intoxicated; Marczinski & Fillmore, 2009; Weafer & Fillmore, 2012). In other words, an individual who plans to visit a local bar also decides whether or not to drive their vehicle to the bar (i.e., Decision to Drive 1). By driving to the bar and consequently having their vehicle present, the individual has then created a context in which they must decide again, at the end of the drinking episode, whether or not they will drive home (i.e., Decision to Drive 2). Importantly, in addition to contextual differences between these two timepoints, such as the presence of peers and accessibility of other modes of transportation, the effects of alcohol have been demonstrated to alter the decision process in the Decision to Drive 2.

The Decision to Drive 1 occurs when the individual is still sober. Provided that the individual has affirmatively made the Decision to Drive 1, the presence of their car parked near the drinking venue presents the necessary conditions for the Decision to Drive 2 after the drinking episode. Acutely, alcohol use has been shown to shift attention from delayed rewards to immediate rewards (i.e. delay discounting; McCarthy et al., 2012). Thus, at the time of the Decision to Drive 2, the immediate rewards of risky driving (e.g., the thrill of speeding) may be more lucrative than the delayed rewards (e.g., safety; Giancola et al., 2010). This may result in the driver being more likely to decide to drive (Giancola et al.,

2010). Furthermore, the Decision to Drive 2 is influenced, among other factors, by greater BAC (particularly on the descending limb of the BAC curve; Amlung et al., 2014), lower subjective intoxication, and lower perceived dangerousness of driving (Carpenter et al., 2015; McCarthy et al., 2012; Motschman, Hatz, et al., 2020), which are further explored in the acute alcohol subsection below. **Figure 1-2** displays a plausible timeline of the relationships among depressed mood, acute alcohol use, the decision to drive, and risky driving.

**Figure 1-2.**

*Conceptual timeline of the decision to drive within the context of depressed mood and alcohol use.*




***Factors Leading to Risky Driving***

In exploring a driver's progression from experiencing a depressed mood and alcohol use/misuse to ultimately engaging in risky driving, the role of decision-making and sensation seeking may aid our understanding of these immediate and long-term factors as shown in **Figure 1-1** (T. G. Brown et al., 2016, 2017; Starkey & Isler, 2016).

**Immediate factors. *Decision-making.*** The neuropsychological domain of decision-making is distinct from the decision to drive in high-risk contexts. Decision-making refers specifically to the process by which an individual chooses an outcome based on their

valuation of available information (Fellows, 2011). Optimal decision-making recruits the coordinated function of a multitude of brain areas, including the ventromedial prefrontal cortex (PFC), dorsolateral PFC, insular cortex, anterior cingulate cortex, parietal cortices, thalamus, and caudate (Bechara et al., 1994; Fellows, 2011; Harris et al., 2011; Krain et al., 2006; Liljenström & Nazir, 2016). Factors that influence decision-making include the probabilities of outcome gains and losses and the presence of ambiguity with respect to these outcome probabilities (Fellows, 2011; Krain et al., 2006).

Importantly, decision-making is not a rational process (Kahneman & Tversky, 1979). Decision-making is conceptualised as consisting of two systems: an "automatic" system (System 1) which depends on heuristics, biases, intuitions, impressions, and emotions to make decisions quickly and with little effort and a "deliberate" system (System 2) which assumes control when more mental effort is required to form beliefs and make choices. While some driving situations, like driving as a novice or navigating the traffic customs of an unfamiliar country, may require the extended and effortful cognitive control of System 2, routine daily driving often relies on the automation of System 1 with only occasional input from System 2. Depressed mood and 0.05% BAC have well-documented effects on neuropsychological functions, such as attention (Arias et al., 2020; Garrisson et al., 2021), which are required for both System 1 and System 2. Disruption of these functions may affect risky driving through decision-making as further discussed in the sections below.

In situations of uncertainty, the processes of decision-making also vary depending on whether the decision is made under risk or ambiguity. Decision-making under risk represents situations where the probability of each outcome is known, whereas decision-making under ambiguity refers to decisions in which the probabilities of outcomes are unknown (Bechara et al., 1994). Differentially, decision-making under risk is more strongly correlated with activation in the ventromedial PFC as opposed to the dorsolateral PFC, whereas decision-

making under ambiguity correlates with greater activation in the dorsolateral PFC than the ventromedial PFC (Krain et al., 2006).

Based on studies of patients with lesions in these areas, the Iowa Gambling Task (IGT; Bechara et al., 1994) was designed as a neuropsychological test that assesses decision-making under both risk and ambiguity. A participant is presented with 4 identical decks of cards and given the goal of earning as much play money as possible. Unbeknownst to the participant, each deck carries probabilities of profit and debt (i.e., gains and losses). Cards from decks A and B result in large profits, but also have large debts which result in a net debt. Cards from decks C and D, however, result in small profits and small debts and result in an overall net profit. With decks A and B being disadvantageous towards the goal of the game and decks C and D being advantageous, lower net scores at the end of the game (the game ends after 100 card selections) suggest more disadvantageous decision-making. Since the probabilities of profits and debts associated with each deck were unknown to the participant at the onset of the game and were, therefore, ambiguous until they had been playing long enough to detect the pattern, the first 40 card selections are indicative of decision-making under ambiguity and the remaining 60 card selections are indicative of decision-making under risk (Bechara et al., 1994). Performance on the IGT has been useful in correlating damage and impaired functioning of the orbitofrontal and ventromedial PFC with the role of emotion in decision-making (Bechara et al., 2000; Phelps et al., 2014).

In the context of risky driving, there is mixed evidence for the contributions of both decision-making under risk and ambiguity to risky driving. Among drivers with a history of mixed driving convictions, decision-making was disadvantageous both under risk and ambiguity and indicated that these drivers attributed higher value to gains as opposed to losses, even when these gains were disadvantageous (Lev et al., 2008). A sample of male drivers with a history of convictions for risky driving were found to make less advantageous

decisions under ambiguity, but performed similarly to controls when under risk (T. G. Brown et al., 2016). Because optimal decision-making depends on so many functional brain areas and their respective cognitive functions that provide input to decision-making, it follows that decision-making required for a complex task like safe driving is easily influenced by depressed mood and alcohol use (Lyvers et al., 2015; Szuhany et al., 2018). The role of decision-making may, therefore, be useful in better understanding the immediate antecedents of risky driving and the decision to drive. These effects are described in the sections below.

***Depressed Mood.*** Humans experience a wide range of moods which can affect cognitive processes (e.g., the decision to drive) and behavioural outcomes (e.g., risky driving; Chung, 2015; Kind, 2013; Mendelovici, 2013). Depressed mood can include feelings of sadness, emptiness, hopelessness, or loss (American Psychiatric Association, 2013; Ferrer et al., 2015) and typically involves ruminative thoughts (Curci et al., 2013). Measurement of depressed mood in North America is most often conducted using self-report questionnaires and interviews (Beck et al., 1996) which have been designed in alignment with the diagnostic criteria provided in the *Diagnostic and Statistical Manual of Mental Disorders, 5$^{th}$ edition* (DSM-5; American Psychiatric Association, 2013) and its earlier editions. Although depressed mood is often used as an indication of depressive disorders (American Psychiatric Association, 2013), it is also present in the general population at an estimated 12-month prevalence rate of 2.8% in men (Topuzoğlu et al., 2015). There is sometimes a lack of clarity from the literature on depressed mood in risky driving. In these instances, we may draw on the adjacent literature on sadness – an emotion often associated with depressed mood – to supplement our understanding of the role of depressed mood in risky driving. Since depressed mood has notable effects on neuropsychological functions, including decision-making (Ferrer et al., 2015), examining how these dynamics may affect risky driving and the decision to drive is addressed in Manuscript 1.

Depressed mood may contribute to risky driving and drivers' decision to drive through its effects on decision-making. In the context of risk, depressed mood affects the subjective value of rewards, a critical element of decision-making (Ferrer et al., 2015). Depressed mood is associated with high reward-seeking in particular (Garg & Lerner, 2013). This may be explained by delay discounting, an aspect of decision-making which is characterised by seeking immediate rewards despite greater future rewards (Szuhany et al., 2018). Depressed mood is a significant predictor of delay discounting, indicating that these individuals may be more likely to seek immediate rewards (Szuhany et al., 2018). High reward-seeking may be a means of coping with the feeling of loss that is often central to depressed mood (Garg & Lerner, 2013). Given the strong evidence for the role of reward and delay discounting in valuation and decision-making (Loganathan et al., 2021), it follows that increased disadvantageous decision-making is quite likely among individuals with a depressed mood (Ferrer et al., 2015; Szuhany et al., 2018).

Among the variety of symptoms of depressed mood, sadness represents one of the core emotions (American Psychiatric Association, 2013). Neurocognitively, sadness is associated with a shift from external and goal-directed attention on the environment (i.e., the road context) to an internally-directed attention on the self (Arias et al., 2020). System 1 decision-making in this context is likely to be heavily influenced by sadness (Bechara, 2004). Furthermore, when sadness is coupled with the motivational symptoms of depressed mood, it may amplify the difficulty of engaging System 2 decision-making when required (Okon-Singer et al., 2015). To better understand these relationships, Manuscript 1 investigates the role of decision-making in mediating the relationship between depressed mood and risky driving.

It is well-established that clinical levels of depression symptoms contribute to risky driving (Dill et al., 2007; Hilton et al., 2009; McDonald et al., 2014; Paxton et al., 2007;

Scott-Parker et al., 2012; Stoduto et al., 2008; Testa & Steinberg, 2010; Vingilis et al., 2014). However, depressed mood in the general population has received much less attention by researchers. Previous studies which included non-clinical samples have examined measures of depressed mood as potential predictors of risky driving (McDonald et al., 2014; Scott-Parker et al., 2012; Testa & Steinberg, 2010; Vingilis et al., 2014). Among these studies, a path model demonstrated the strongest evidence for the direct effect of depressed mood on risky driving among male drivers (Scott-Parker et al., 2012). Another study (McDonald et al., 2014) analysed sex differences and depressed mood symptoms in relation to risky driving. Although results showed greater depressed mood symptoms among females, depressed mood was still a significant independent predictor of risky driving regardless of sex (McDonald et al., 2014). The only known study in which depressed mood was not observed to be a significant predictor of risky driving used the General Health Questionnaire-12 (Goldberg & Hillier, 1979) as a measure of depressed mood (Vingilis et al., 2014). Notably, the scores used from this questionnaire measure a mixture of anxiety and depression symptoms, therefore, limiting the specificity of this questionnaire as a measure of depressed mood only. All of the studies, however, failed to distinguish between participants with and without a clinical diagnosis of a depressive disorder. The Beck Depression Inventory-II (BDI-II; Beck et al., 1996) and the Major Depression scale from the Millon Clinical Multiaxial Inventory III (MCMI-III; Millon & Davis, 1997) are used in Manuscript 1 and Manuscript 2, respectively, to more specifically identify individuals with depressed mood that falls below the threshold for clinical diagnosis.

Despite the lack of traffic safety research on depressed mood among the general population, research using experimentally-induced sadness informs the literature by identifying a complex relationship between sadness and risky driving. Sadness can result in decreased fixation time on the road area (i.e., attention (Megías, Maldonado, Catena, et al.,

2011)) and more driving errors (e.g., when locating road objects such as traffic lights and pedestrians (Jallais et al., 2014)), indicating an increase in risky driving. However, participants also brake faster in response to a risky situation (Megías, Maldonado, Catena, et al., 2011). While drivers drive at a slower speed (z-axis) when experiencing sadness, they also swerve (x-axis) more indicating that their slower speed may be due to the increased swerving, a measure of risky driving (Chan & Singhal, 2015; Jeon & Croschere, 2015). Taken together, these studies on sadness in non-clinical samples supplement the mixed literature on depressed mood in both clinical and non-clinical samples to suggest that increased risky driving may plausibly occur among male drivers experiencing a depressed mood.

***Acute Alcohol.*** The effects of acute alcohol consumption on risky driving are well-established. With global estimates suggesting that one-fifth of fatalities from road traffic crashes involve drink-driving (i.e., > 0.00% BAC); on Canadian highways, this proportion is estimated to be as high as one-third (S. W. Brown et al., 2015; Vissers et al., 2018). Although the *per se* criminal legal threshold in Canada is 0.08% BAC, the effects of alcohol on risky driving have also been observed at 0.05% BAC, emphasising that alcohol's effects on risky driving are, in fact, dose-dependent (Phillips et al., 2014).

The dose-dependent acute effects of alcohol on driving risk have been used to define laws in many jurisdictions. In comparison to drivers with 0.00% BAC, there is a doubled odds ratio of road traffic injury with as little as 24g/day of alcohol (approximately 1 standard drink equivalent in men; Taylor et al., 2010) and at least a seven times higher risk of single-vehicle crash fatality at 0.05% BAC (approximately 2 standard drink equivalents in men; Fell & Voas, 2014). As such, mounting evidence of alcohol's acute impact on driving behaviours, such as braking, steering, changing lanes, judgement, and divided attention, and its dose-dependent road traffic injury risk support the lowering of 0.08% BAC *per se* criminal legal

thresholds (Fell & Voas, 2014). While maintaining a 0.00% BAC during driving continues to be strongly recommended, the challenges of legally enforcing a threshold so stringent limits its feasibility in the real world. Therefore, 0.05% BAC has emerged as a more reasonable target and is the legal threshold currently used in Australia and many European countries (Fell & Voas, 2014). In addition to the risks of 0.05% BAC alone, research on the risks of 0.05% BAC in combination with other human factors, such as depressed mood, contributes to identifying a more holistic risk profile of 0.05% BAC, supporting its adoption in a Canadian context.

Alcohol's detrimental effects on affect, cognition, and behaviour have been studied extensively. Once in the brain, alcohol primarily exerts its effects as an agonist for gamma-aminobutyric acid (GABA) receptors and as an antagonist for glutamatergic receptors, resulting in the dose-dependent sedation of brain function (Lovinger & Roberto, 2013). Alcohol also stimulates dopaminergic and serotonergic pathways, each of which have effects on reward processing (Homberg, 2012; Lovinger & Roberto, 2013; Volkow et al., 2017). Some of alcohol's effects on decision-making are most likely through its stimulation of the mesolimbic and mesocortical dopaminergic pathways (Volkow et al., 2017). With bidirectional projections between the ventromedial PFC and the amygdala, there is support for the dysregulation of this pathway correlating with disruption of valuation in decision-making (Fellows, 2011). Alcohol also dysregulates serotonergic pathways, which are important for functions like delay discounting (Homberg, 2012; Lovinger & Roberto, 2013). As such, alcohol dysregulates many of the brain regions critical to decision-making, resulting in poorer decision-making under risk at mean BACs ranging 0.06-0.08% (George et al., 2005; Gilman et al., 2012; Lyvers et al., 2015). While BACs $\leq$ 0.05% can begin to have a significant effect on driving-related neuropsychological functions, such as attention, cognitive control, and psychomotor function, others are not significantly affected until BACs

> 0.05% (Anderson et al., 2011; Schnabel, 2011; Wester et al., 2010). It is, therefore, unclear whether decision-making is affected by 0.05% BAC strongly enough to be an underlying mechanism of the effects of 0.05% BAC on risky driving.

In corroboration of the dire realities reflected by traffic injury and fatality statistics (S. W. Brown et al., 2015), experimental studies (Liu & Ho, 2010; Starkey & Charlton, 2014) provide evidence of the detrimental effects of alcohol on risky driving, even at BACs below the *per se* criminal legal threshold. In reviews of driving simulation under the effects of alcohol, SDLP (i.e., movement along the *x*-axis) and speed deviation (i.e., acceleration) have emerged as the most negatively affected measures of risky driving, irrespective of BAC (Martin et al., 2013; Rezaee-zavareh et al., 2017). Results from placebo-controlled simulator studies specifically testing 0.05% BAC parallel the conclusions of these reviews through the well-replicated findings of significant increases in SDLP and mean speed (T. L. Brown et al., 2019; Jongen et al., 2018; Meda et al., 2009). The external validity of these simulator studies is supported by findings of greater SDLP among drivers with 0.05% BAC during on-the-road testing (Jongen et al., 2017). One randomised controlled trial simulator study found that, compared to drivers in the placebo condition, drivers at 0.05% BAC had a 4.5% greater SDLP and drove an average of 1.0 km/h faster (T. L. Brown et al., 2019). They also had a 19.6% greater frequency of lane departures (T. L. Brown et al., 2019). Drivers at 0.05% BAC did not differ from the placebo condition in the percentage of time spent glancing at the roadway (T. L. Brown et al., 2019). A repeated-measures study testing risky driving at different doses, found significant effects of both dose and sex, whereby, at 0.05% BAC, participants displayed more speeding compared to 0.00% BAC and male drivers drove an average of 12.1 km/h faster than female drivers (Yadav et al., 2020). In this same study, reaction time also emerged as a significantly affected variable among male drivers at 0.05%

BAC, however, acceleration variability did not (Yadav et al., 2020). The impact of 0.05% BAC on measures of risky driving in a simulator are explored in Manuscript 1.

There is also evidence that alcohol use contributes to higher frequencies in the decision to drive (Amlung et al., 2014; Marczinski & Fillmore, 2009; Starkey & Charlton, 2014; Weafer & Fillmore, 2012). The descending limb of the BAC curve is marked by acute tolerance to the subjective effects of alcohol. In other words, while many of the cognitive and behavioural effects of alcohol are the same at 0.05% BAC on both the ascending limb and the descending limb, subjective intoxication is often markedly lower at 0.05% BAC on the descending limb compared to 0.05% BAC on the ascending limb (Marczinski & Fillmore, 2009). This means that an individual may feel less intoxicated than they actually are. This underestimation of their intoxication may make them more prone to also underestimate their risk as a driver (Morris et al., 2014). The descending limb often corresponds with the timing of an individual's departure from a venue at the end of a drinking episode. This is particularly dangerous because, the acute tolerance of the descending curve is not only associated with a decrease in subjective intoxication, but also an increase in the decision to drive (Amlung et al., 2014; Marczinski & Fillmore, 2009; Starkey & Charlton, 2014; Weafer & Fillmore, 2012). Given the evidence of alcohol's role as a harbinger of the decision to drive, Manuscript 1 specifically tests acute alcohol at 0.05% BAC on the descending limb for its effects on the decision to drive.

**Long-term factors.** ***Sensation-seeking.*** Sensation-seeking is another factor by which we may better understand how risky driving arises. Sensation-seeking is a personality trait that is characterised by the seeking of varied and intense sensations and experiences (i.e., rewards), and the willingness to take risks to obtain these sensations and experiences (Zuckerman, 1994). In the context of driving, sensation-seekers are described as having a greater threshold for perceived risk and also a greater threshold for arousal in comparison to

drivers who are low in sensation-seeking (Zuckerman, 2007b). However, when they do experience intense and novel stimuli that meet or exceed this threshold, they experience greater cortical arousal, particularly in the functional connectivity between the medial orbitofrontal cortex and the anterior cingulate cortex, areas important for reward and goal-seeking (Wan et al., 2020). A meta-analysis including 13 studies ($n$ = 8759) on sensation-seeking and risky driving found a positive correlation between these two variables ($r$ = 0.28, 95% $CI$ = [0.23, 0.33], $p$ < .0001; Akbari et al., 2019). There was a large amount of heterogeneity between the samples included in these studies ($I^2$ = 74.9%) and results were robust across geographical locations, measures used, age, and gender. This evidence suggests that individuals high in sensation-seeking may present a key population for research aimed at reducing risky driving.

In relation to alcohol misuse, sensation-seeking has primarily been studied as a risk factor (Jurk et al., 2015; Moreno Padilla et al., 2017; O'Halloran et al., 2018). Sensation-seeking encompasses four distinct facets: thrill- and adventure-seeking, experience-seeking, disinhibition, and boredom susceptibility (Zuckerman, 1994). Disinhibition, in particular, has been demonstrated to be the strongest predictor of intoxication frequency and consumption frequency (O'Halloran et al., 2018). Experience-seeking, however, may not contribute to alcohol misuse as experience-seeking behaviours often require planning and, therefore, may depend less on impulsivity (O'Halloran et al., 2018). As individuals high in sensation-seeking typically seek varied sensations, evidence demonstrating both high sensation-seeking and alcohol misuse among a population of risky drivers holds well (T. G. Brown et al., 2016). In addition to alcohol misuse, risky driving, therefore, represents one of many types of risky behaviours in which high sensation-seekers may engage (Zuckerman, 2007a).

Sensation-seeking is also highly affect-driven. Individuals high in sensation-seeking who misuse alcohol display compromised functional connectivity between the amygdala and

the orbitofrontal cortex, a pathway that is important for emotional processing (Crane et al., 2018). Alcohol misuse may even develop as a means of coping with depressed mood in individuals who are high in sensation-seeking (Jurk et al., 2015; Moreno Padilla et al., 2017). While both high sensation-seeking and greater depressive symptoms have been found to be predictive of risky driving in one study (Scott-Parker et al., 2012), the sample did not exclude clinical depression. The exploratory hypothesis in Manuscript 2 aims to build on the literature on the established role of sensation-seeking in alcohol misuse and risky driving by incorporating depressed mood.

***Depressed Mood.*** In relation to the sensation-seeking pathway to risky driving, the literature is less clear. Depressed mood has been studied among risk-takers, including drink-drivers (Dill et al., 2007; Paxton et al., 2007). Among a cluster of extreme risk-takers, 95% self-reported that within the past 30 days, they had either engaged in drink-driving or been a passenger while someone was drink-driving. These extreme risk-takers were 14.2 times more likely to have experienced a depressed mood within the past 12 months (Paxton et al., 2007), highlighting the high prevalence of depressed mood in this population. Furthermore, a study examining the emotional states of first-time DWI offenders found that being in a depressed mood significantly predicted greater alcohol temptation and negative affect prior to and during drink-driving (Dill et al., 2007). This research contributed to the conceptualisation of a model for the role of depressed mood and alcohol temptation in DWI recidivism (Wells-Parker et al., 2009), however, a gap in the literature remains as it did not measure alcohol misuse or address other types of risky driving among DWI offenders. Building on these findings and research mentioned in the previous section, depressed mood represents a plausible variable of interest in predicting risky driving, particularly in combination with alcohol misuse.

***Alcohol Misuse.*** Alcohol misuse is characterised by drinking that exceeds dietary guidelines and poses a risk to the health or wellbeing of the individual and/or others. Additionally, in the context of this dissertation, alcohol misuse refers to drinking behaviour that does not meet criteria for alcohol abuse or dependence (American Psychiatric Association, 2000; Rizer & Lusk, 2017), but is still harmful or hazardous. Alcohol misuse represents a chronic behavioural pattern that is associated with a genetic, immunological, neurobiological, affective, and cognitive profile. Extensive research on its aetiology and mechanisms have identified the role of serotonin receptor genes; microbiome dysregulation; depressed mood; dysregulation of frontolimbic and reward pathways that serve the neurotransmission of glutamate, GABA, and dopamine; personality traits of sensation-seeking and impulsivity; and alcohol-related beliefs (Alasmari et al., 2018; Carbia et al., 2021; Leamy et al., 2016).

Consistent with its characterisation as a risk-taking behaviour, alcohol misuse also elevates the risk of engaging in risky driving (Scott-Parker & Weston, 2017). Although much of the literature examines its role as a necessary precursor of DWI, there is also evidence to support the presence of greater alcohol misuse severity among individuals with convictions for a mixture of both DWI and non-DWI risky driving (T. G. Brown et al., 2016). This extends beyond common conceptualisations of alcohol's effects on risky driving being limited to acute intoxication at the time of driving. These individuals with mixed convictions additionally had significantly greater drug misuse and history of non-driving criminal convictions compared to controls, whereas individuals with pure DWI convictions did not significantly differ from controls on these variables (T. G. Brown et al., 2016). This offers further support of the role of sensation-seeking in risky driving outcomes among individuals with mixed convictions. Through its chronic misuse, alcohol may therefore be a risk factor for risky driving, even while a driver is not acutely intoxicated. In better understanding this

relationship, Manuscript 2 examines how these effects may be modulated by sensation-seeking.

***Combined Depressed Mood and Alcohol Use/Misuse in Risky Driving***

Greater alcohol use and alcohol misuse may arise as a maladaptive means of coping with depressed mood, particularly among males (Cyders et al., 2016; Mezquita et al., 2014). Moreover, this significantly greater alcohol misuse is apparent 5 years later (Mezquita et al., 2014), highlighting that the effects of depressed mood are not limited to acutely contributing to alcohol use, but are also part of a long-term pattern of alcohol misuse.

Depressed mood and alcohol use both increase the likelihood of disadvantageous decision-making under risk (Gilman et al., 2012; Suhr & Tsanadis, 2007) and the likelihood of risky driving (Scott-Parker et al., 2012). Notably, depressed mood is more strongly correlated with the behavioural inhibition system (BIS) than it is with the behavioural activation system (BAS; Merchán-Clavellino et al., 2019) and the mechanisms by which depressed mood influences decision-making under risk are independent of BAS (Suhr & Tsanadis, 2007). This suggests that while depressed mood may contribute to risky driving through its effects on decision-making under risk, the role of sensation-seeking is likely independent of these effects. In the context of alcohol use, however, decision-making under risk is even stronger among individuals who self-report experiencing alcohol's stimulatory effects as opposed to its sedative effects (Gilman et al., 2012). These stimulatory experiences correspond with increased dopamine release in the nucleus accumbens, a brain area implicated in modulating reward (Salgado & Kaplitt, 2015) and sensation-seeking (Morales et al., 2019). Individuals high in sensation-seeking, such as DWI offenders, exhibit a cluster of behaviours including greater alcohol use, alcohol misuse, and risky driving (Adams et al., 2012; Lydon-Staley et al., 2020; Smorti, 2014; Vaughn & King, 2016). Neuroimaging data suggest that these relationships are mediated by decreased functional connectivity between

the amygdala and the orbitofrontal cortex, a pathway that is critical for emotion regulation and decision-making (Crane et al., 2018). Taken together, it is likely that the co-occurrence of depressed mood and alcohol use/misuse contribute to and possibly further amplify risky driving, albeit through different processes. Based on these findings, Manuscript 1 examines the immediate antecedents of risky driving, including depressed mood, alcohol use at 0.05% BAC, and decision-making among male drivers. Manuscript 2 then examines the long-term prediction of risky driving by depressed mood, alcohol misuse, and sensation-seeking among DWI offenders.

***Summary***

Risky driving represents a major contributor to road traffic crashes (Jafarpour & Rahimi-Movaghar, 2014), resulting in 114,224 victims in Canada in 2018 and immeasurable ongoing human suffering (International Transport Forum, 2020). With the aim of improving risky driving prevention, the decision-to-drive and a first-time DWI offence both represent critical points of intervention for the prevention of risky driving.

Given the high prevalence and implications of their co-occurrence, investigating the potential combined contributions of depressed mood and alcohol use/misuse in risky driving addresses important gaps in the traffic safety literature, particularly among male drivers and DWI offenders, both of whom demonstrate an elevated risk for risky driving. This dissertation examines two ways in which depressed mood and alcohol use/misuse likely exert their effects on risky driving: immediately and in the long-term. Immediate effects isolate decision-making as a potential mechanism by which depressed mood and alcohol use contribute to risky driving. In the long-term, sensation-seeking is explored as a modulator of alcohol misuse's effects on risky driving. Importantly, there is likely crossover between these two pathways to risky driving since risky driving arises from a combination of long-term characteristics, such as personality traits, and the more immediate effects of

neuropsychological function in the moments prior to the decision to drive and risky driving (T. G. Brown et al., 2016, 2017; Starkey & Isler, 2016). However, for ease of understanding, they are presented in this dissertation as two distinct pathways; the study designs of Manuscript 1 and Manuscript 2 follow accordingly.

To our knowledge, these studies will be the first contributions to the literature examining whether the risky driving outcomes of a BAC below the *per se* criminal legal threshold are amplified by depressed mood. While Manuscript 1 examines these potential effects using real-time cognitive and behavioural outcomes within the lab, Manuscript 2 offers a longitudinal analysis of personality traits and real-world outcomes both after 3 years and for up to 9 years after initial assessment (**Figure 1-1**). Together, the designs of these two studies complement each other to provide this dissertation with a comprehensive view of the combined effects of depressed mood and alcohol on risky driving. **Table A-1** summarises each of the variables and their corresponding measures as applied and described in Manuscript 1 and Manuscript 2.

## References

Adams, Z. W., Kaiser, A. J., Lynam, D. R., Charnigo, R. J., & Milich, R. (2012). Drinking motives as mediators of the impulsivity-substance use relation: Pathways for negative urgency, lack of premeditation, and sensation seeking. *Addictive Behaviors*, *37*(7), 848–855. https://doi.org/10.1016/j.addbeh.2012.03.016

Adanu, E. K., & Jones, S. (2017). Effects of human-centered factors on crash injury severities. *Journal of Advanced Transportation*, *2017*(Special Issue). https://doi.org/10.1155/2017/1208170

Akbari, M., Lankarani, K. B., Heydari, S. T., Motevalian, S. A., Tabrizi, R., Asadi-Shekari, Z., & Sullman, M. J. M. (2019). Meta-analysis of the correlation between personality characteristics and risky driving behaviors. *Journal of Injury and Violence Research*, *11*(2), 107–122. https://doi.org/10.5249/jivr.v11i2.1172

Alasmari, F., Goodwani, S., Mccullumsmith, R. E., & Sari, Y. (2018). Role of glutamatergic system and mesocorticolimbic circuits in alcohol dependence. *Progress in Neurobiology*, *171*(December), 32–49. https://doi.org/10.1016/j.pneurobio.2018.10.001

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders IV TR*. American Psychiatric Association.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5* (5th ed.). American Psychiatric Association.

Amlung, M. T., Morris, D. H., & McCarthy, D. M. (2014). Effects of acute alcohol tolerance on perceptions of danger and willingness to drive after drinking. *Psychopharmacology*, *231*(22), 4271–4279. https://doi.org/10.1007/s00213-014-3579-1

Anderson, B. M., Stevens, M. C., Meda, S. A., Jordan, K., Calhoun, V. D., & Pearlson, G. D. (2011). Functional imaging of cognitive control during acute alcohol intoxication. *Alcoholism: Clinical and Experimental Research*, *35*(1), 156–165.

https://doi.org/10.1111/j.1530-0277.2010.01332.x

Arias, J. A., Williams, C., Raghvani, R., Aghajani, M., Baez, S., Belzung, C., Booij, L., Busatto, G., Chiarella, J., Fu, C. H., Ibanez, A., Liddell, B. J., Lowe, L., Penninx, B. W. J. H., Rosa, P., & Kemp, A. H. (2020). The neuroscience of sadness: A multidisciplinary synthesis and collaborative review. *Neuroscience and Biobehavioral Reviews*, *11*, 199–228. https://doi.org/10.1016/j.neubiorev.2020.01.006

Bachani, A. M., Peden, M., Gururaj, G., Norton, R., & Hyder, A. A. (2017). Road traffic injuries. In C. N. Mock, R. Nugent, O. Kobusingye, & K. R. Smith (Eds.), *Disease control priorities: Injury prevention and environmental health* (3rd ed., pp. 35–54). The World Bank. https://doi.org/10.1596/978-1-4648-0522-6_ch7

Bechara, A. (2004). The role of emotion in decision-making: Evidence from neurological patients with orbitofrontal damage. *Brain and Cognition*, *55*(1), 30–40. https://doi.org/10.1016/j.bandc.2003.04.001

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition*, *50*, 7–15. https://doi.org/10.1016/0010-0277(94)90018-3

Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, decision making and the orbitofrontal cortex. *Cerebral Cortex, 10*(3), 295–307. https://doi.org/10.1093/cercor/10.3.295

Beck, A., Steer, R. A., & Brown, G. K. (1996). *Beck depression inventory-II*. Pearson Canada Assessment, Inc.

Brown, S. W., Vanlaar, W. G. M., & Robertson, R. D. (2015). *Alcohol and drug-crash problem in Canada 2012 report*.

Brown, T. G., Ouimet, M. C., Eldeb, M., Tremblay, J., Vingilis, E., Nadeau, L., Pruessner, J., & Bechara, A. (2016). Personality, executive control, and neurobiological characteristics

associated with different forms of risky driving. *PLOS ONE*, *11*(2), e0150227. https://doi.org/10.1371/journal.pone.0150227

Brown, T. G., Ouimet, M. C., Eldeb, M., Tremblay, J., Vingilis, E., Nadeau, L., Pruessner, J., & Bechara, A. (2017). The effect of age on the personality and cognitive characteristics of three distinct risky driving offender groups. *Personality and Individual Differences*, *113*, 48–56. https://doi.org/10.1016/j.paid.2017.03.007

Brown, T. G., Ouimet, M. C., Nadeau, L., Tremblay, J., Gianoulakis, C., Couture, S., & Moxley-Kelly, N. (2020). Cortisol stress response predicts 9-year risky driving convictions in male first-time driving-while-impaired offenders. *Psychopharmacology*, *237*, 177–187. https://doi.org/10.1007/s00213-019-05359-0

Brown, T. G., Ouimet, M. C., Nadeau, L., Tremblay, J., & Pruessner, J. (2015). Sex differences in the personality and cognitive characteristics of first-time DWI offenders. *Journal of Studies on Alcohol and Drugs*, *76*(6), 928–934.

Brown, T. L., Lee, J. D., & Fiorentino, D. (2019). Effects of alcohol at 0.05% blood alcohol concentration (BAC) on low speed urban driving. *Traffic Injury Prevention*, *19*(sup2), S175–S177. https://doi.org/10.1080/15389588.2018.1532220

Canadian Centre on Substance Use and Addiction. (2019). *Canadian Drug Summary: Alcohol*. 1–17.

Carbia, C., Lannoy, S., Maurage, P., López-Caneda, E., O'Riordan, K. J., Dinan, T. G., & Cryan, J. F. (2021). A biological framework for emotional dysregulation in alcohol misuse: From gut to brain. *Molecular Psychiatry*, *26*, 1098–1118. https://doi.org/10.1038/s41380-020-00970-6

Carpenter, K. M., Bedi, G., & Vadhan, N. P. (2015). Understanding and shifting drug-related decisions: Contributions of automatic decision-making processes. *Current Psychiatry Reports*, *17*(8), 607. https://doi.org/10.1007/s11920-015-0607-8

Carroll, L. J., & Rothe, J. P. (2014). Viewing vehicular violence through a wide angle lens: Contributing factors and a proposed framework. *Canadian Journal of Criminology & Criminal Justice, 56*(2), 1–25. https://doi.org/10.3138/cjccj.2014.ES01

Chan, M., & Singhal, A. (2015). Emotion matters: Implications for distracted driving. *Safety Science, 72*, 302–309. https://doi.org/10.1016/j.ssci.2014.10.002

Chen, S., Kuhn, M., Prettner, K., & Bloom, D. E. (2019). The global macroeconomic burden of road injuries: Estimates and projections for 166 countries. *Lancet Planetary Health, 3*, e390-98. https://doi.org/10.1016/S2542-5196(19)30170-6

Chung, Y.-S. (2015). Seemingly irrational driving behavior model: The effect of habit strength and anticipated affective reactions. *Accident Analysis and Prevention, 82*, 79–89. https://doi.org/10.1016/j.aap.2015.05.003

Crane, N. A., Gorka, S. M., Phan, K. L., & Childs, E. (2018). Amygdala-orbitofrontal functional connectivity mediates the relationship between sensation seeking and alcohol use among binge-drinking adults. *Drug and Alcohol Dependence, 192*, 208–214. https://doi.org/10.1016/j.drugalcdep.2018.07.044

Curci, A., Lanciano, T., Soleti, E., & Rimé, B. (2013). Negative emotional experiences arouse rumination and affect working memory capacity. *Emotion, 13*(5), 867–880. https://doi.org/10.1037/a0032492

Cyders, M. A., VanderVeen, J. D., Plawecki, M., Millward, J. B., Hays, J., Kareken, D. A., & O'Connor, S. (2016). Gender-specific effects of mood on alcohol-seeking behaviors: Preliminary findings using intravenous alcohol self-administration. *Alcoholism: Clinical and Experimental Research, 40*(2), 393–400. https://doi.org/10.1111/acer.12955

Dill, P. L., Wells-Parker, E., Cross, G. W., Williams, M., Mann, R. E., Stoduto, G., & Shuggi, R. (2007). The relationship between depressed mood, self-efficacy and affective states during the drinking driving sequence. *Addictive Behaviors, 32*(8), 1714–1718.

https://doi.org/10.1016/j.addbeh.2006.11.011

Fell, J. C., & Voas, R. B. (2014). The effectiveness of a 0.05 blood alcohol concentration (BAC) limit for driving in the United States. *Addiction*, *109*(6), 869–874. https://doi.org/10.1111/add.12365

Fellows, L. K. (2011). The neurology of value. In J. A. Gottfried (Ed.), *Neurobiology of Sensation and Reward* (pp. 351–568). CRC Press.

Ferrer, R., Klein, W., Lerner, J., Reyna, V., & Keltner, D. (2015). Emotions and health decision making: Extending the appraisal tendency framework to improve health and healthcare. In C. A. Roberto & I. Kawachi (Eds.), *Behavioral Economics and Public Health* (pp. 1–35). Oxford University Press. https://doi.org/10.1093/med/9780199398331.001.0001

Garg, N., & Lerner, J. S. (2013). Sadness and consumption. *Journal of Consumer Psychology*, *23*(1), 106–113. https://doi.org/10.1016/j.jcps.2012.05.009

Garrisson, H., Scholey, A., Ogden, E., & Benson, S. (2021). The effects of alcohol intoxication on cognitive functions critical for driving: A systematic review. *Accident Analysis and Prevention*, *154*(December 2020), 106052. https://doi.org/10.1016/j.aap.2021.106052

George, S., Rogers, R. D., & Duka, T. (2005). The acute effect of alcohol on decision making in social drinkers. *Psychopharmacology*, *182*(1), 160–169. https://doi.org/10.1007/s00213-005-0057-9

Giancola, P. R., Josephs, R. A., Parrott, D. J., & Duke, A. A. (2010). Alcohol myopia revisited: Clarifying aggression and other acts of disinhibition through a distorted lens. *Perspectives on Psychological Science*, *5*(3), 265–278. https://doi.org/10.1177/1745691610369467

Gilman, J. M., Smith, A. R., Ramchandani, V. A., Momenan, R., & Hommer, D. W. (2012).

The effect of intravenous alcohol on the neural correlates of risky decision making in healthy social drinkers. *Addiction Biology*, *17*(2), 465–478. https://doi.org/10.1111/j.1369-1600.2011.00383.x

Goldberg, D. P., & Hillier, V. F. (1979). A scaled version of the General Health Questionnaire. *Psychological Medicine*, *9*, 139–145.

Graefe, A. (2013). *Risky driving behavior in young adults: Decision making and executive functioning correlates* [Drexel University]. http://dspace.library.drexel.edu/handle/1860/4301

Halpern-Felsher, B., Ramos, M., Exley, T., & Aggarwal, S. (2017). Developmental factors in driving risk. In *Handbook of teen and novice drivers: Research, practice, policy, and directions* (pp. 107–116). CRC Press/Taylor & Francis Group.

Harris, A., Adolphs, R., Camerer, C., & Rangel, A. (2011). Dynamic construction of stimulus values in the ventromedial prefrontal cortex. *PLoS ONE*, *6*(6), e21074. https://doi.org/10.1371/journal.pone.0021074

Hilton, M. F., Staddon, Z., Sheridan, J., & Whiteford, H. A. (2009). The impact of mental health symptoms on heavy goods vehicle drivers' performance. *Accident Analysis and Prevention*, *41*(3), 453–461. https://doi.org/10.1016/j.aap.2009.01.012

Hogarth, L. (2020). Addiction is driven by excessive goal-directed drug choice under negative affect: Translational critique of habit and compulsion theory. *Neuropsychopharmacology*, *45*, 720–735. https://doi.org/10.1038/s41386-020-0600-8

Hogarth, L., Hardy, L., Mathew, A. R., & Hitsman, B. (2018). Negative mood-induced alcohol-seeking is greater in young adults who report depression symptoms, drinking to cope, and subjective reactivity. *Experimental and Clinical Psychopharmacology*, *26*(2), 138–146. https://doi.org/10.1037/pha0000177

Homberg, J. R. (2012). Serotonin and decision making processes. *Neuroscience and*

*Biobehavioral Reviews*, *36*(1), 218–236. https://doi.org/10.1016/j.neubiorev.2011.06.001

International Transport Forum. (2020). *Road safety annual report 2020: Canada*. https://www.itf-oecd.org/sites/default/files/canada-road-safety.pdf

Jafarpour, S., & Rahimi-Movaghar, V. (2014). Determinants of risky driving behavior: A narrative review. *Medical Journal of the Islamic Republic of Iran*, *28*(1), 1–8.

Jallais, C., Gabaude, C., & Paire-ficout, L. (2014). When emotions disturb the localization of road elements: Effects of anger and sadness. *Transportation Research Part F-Traffic Psychology and Behaviour*, *23*, 125–132. https://doi.org/10.1016/j.trf.2013.12.023

Jeon, M., & Croschere, J. (2015). Sorry, I'm late; I'm not in the mood: Negative emotions lengthen driving time. *International Conference on Engineering Psychology and Cognitive Ergonomics*, *9174*, 237–244. https://doi.org/10.1007/978-3-319-20373-7_22

Joly, P., & Bergeron, J. (1987). Étude des comportements de risque au volant à l'aide du questionnaire ACR. *Accident Analysis & Prevention: Proceedings of the Canadian Multidisciplinary Road Safety Conference V*, *20*(2), 156–157.

Jonah, B. A., & Boase, P. (2017). Speeding and other risky driving behavior among young drivers. In *Handbook of teen and novice drivers: Research, practice, policy, and directions* (pp. 145–165). CRC Press.

Jongen, S., Van Der Sluiszen, N. N. J. J. M., Brown, D., & Vuurman, E. F. P. M. (2018). Single-and dual-task performance during on-the-road driving at a low and moderate dose of alcohol: A comparison between young novice and more experienced drivers. *Human Psychopharmacology: Clinical and Experimental*, *33*, e2661. https://doi.org/10.1002/hup.2661

Jongen, S., Vermeeren, & A., Van Der Sluiszen, & N. N. J. J. M., Schumacher, M. B., Theunissen, E. L., Kuypers, & K. P. C., Vuurman, E. F. P. M., & Ramaekers, J. G.

(2017). A pooled analysis of on-the-road highway driving studies in actual traffic measuring standard deviation of lateral position (i.e., “weaving”) while driving at a blood alcohol concentration of 0.5 g/L. *Psychopharmacology, 234*, 837–844. https://doi.org/10.1007/s00213-016-4519-z

Jurk, S., Kuitunen-Paul, S., Kroemer, N. B., Artiges, E., Banaschewski, T., Bokde, A. L. W., Büchel, C., Conrod, P., Fauth-Bühler, M., Flor, H., Frouin, V., Gallinat, J., Garavan, H., Heinz, A., Mann, K. F., Nees, F., Paus, T., Pausova, Z., Poustka, L., … Smolka, M. N. (2015). Personality and substance use: Psychometric evaluation and validation of the Substance Use Risk Profile Scale (SURPS) in English, Irish, French, and German adolescents. *Alcoholism: Clinical and Experimental Research*, *39*(11), 2234–2248. https://doi.org/10.1111/ACER.12886

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, *47*(2), 263–291.

Kind, A. (2013). The case against representationalism about moods. In U. Kriegel (Ed.), *Current controversies in the philosophy of mind* (pp. 113–134). Routledge.

Krain, A. L., Wilson, A. M., Arbuckle, R., Castellanos, F. X., & Milham, M. P. (2006). Distinct neural mechanisms of risk and ambiguity: A meta-analysis of decision-making. *NeuroImage*, *32*, 477–484. https://doi.org/10.1016/j.neuroimage.2006.02.047

Leamy, T. E., Connor, J. P., Voisey, J., Young, R. M., & Gullo, M. J. (2016). Alcohol misuse in emerging adulthood: Association of dopamine and serotonin receptor genes with impulsivity-related cognition. *Addictive Behaviors*, *63*, 29–36. https://doi.org/10.1016/j.addbeh.2016.05.008

Lev, D., Hershkovitz, E., & Yechiam, E. (2008). Decision making and personality in traffic offenders: A study of Israeli drivers. *Accident Analysis and Prevention*, *40*, 223–230. https://doi.org/10.1016/j.aap.2007.05.009

Lheureux, F., Auzoult, L., Charlois, C., Hardy-Massard, S., & Minary, J.-P. (2016). Traffic offences: Planned or habitual? Using the theory of planned behaviour and habit strength to explain frequency and magnitude of speeding and driving under the influence of alcohol. *British Journal of Psychology, 107*, 52–71. https://doi.org/10.1111/bjop.12122

Liljenström, H., & Nazir, A. H. (2016). Neurodynamics of decision making: A computational approach. In R. Wang & X. Pan (Eds.), *Advances in cognitive neurodynamics* (pp. 1–7). Springer Singapore. www.sigtunastiftelsen.se/agoraforbiosystems

Liu, Y.-C., & Ho, C. H. (2010). Effects of different blood alcohol concentrations and post-alcohol impairment on driving behavior and task performance. *Traffic Injury Prevention*, *11*(4), 334–341. https://doi.org/10.1080/15389581003747522

Loganathan, K., Lv, J., Cropley, V., Ho, E. T. W., & Zalesky, A. (2021). Associations between delay discounting and connectivity of the valuation-control system in healthy young adults. *Neuroscience*, *452*, 295–310. https://doi.org/10.1016/j.neuroscience.2020.11.026

Lovinger, D. M., & Roberto, M. (2013). Synaptic effects induced by alcohol. *Current Topics in Behavioral Neurosciences Series*, *13*, 31–86. https://doi.org/10.1007/7854_2011_143

Lydon-Staley, D. M., Falk, E. B., & Bassett, D. S. (2020). Within-person variability in sensation-seeking during daily life: Positive associations with alcohol use and self-defined risky behaviors. *Psychology of Addictive Behavior*, *34*(2), 257–268. https://doi.org/10.31234/osf.io/djb5c

Lyvers, M., Mathieson, N., & Edwards, M. S. (2015). Blood alcohol concentration is negatively associated with gambling money won on the Iowa Gambling Task in naturalistic settings after controlling for trait impulsivity and alcohol tolerance. *Addictive Behaviors*, *41*, 129–135. https://doi.org/10.1016/j.addbeh.2014.10.008

Marczinski, C. A., & Fillmore, M. T. (2009). Acute alcohol tolerance on subjective

intoxication and simulated driving performance in binge drinkers. *Psychology of Addictive Behaviors*, *23*(2), 238–247. https://doi.org/10.1037/a0014633

Martin, T. L., M Solbeck, P. A., Mayers, D. J., Langille, R. M., Buczek, Y., & Pelletier, M. R. (2013). A review of alcohol-impaired driving: The role of blood alcohol concentration and complexity of the driving task. *Journal of Forensic Sciences*, *58*(5), 1238–1250. https://doi.org/10.1111/1556-4029.12227

McCarthy, D. M., Niculete, M. E., Treloar, H. R., Morris, D. H., & Bartholow, B. D. (2012). Acute alcohol effects on impulsivity: Associations with drinking and driving behavior. *Addiction*, *107*(12), 2109–2114. https://doi.org/10.1111/j.1360-0443.2012.03974.x

McDonald, C. C., Sommers, M. S., & Fargo, J. D. (2014). Risky driving, mental health, and health-compromising behaviours: Risk clustering in late adolescents and adults. *Injury Prevention*, *20*(6), 365–372. https://doi.org/10.1136/injuryprev-2014-041150

Meda, S. A., Calhoun, V. D., Astur, R. S., Turner, B. M., Ruopp, K., & Pearlson, G. D. (2009). Alcohol dose effects on brain circuits during simulated driving: An fMRI study. *Human Brain Mapping*, *30*(4), 1257–1270. https://doi.org/10.1002/hbm.20591

Megías, A., Maldonado, A., Catena, A., Di Stasi, L. L., Serrano, J., & Cándido, A. (2011). Modulation of attention and urgent decisions by affect-laden roadside advertisement in risky driving scenarios. *Safety Science*, *49*(10), 1388–1393. https://doi.org/10.1016/j.ssci.2011.06.001

Mendelovici, A. (2013). Intentionalism about Moods. *Thought: A Journal of Philosophy*, *2*(2), 126–136. https://doi.org/10.1002/tht3.81

Merchán-Clavellino, A., Ramón, J., -Bailén, A., Zayas García, A., & Guil, R. (2019). Mediating effect of trait emotional intelligence between the behavioral activation system (BAS)/behavioral inhibition system (BIS) and positive and negative affect. *Frontiers in Psychology*, *10*(424). https://doi.org/10.3389/fpsyg.2019.00424

Mezquita, L., Ibáñez, M. I., Moya, J., Villa, H., & Ortet, G. (2014). A longitudinal examination of different etiological pathways to alcohol use and misuse. *Alcoholism: Clinical and Experimental Research*, *38*(6), 1770–1779. https://doi.org/10.1111/acer.12419

Michon, J. A. (1979). *Dealing with danger (Technical Report VK 79-01)*. http://jamichon.nl/jam_writings/1979_dealing_with_danger.pdf

Millon, T., & Davis, R. D. (1997). The MCMI-III: Present and future directions. *Journal of Personality Assessment*, *68*(1), 69–85. https://doi.org/10.1207/s15327752jpa6801

Morales, A. M., Boyd, S. J., Seghete, K. L. M., Johnson, A. J., De Bellis, M. D., & Nagel, &bonnie J. (2019). Sex differences in the effect of nucleus accumbens volume on adolescent drinking: The mediating role of sensation seeking in the NCANDA sample. *Journal of Studies on Alcohol and Drugs*, *80*, 594–601.

Moreno Padilla, M., O'Halloran, L., Bennett, M., Cao, Z., & Whelan, R. (2017). Impulsivity and reward processing endophenotypes in youth alcohol misuse. *Current Addiction Reports*, *4*(4), 350–363. https://doi.org/10.1007/s40429-017-0167-6

Morris, D. H., Treloar, H. R., Niculete, M. E., & Mccarthy, D. M. (2014). Perceived danger while intoxicated uniquely contributes to driving after drinking. *Alcoholism: Clinical and Experimental Research*, *38*(2), 521–528. https://doi.org/10.1111/acer.12252

Motschman, C. A., Hatz, L. E., McCarty, K. N., Merkle, E. C., Trull, T. J., & Mccarthy, D. M. (2020). Event-level predictors of alcohol-impaired driving intentions. *Journal of Studies on Alcohol and Drugs*, *81*(September), 647–654.

O'Halloran, L., Pennie, B., Jollans, L., Kiiski, H., Vahey, N., Rai, L., Bradley, L., Lalor, R., & Whelan, R. (2018). A combination of impulsivity subdomains predict alcohol intoxication frequency. *Alcoholism: Clinical and Experimental Research*, *42*(8), 1530–1540. https://doi.org/10.1111/acer.13779

Okon-Singer, H., Hendler, T., Pessoa, L., & Shackman, A. J. (2015). The neurobiology of emotion-cognition interactions: Fundamental questions and strategies for future research. *Frontiers in Human Neuroscience*, *9*(February), 1–14. https://doi.org/10.3389/fnhum.2015.00058

Ouimet, M. C., Brown, T. G., Corado, L., Paquette, M., & Robertson, R. D. (2020). The effects of alcohol dose, exposure to an in-vehicle alcohol feedback device, and subjective responses to alcohol on the decision to drink-drive in young drivers. *Accident Analysis and Prevention*, *139*, 105495. https://doi.org/10.1016/j.aap.2020.105495

Paxton, R. J., Valois, R. F., Watkins, K. W., Huebner, E. S., & Drane, J. W. (2007). Associations between depressed mood and clusters of health risk behaviors. *American Journal of Health Behavior*, *31*(3), 272–283. https://doi.org/10.5993/AJHB.31.3.5

Perreault, S. (2016). Impaired driving in Canada, 2015. In *Juristat* (Issues 85-002–X). http://www.statcan.gc.ca/pub/85-002-x/2013001/article/11739-eng.htm#a4

Phelps, E. A., Lempert, K. M., & Sokol-Hessner, P. (2014). Emotion and decision making: Multiple modulatory neural circuits. *Annual Review of Neuroscience*, *37*, 263–287. https://doi.org/10.1146/annurev-neuro-071013-014119

Phillips, D. P., Sousa, A. L. R., & Moshfegh, R. T. (2014). Official blame for drivers with very low blood alcohol content: There is no safe combination of drinking and driving. *Injury Prevention*, *3*, 1–8. https://doi.org/10.1136/injuryprev-2013-040925

Potard, C., Kubiszewski, V., Camus, G., Courtois, R., & Gaymard, S. (2018). Driving under the influence of alcohol and perceived invulnerability among young adults: An extension of the theory of planned behavior. *Transportation Research Part F: Traffic Psychology and Behaviour*, *55*, 38–46. https://doi.org/10.1016/j.trf.2018.02.033

Reason, J., Manstead, A., Stradling, S., Baxter, J., & Campbell, K. (1990). Errors and violations on the roads: A real distinction? *Ergonomics*, *33*(10–11), 1315–1332.

https://doi.org/10.1080/00140139008925335

Rezaee-zavareh, M. S., Salamati, P., Ramezani-binabaj, M., & Saeidnejad, M. (2017). Alcohol consumption for simulated driving performance: A systematic review. *Chinese Journal of Traumatology*, *20*(3), 166–172. https://doi.org/10.1016/j.cjtee.2017.04.002

Rizer, C. A., & Lusk, M. D. (2017). Screening and initial management of alcohol misuse in primary care. *The Journal for Nurse Practitioners*, *13*(10), 660–666. https://doi.org/https://doi.org/10.1016/j.nurpra.2017.08.011

Roidl, E., Siebert, F. W., Oehl, M., & Höger, R. (2013). Introducing a multivariate model for predicting driving performance: The role of driving anger and personal characteristics. *Journal of Safety Research*, *47*, 47–56. https://doi.org/10.1016/j.jsr.2013.08.002

Salgado, S., & Kaplitt, M. G. (2015). The nucleus accumbens: A comprehensive review. *Stereotactic and Functional Neurosurgery*, *93*, 75–93. https://doi.org/10.1159/000368279

Schnabel, E. (2011). *Alcohol and driving-related performance: A comprehensive meta-analysis focusing the significance of the non-significant* [Julius Maximilian University of Würzburg]. http://hdl.handle.net/20.500.12424/1059913

Scott-Parker, B., Watson, B., King, M. J., & Hyde, M. K. (2012). The influence of sensitivity to reward and punishment, propensity for sensation seeking, depression, and anxiety on the risky behaviour of novice drivers: A path model. *British Journal of Psychology*, *103*(2), 248–267. https://doi.org/10.1111/j.2044-8295.2011.02069.x

Scott-Parker, B., & Weston, L. (2017). Sensitivity to reward and risky driving, risky decision making, and risky health behaviour: A literature review. *Transportation Research Part F: Traffic Psychology and Behaviour*, *49*, 93–109. https://doi.org/10.1016/j.trf.2017.05.008

Shakra, M. A., Leyton, M., Moghnieh, H., Pruessner, J., Dagher, A., & Pihl, R. (2018).

Neurobiological correlates and predictors of two distinct personality trait pathways to escalated alcohol use. *EBioMedicine*, *27*, 86–93. https://doi.org/10.1016/j.ebiom.2017.11.025

Singh, S. (2018). *Critical reasons for crashes investigated in the National Motor Vehicle Crash Causation Survey. (Traffic Safety Facts Crash•Stats. Report No. DOT HS 812 506)*.

Smorti, M. (2014). Sensation seeking and self-efficacy effect on adolescents risky driving and substance abuse. *Procedia: Social and Behavioral Sciences*, *140*, 638–642. https://doi.org/10.1016/j.sbspro.2014.04.484

Starkey, N. J., & Charlton, S. G. (2014). The effects of moderate alcohol concentrations on driving and cognitive performance during ascending and descending blood alcohol concentrations. *Human Psychopharmacology*, *29*(4), 370–383. https://doi.org/10.1002/hup.2415

Starkey, N. J., & Isler, R. B. (2016). The role of executive function, personality and attitudes to risks in explaining self-reported driving behaviour in adolescent and adult male drivers. *Transportation Research Part F: Traffic Psychology and Behaviour*, *38*, 127–136. https://doi.org/10.1016/j.trf.2016.01.013

Stephens, A. N., Bishop, C. A., Liu, S., & Fitzharris, M. (2017). Alcohol consumption patterns and attitudes toward drink-drive behaviours and road safety enforcement strategies. *Accident Analysis and Prevention*, *98*, 241–251. https://doi.org/10.1016/j.aap.2016.10.011

Stoduto, G., Dill, P., Mann, R. E., Wells-Parker, E., Toneatto, T., & Shuggi, R. (2008). Examining the link between drinking-driving and depressed mood. *Journal of Studies on Alcohol and Drugs*, *69*(5), 777–780. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=psyc6&NEWS=N&A

N=2008-18392-018

Suhr, J. A., & Tsanadis, J. (2007). Affect and personality correlates of the Iowa Gambling Task. *Personality and Individual Differences*, *43*(1), 27–36. https://doi.org/10.1016/j.paid.2006.11.004

Szuhany, K. L., Mackenzie, D., & Otto, M. W. (2018). The impact of depressed mood, working memory capacity, and priming on delay discounting. *Journal of Behavior Therapy and Experimental Psychiatry*, *60*, 37–41. https://doi.org/10.1016/j.jbtep.2018.03.001

Taylor, B., Irving, H. M., Kanteres, F., Room, R., Borges, G., Cherpitel, C., Greenfield, T., & Rehm, J. (2010). The more you drink, the harder you fall: A systematic review and meta-analysis of how acute alcohol consumption and injury or collision risk increase together. *Drug and Alcohol Dependence*, *110*(1–2), 108–116. https://doi.org/10.1016/j.drugalcdep.2010.02.011

Testa, C. R., & Steinberg, L. (2010). Depressive symptoms and health-related risk-taking in adolescence. *Suicide and Life-Threatening Behavior*, *40*(3), 298–305.

Topuzoğlu, A., Binbay, T., Ulaş, H., Elbi, H., Aksu Tanik, F., Zaıli, N., & Alptekin, K. (2015). The epidemiology of major depressive disorder and subthreshold depression in Izmir, Turkey: Prevalence, socioeconomic differences, impairment and help-seeking. *Journal of Affective Disorders*, *181*, 78–86. https://doi.org/10.1016/j.jad.2015.04.017

Van Skike, C. E., Goodlett, C., Matthews, D. B., & Matthews, D. B. (2019). Acute alcohol and cognition: Remembering what it causes us to forget. *Alcohol*, *79*, 105–125. https://doi.org/10.1016/j.alcohol.2019.03.006

Vaughn, M. G., & King, K. M. (2016). Premeditation and sensation seeking moderate the reasoned action and social reaction pathways in the prototype/willingness model of alcohol use. *Substance Use & Misuse*, *51*(6), 711–721.

https://doi.org/10.3109/10826084.2016.1152500

Vingilis, E., Mann, R. E., Erickson, P., Toplak, M., Kolla, N. J., Seeley, J., & Jain, U. (2014). Attention deficit hyperactivity disorder, other mental health problems, substance use, and driving: Examination of a population-based, representative Canadian sample. *Traffic Injury Prevention*, *15*(sup1), S1–S9. https://doi.org/10.1080/15389588.2014.926341

Vissers, L., Houwing, S., & Wegman, F. (2018). *Alcohol-related road casualties in official crash statistics*. https://www.itf-oecd.org/alcohol-related-road-casualties-official-crash-statistics

Volkow, N. D., Wiers, C. E., Shokri-Kojori, E., Tomasi, D., Wang, G.-J., & Baler, R. (2017). Neurochemical and metabolic effects of acute and chronic alcohol in the human brain: Studies with positron emission tomography. *Neuropharmacology Journal*, *122*, 175–188. https://doi.org/10.1016/j.neuropharm.2017.01.012

Wager, T. D., Kang, J., Johnson, J. D., Nichols, T. E., Satpute, A. B., & Barrett, L. F. (2015). A Bayesian model of category-specific emotional brain responses. *PLoS Computational Biology*, *11*(4), 1004066. https://doi.org/10.1371/journal.pcbi.1004066

Wan, Z., Rolls, E. T., Cheng, W., & Feng, J. (2020). Sensation-seeking is related to functional connectivities of the medial orbitofrontal cortex with the anterior cingulate cortex. *NeuroImage*, *215*(116845). https://doi.org/10.1016/j.neuroimage.2020.116845

Weafer, J., & Fillmore, M. T. (2012). Acute tolerance to alcohol impairment of behavioral and cognitive mechanisms related to driving: Drinking and driving on the descending limb. *Psychopharmacology*, *220*(4), 697–706. https://doi.org/10.1007/s00213-011-2519-6

Wells-Parker, E., Mann, R. E., Dill, P. L., Stoduto, G., Shuggi, R., & Cross, G. W. (2009). Negative affect and drinking drivers: A review and conceptual model linking dissonance, efficacy and negative affect to risk and motivation for change. *Current Drug*

*Abuse Reviews*, *2*, 115–126. https://crepuq.vdxhost.com/zportal/zengine?VDXaction=DocFetch&docfetch_seencopyright=true&docfetch_key=0d670000787bd000&docfetch_user=mVbIQ3yu&docfetch_password=xPoGahRo

Wester, A. E., Verster, J. C., Volkerts, E. R., Böcker, K. B. E., & Kenemans, J. L. (2010). Effects of alcohol on attention orienting and dual-task performance during simulated driving: An event-related potential study. *Journal of Psychopharmacology*, *24*(9), 1333–1348. https://doi.org/10.1177/0269881109348168

World Health Organization. (2018). *Global status report on road safety 2018*. https://doi.org/10.22201/fq.18708404e.2004.3.66178

World Health Organization. (2020). *Global health estimates 2020: Disease burden by cause, age, sex, by country and by region, 2000-2019*.

Yadav, A. K., Khanuja, R. K., & Velaga, N. R. (2020). Gender differences in driving control of young alcohol-impaired drivers. *Drug and Alcohol Dependence*, *213*, 1–7. https://doi.org/10.1016/j.drugalcdep.2020.108075

Zhang, Y., & Sloan, F. A. (2014). Depression, alcohol dependence and abuse, and drinking and driving behavior. *Journal of Behavioral Health*, *3*(4), 212–219. https://doi.org/10.5455/jbh.20141115011440

Zuckerman, M. (1994). *Behavioral expressions and biosocial bases of sensation seeking*. Cambridge University Press.

Zuckerman, M. (2007a). The sensation seeking scale V (SSS-V): Still reliable and valid. *Personality and Individual Differences*, *43*, 1303–1305. https://doi.org/10.1016/j.paid.2007.03.021

Zuckerman, M. (2007b). Sensation seeking and risky driving, sports, and vocations. In *Sensation seeking and risky behavior* (pp. 73–106). American Psychological

Association. https://doi.org/10.1037/11555-003

# Chapter 2: Manuscript 1 – The Effects of Depressed Mood and 0.05% Blood Alcohol Concentration on Risky Driving in Males

Case, Nevicia F.[1,2]. Brown, Thomas G.[1,2].

[1]Department of Psychiatry, McGill University, Montreal, QC, Canada

[2]Addiction Research Program, Research Centre of the Douglas Mental Health, University Institute, Montreal, QC, Canada

Correspondence: Thomas Brown, Department of Psychiatry, McGill University, Douglas Mental Health University Institute, 6875 LaSalle Boulevard, Verdun, Montreal, Quebec H4H 1R3, Canada

Email: thomas.brown@mcgill.ca

## Abstract

Males are more likely than females to use alcohol as a maladaptive coping mechanism to alleviate symptoms of depressed mood. The effects of a combination of subclinical depressed mood and doses of alcohol below the *per se* legal threshold of 0.08% blood alcohol concentration (BAC) on risky driving are unclear, however. This manuscript presents a quasi-experimental, between-subjects study testing the influence of combined subclinical depressed mood and 0.05% BAC on risky driving in a simulator and the mediation of decision-making. Following assessment of depressed mood (Beck Depression Inventory-II), a double-blinded protocol was used to randomise participants and administer either an alcohol (0.05% BAC) or a placebo (0.00% BAC) beverage. The Iowa Gambling Task tested decision-making and participants indicated whether they would decide to drive in the simulator. Driving simulation measured risky driving in real-time. Participants were healthy male drivers ($n$ = 57; age $M$ = 38.2, $SD$ = 7.5). Using ANOVA, there were non-significant group differences in risky driving. Logistic regression revealed non-significant effects between groups in predicting the decision to drive. Mediation regression was used to explore the underlying mechanisms of decision-making on the prediction of risky driving under depressed mood. However, decision-making under risk was only identified as a significant predictor of mean merge acceleration on the highway. In addition to the limited sample size, outcomes were likely impacted by the mediation of emotion regulation. As this research area remains promising, recommendations are highlighted. One of them includes the use of a measure of depressed mood that is more sensitive to externalising behavioural symptoms in males.

## Introduction

In Canada, there were estimated to be over 114,000 road traffic crash victims in 2018 (International Transport Forum, 2020). An overwhelming proportion of road traffic crashes arise from risky driving manoeuvres, such as speeding, tailgating, and crossing intersections during a yellow light (Joly & Bergeron, 1987). Engaging in one of these behaviours is also correlated with engaging in other risky driving behaviours, giving rise to what has been referred to as a risky driving syndrome (Jonah & Boase, 2017). In preventing risky driving, the decision to drive in a high-risk context represents an important point of intervention and it is, thus, important to understand the factors that contribute to this perilous decision. Male drivers represent an important subgroup of focus for the prevention of road crashes as they are three times as likely to engage in risky driving and be deemed at-fault in road traffic crashes (Paaver et al., 2013). The focus of this study is on risky driving behaviours and the decision to drive among male drivers in the general population who: (a) experience depressed mood symptoms that fall below the threshold for clinical diagnosis and (b) engage in risky driving while below the 0.08% BAC *per se* legal threshold for DWI that is recognised in Canada.

### *Risky driving*

Depressed mood has been identified as an important predictor of risky driving (Scott-Parker et al., 2012). Furthermore, the relationship between depressed mood and risky driving is even more pronounced among male drivers (Scott-Parker et al., 2012). Numerous studies support the contributions of depressed mood to risky driving (Dill et al., 2007; Hilton et al., 2009; McDonald et al., 2014; Paxton et al., 2007; Scott-Parker et al., 2012; Stoduto et al., 2008; Testa & Steinberg, 2010). However, many of these studies report findings on mixed samples that also include participants with clinical diagnoses of depression, anxiety symptoms, and individuals who engage in other non-driving risk-taking behaviours.

One study which used the General Health Questionnaire-12 (Goldberg & Hillier, 1979) as a measure of both depressed mood and anxiety symptoms found that scores on this questionnaire did not significantly predict risky driving (Vingilis et al., 2014), however, the effects of depressed mood alone are unclear from these findings. Although the literature includes samples with depressed mood symptoms that fall below the clinical threshold for depression, they do not distinguish it from depressed mood symptoms that may be part of clinical diagnoses (McDonald et al., 2014; Scott-Parker et al., 2012; Testa & Steinberg, 2010; Vingilis et al., 2014) despite the importance of understanding any potential effects of depressed mood within the general population. Therefore, it is unclear if and how depressed mood below clinical thresholds affects risky driving and the decision to drive.

One way that depressed mood may increase risky driving among males is through increased alcohol use (Cyders et al., 2016). The direct effects of alcohol use on risky driving have also been extensively researched (Martin et al., 2013). The *per se* legal threshold of 0.08% BAC that is used in North American jurisdictions is the highest in the world. Jurisdictions such as Australia and many European countries have enforced a *per se* legal threshold of 0.05% BAC (World Health Organization, 2018a). However, even at 0.05% BAC, the risk of single-vehicle crash fatality is seven times higher than that of a sober driver (Fell & Voas, 2014). In simulated driving studies, drivers at 0.05% BAC have significantly greater mean speed and SDLP than sober drivers (Martin et al., 2013; Meda et al., 2009; Rezaee-zavareh et al., 2017). This is likely due, in part, to impairments in attention, cognitive control, and psychomotor function that have been observed at BACs ≤ 0.05% (Anderson et al., 2011; Schnabel, 2011; Wester et al., 2010). With the dangers of driving at 0.05% BAC already established, it is likely that this risk is even further elevated when experienced in combination with a depressed mood.

Although depressed mood is twice as prevalent among females (Bromet et al., 2011), males with depressed mood are more likely to employ maladaptive coping mechanisms, such as alcohol use, in an effort to attenuate their symptoms (Cyders et al., 2016; Khan et al., 2018; Mezquita et al., 2014). It is quite likely that the co-occurrence of depressed mood and 0.05% BAC in males may even further exacerbate risky driving (Carroll & Rothe, 2014). However, no studies have examined this relationship. Examining how they affect the neuropsychological functions that are critical for safe driving, such as decision-making (T. G. Brown et al., 2016; Ferrer et al., 2015; Lev et al., 2008; Szuhany et al., 2018), may further inform us on the underlying mechanisms at play.

Driving safely is dependent on optimal decision-making. Decision-making requires the functioning of several brain areas to gauge the value of stimuli and make a choice (Fellows, 2011). These areas include the ventromedial prefrontal cortex (PFC), dorsolateral PFC, insular cortex, anterior cingulate cortex, parietal cortices, thalamus, and caudate (Bechara et al., 1994; Fellows, 2011; Harris et al., 2011; Krain et al., 2006; Liljeström & Nazir, 2016). The process of decision-making, however, differs under conditions of risk and conditions of ambiguity (Bechara et al., 1994). Decision-making under risk refers to choices with known outcome probabilities (Bechara et al., 1994). In contrast, decision-making under ambiguity occurs when the outcome probabilities are unknown (Bechara et al., 1994). Decision-making under both of these conditions may be affected by depressed mood.

Advantageous decision-making under both risk and ambiguity are dependent, in part, on mood (Bechara, 2004; Bechara et al., 2000). In fact, the somatic marker hypothesis, which forms the theoretical basis of the IGT, was posited to argue for the critical role of emotion in decision-making (Bechara et al., 2000). Depressed mood, in particular, is associated with significantly greater delay discounting and greater reward-seeking (Ferrer et al., 2015; Szuhany et al., 2018). Delay discounting occurs when the subjective valuation of a smaller,

but immediate reward is greater than the subjective valuation of a larger, but delayed reward (McClure & Bickel, 2014). As many of the brain areas that support advantageous decision-making are impacted by depressed mood (Lyvers et al., 2015; Szuhany et al., 2018), decision-making may represent an important underlying mechanism through which depressed mood affects risky driving neuropsychologically.

### *Decision to Drive in a High-risk Context*

The decision to drive in a high-risk context is a broader construct than the neuropsychology of decision-making. The decision to drive is influenced by a wide range of factors, including social norms and the accessibility of alternative modes of transportation (Ouimet et al., 2020). The decision to drive often first occurs prior to driving to the drinking establishment (i.e., while sober; Stephens et al., 2017) and then after drinking (i.e., while the BAC is still above 0.00% BAC; Marczinski & Fillmore, 2009; Weafer & Fillmore, 2012). In other words, an individual's decision to drive their vehicle to a bar, for example, is a necessary condition for their subsequent decision to drive their vehicle home after drinking.

Depressed mood may make it more difficult for individuals to seek alternatives to deciding to drive. It has been demonstrated that individuals with a clinical diagnosis of depression and poor mental health are less likely to employ the use of protective behavioural strategies, such as soliciting a designated driver (Labrie et al., 2010; Zhang & Sloan, 2014). As soliciting a designated driver requires social interaction, individuals with a depressed mood who often experience social withdrawal, may instead resort to deciding to drive in a high-risk context (Zhang & Sloan, 2014). The acute effects of alcohol may add another layer of complexity to this relationship.

The effects of alcohol use on the decision to drive occur exclusively at the second timepoint (i.e., after drinking). The BAC curve ascends during a drinking episode and subsequently descends after the episode has ended (Starkey & Charlton, 2014). Acute

tolerance to alcohol has been observed as low as 0.065% BAC on the descending limb. That is, individuals experience a perilous combination of lower subjective intoxication and lower perceived danger (Amlung et al., 2014; Marczinski & Fillmore, 2009; Motschman, Hatz, et al., 2020; Weafer & Fillmore, 2012). It is under these conditions during this descending limb of the BAC curve when the decision to drive is often made. To our knowledge, no studies have examined the decision to drive in individuals at 0.05% BAC.

Drawing from the above literature, it is possible that when individuals are under the effects of both depressed mood and 0.05% BAC, acute tolerance to alcohol minimises the perceived need for alternatives to the decision to drive, such as soliciting a designated driver. Individuals are likely, therefore, more inclined to decide to drive. This study is the first to explore the effects of both depressed mood and 0.05% BAC on the decision to drive.

***Rationale***

The above literature highlights the existing literature on the role of depressed mood in risky driving, but does not inform on the effects of depressed mood below the clinical threshold for diagnosis specifically. Furthermore, it remains unclear how the combined effects of depressed mood and 0.05% BAC may affect risky driving. The potential effects of either depressed mood or 0.05% BAC are even less understood in relation to the decision to drive.

In response to these gaps, this study examines the combined contributions of depressed mood and 0.05% BAC to risky driving and to the decision to drive in a high-risk context. It also explores decision-making as a neuropsychological function that may be an underlying mechanism of the contributions of depressed mood to risky driving. There is a paucity of traffic safety research on depressed mood in non-clinical samples. Furthermore, none of the existing studies on depressed mood employs a driving simulator to measure risky driving. Despite the greater tendency for males to drink while in a depressed mood and their

greater risk on the road, no studies have determined how the combination of depressed mood and alcohol may contribute to both risky driving and the decision to drive. With its quasi-experimental, double-blinded, placebo-controlled, between-subjects design, this study, therefore, aims to fill several gaps in the literature:

- the isolated effects of depressed mood on simulated driving,
- the combined effects of depressed mood and 0.05% BAC on simulated driving,
- the combined effects of depressed mood and 0.05% BAC on the decision to drive, and
- the underlying neuropsychological mechanisms of the isolated effects of depressed mood on simulated driving.

***Hypotheses***

As shown in **Figure 2-1**, this study hypotheses:

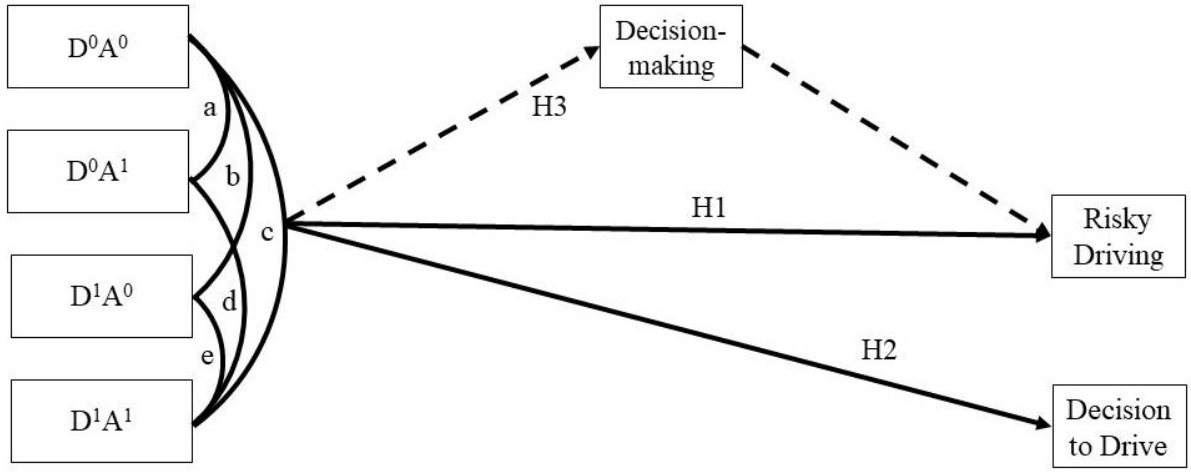
1. Risky driving
    a. under placebo beverage, depressed mood participants ($D^1A^0$) have higher risky driving scores than non-depressed mood participants ($D^0A^0$);
    b. under non-depressed mood, alcohol participants ($D^0A^1$) have higher risky driving scores than placebo participants ($D^0A^0$);
    c. depressed mood and alcohol beverage participants ($D^1A^1$) have higher risky driving scores than non-depressed mood and placebo beverage participants ($D^0A^0$);
    d. under depressed mood, alcohol beverage participants ($D^1A^1$) have higher risky driving scores than placebo beverage participants ($D^1A^0$); and
    e. under alcohol, depressed mood participants ($D^1A^1$) have higher risky driving scores than non-depressed mood participants ($D^0A^1$).
2. Decision to drive

a. under placebo beverage, depressed mood participants ($D^1A^0$) decide to drive more frequently than non-depressed mood participants ($D^0A^0$);
b. under non-depressed mood, alcohol participants ($D^0A^1$) decide to drive more frequently than placebo participants ($D^0A^0$);
c. depressed mood and alcohol beverage participants ($D^1A^1$) decide to drive more frequently than non-depressed mood and placebo beverage participants ($D^0A^0$);
d. under depressed mood, alcohol beverage participants ($D^1A^1$) decide to drive more frequently than placebo beverage participants ($D^1A^0$); and
e. under alcohol, depressed mood participants ($D^1A^1$) decide to drive more frequently than non-depressed mood participants ($D^0A^1$).

3. As an exploratory hypothesis, decision-making processes mediate the relationship between depressed mood and risky driving scores, whereby lower IGT scores for decision-making under ambiguity and risk partially predict variance in risky driving.

**Figure 2-1.**

*Schematic of hypotheses, H1-H3.*




## Methods

### *Participants*

Males age 24-50 were recruited to take part in a larger study on decision-making in drivers with convictions of driving while intoxicated by alcohol and drivers without any such conviction (healthy controls). Healthy controls were the group of interest in the present study and were recruited via advertisements in regular, free-press, and university newspapers in Montreal. Inclusion criteria were: i) male sex; ii) age 24-50 years; iii) had experience of Québec-licensed driving in the past 3 months; iv) self-reported drinking on a regular basis over the past 3 months; and v) psychoactive medication free. Exclusion criteria were: i) currently trying to stop drinking either on their own or with treatment for alcohol use disorder; ii) simulation sickness during the practice simulation session; iii) less than Grade 6 education; iv) having had any medical condition or treatment with a contraindication for study participation (i.e., chronic medical illness, psychiatric illness, intellectual deficiency, developmental disorder, alcohol-induced discomfort, or other source of physical/psychological distress).

### *Screening and Consent*

Telephone screening verified that inclusion/exclusion criteria were met before inviting the candidates to the lab. In-person screening of the study candidates' driver's licenses was done to verify their validity and the candidates' age. Finally, after receiving both a verbal and written explanation of the study and an opportunity to ask questions, all study candidates were provided the opportunity for informed consent.

### *Measures*

**BDI-II.** The BDI-II (Beck et al., 1996) is a self-report questionnaire used for assessing depressive symptoms in alignment with DSM-IV criteria. Consisting of 21 items, the BDI-II takes approximately 5-10 minutes to complete. Total scores of 0-13 suggest the presence of minimal depressed mood (below the clinical threshold) and scores ≥ 14 suggest the presence of mild, moderate, or severe depressed mood (above the clinical threshold). Importantly, the BDI-II has strong sensitivities of 0.70-0.87 in non-clinical samples, even when using threshold scores as low as 10 (Y.-P. Wang & Gorenstein, 2013). Notably, however, non-clinical samples typically consisted of university-recruited student samples and school-based adolescent samples as opposed to adult samples. Factor analyses of the BDI-II in adult and community-based non-clinical samples indicated that scores were most strongly guided by cognitive-affective symptoms. There was also strong construct validity of the cognitive-affective symptoms, indicating that they relate strongly to measures of theory-driven constructs. Furthermore, the BDI-II is not exempt from the common overlap between depressive and anxiety symptoms that is often found due to symptomatic co-occurrence (Y.-P. Wang & Gorenstein, 2013). Therefore, while caution should be used in the interpretation of BDI-II scores, particularly in relation to overlapping anxiety symptoms, the BDI-II provides an assessment that is highly sensitive to the cognitive-affective symptoms of depressed mood in adult and community non-clinical samples.

**IGT.** The IGT, a card game designed to measure decision-making, provided an integrated assessment of executive function by assessing the emotional aspects of decision-making purported by the emotional/motivational network (Buelow & Suhr, 2009). A computerised version of the IGT-ABCD version (Bechara et al., 1994) assessed baseline decision-making. Participants were asked to select one card at a time from 4 decks of cards. The goal was to earn as much play money as possible. Each deck was associated with a different proportion of wins and losses that was unknown to the participant. In this way, Decks A and B were "disadvantageous" to the goal of the game and Decks C and D were "advantageous". A total net score on the IGT was calculated as the number of cards selected from Decks A and B subtracted from the number of cards selected from Decks C and D. Lower net scores were indicative of poorer decision-making.

The IGT can also be divided into ambiguity and risk scores. Since participants were initially unaware of which decks were advantageous or disadvantageous, the first 40 card selections were indicative of decision-making under ambiguity. Performance on the remaining 60 card selections measured decision-making under risk. As there is evidence that IGT ambiguity scores are predictive of risky driving (Bouchard et al., 2012) and IGT risk scores are reflective of executive functioning (Gansler et al., 2011), both scores were included in the statistical analyses as measures of decision-making.

The repeated use of the IGT-ABCD version in repeated-measures study designs has been cautioned due to practice effects and a general paucity of data on its temporal reliability (Verdejo-Garcia et al., 2006). Therefore, the additional use of a parallel version, IGT-KLMN, provided a reliable measure of post-manipulation decision-making (Verdejo-Garcia et al., 2006). The IGT-KLMN is more difficult than the IGT-ABCD to account for practice effects (Verdejo-Garcia et al., 2006). It uses the same scoring as the IGT-ABCD.

**Decision to Drive.** This study extends the more commonly used experimental methods of self-report by first using a scripted scenario which is then followed by a dichotomous question on the decision to drive while intoxicated by alcohol. The scenario and question are first provided to participants while sober (Decision to Drive Scenario 1) and then again while under acute alcohol/placebo (Decision to Drive Scenario 2). This is a quick (≈ 4 minutes total) way of assessing the decision to drive at both timepoints.

In Decision to Drive Scenario 1, participants were presented with a contingency scenario to which they were asked to respond indicating whether or not they were willing to drive in the simulator after drinking a beverage that could have impaired them. They were told that if they decided not to drive, they would receive the same $25 in remuneration to which they initially consented at the onset of their participation in the study. If they decided to drive and did not have any crashes or violations, they would receive an additional $25 for a total of $50. If they decided to drive and did have any crashes or violations, they would receive $25 less for a total of $0. The scenario was intended to mimic real-world situations with their associated contingencies (i.e., decisions involving both risk and reward) that often influence the decision to drive while possibly impaired by alcohol. Regardless of the participant's response to the contingency scenario, they were invited to drive the simulator.

For the Decision to Drive Scenario 2, participants were presented with an opportunity to reconsider the decision they made previously. Responses were recorded, but all participants were asked to drive in the simulator again. Regardless of their performance in the driving simulator, all participants received $50 in remuneration at the end of the study (total of $210 for completion of the full parent study).

**Driving Simulation.** Driving simulation is used as a method of risky driving in this study as it provides a safe environment for drivers to engage in risky driving, particularly

under the effects of alcohol. It also allows for a high degree of experimental control and relative validity through the measurement of different aspects of risky driving.

The driving simulation software and simulator used in this study were developed in partnership with Dr. Marie Claude Ouimet's lab at the University of Sherbrooke. Participants sat in a vehicle seat in front of three 19-inch monitors with a steering wheel, accelerator, and brake pedals. The simulated environment was fully interactive, creating a naturalistic experience. Two driving scenarios were available: a rural scenario with highways and an urban scenario with city streets. The order in which each participant completed the two scenarios was counterbalanced. Participants were instructed to drive normally in both rural and urban scenarios. The simulation task took approximately 25 minutes to complete in total.

Data corresponding with several risky driving variables were collected, including speed deviation, mean speed, and speed change in response to another car merging. Speed deviation was measured by the position of the accelerator ranging from 0 to 1 throughout the full duration of both simulations. Mean speed was measured in km/h throughout the full duration of the highway scenario. Speed change in response to another car merging was measured by the position of the accelerator ranging from 0 to 1 in the highway simulation. Vehicle positioning was measured in centimetres between cars. Data on SDLP were unavailable due to a technical failure of the driving simulator.

***Procedure***

As shown in **Figure 2-2**, after participants consented to the study, baseline data were collected by Experimenter A regarding the following: AUDIT, Drug Use Disorders Identification Test (DUDIT; Berman et al., 2003), Alco-Sensor IV®, Alere Oratect® III, physical data (i.e., weight, height, and blood pressure), practice driving simulation, BDI-II, demographics, health questionnaire, Timeline Follow-back (Robinson et al., 2014), the IGT-ABCD, the Decision to Drive Scenario 1, the first driving simulation. The AUDIT and

DUDIT were administered first. The Alco-Sensor IV® with memory (AlcoPro®) was then used to screen for the presence of any alcohol. Individuals testing positive for alcohol were retested a second time 5 minutes later and then rescheduled if the second test was positive. Alere Oratect® III saliva screening tests were used to detect use of cannabis in the past 14 hours, amphetamine and methamphetamine use in the past 72 hours, cocaine use in the past 24 hours, and opiate use in the past 24-48 hours. Individuals testing positive for any drug were rescheduled. The participant's weight, height, and blood pressure were measured. A practice driving simulation session was conducted to detect whether the participant suffered simulation sickness and to minimise any potential practice effects on the simulation task. The BDI-II assessed the presence and severity of depression symptoms. A socio-demographics questionnaire collected information on age, ethnicity, level of education, socio-economic status, and legal history of major driving violations (e.g., driving while impaired, reckless driving, speeding, etc.). A health questionnaire assessed general health, the presence of various diseases, and the use of prescription and non-prescription medications. The Timeline Follow-back for cannabis (Robinson et al., 2014) was administered using BatterieQuest™ software and the interview audio was recorded to ensure accuracy. The Decision to Drive Scenario 1, the first driving simulation scenario (counterbalanced), and the IGT-ABCD were then administered. Participants were then randomised to receive either 0.00% BAC (placebo) or 0.05% BAC.

**Alcohol administration.** Blinded to the condition they were in, each participant received a beverage containing a volume of alcohol sufficient to produce either 0.00% BAC (placebo) or 0.05% BAC, depending on their random assignment. To ensure that Experimenter A also remained blind to the condition, all beverages were prepared by Experimenter B with a witness (another lab member who was not directly involved with the study) present to minimise human error. The placebo beverage contained a mixture of

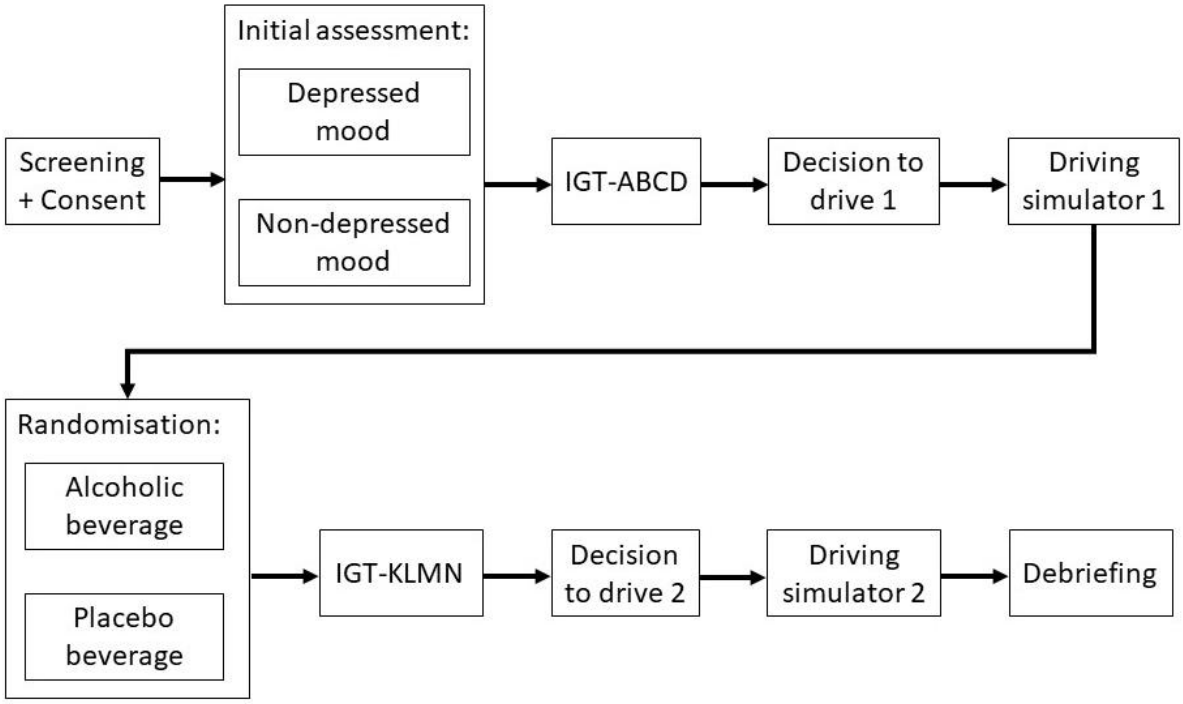
dealcoholised alcohol (e.g., rum extract), orange juice, and a trace of ethanol on the surface of the beverage to simulate the smell and taste of alcohol. The alcohol beverage contained a mixture of ethanol and orange juice intended for the participant to reach a BAC of 0.05% on the descending curve. The weight of ethanol in the alcohol beverage was calculated according to a formula derived from (H. R. Fisher et al., 1987; Watson et al., 1981) using the participant's sex and height information.

Regardless of alcohol condition, the first half of the beverage was consumed within 2 minutes and the second half was consumed within 6 minutes. After asking the participant to rinse their mouth twice with water to flush out any residual traces of alcohol remaining in their mouth, BAC was then tested every 5-10 minutes using the Alco-Sensor IV® for a total duration of approximately 40 minutes (for the $A^0$ conditions) or until the target BAC of ≈ 0.05% on the descending curve (for the $A^1$ conditions) had been achieved. The participant remained blind to the BAC reading on the Alco-Sensor IV®.

The manipulation took approximately 50 minutes. After this had been completed, Experimenter B left the room and Experimenter A returned to complete the remainder of the data-gathering protocol. The IGT-KLMN was then administered followed by the Decision to Drive Scenario 2, and the second driving simulation scenario (counterbalanced).

**Figure 2-2.**

*Manuscript 1 procedure.*




***Statistical Analyses***

Upon review of the grouped raw data, outlier values (+/-3 SD) were identified and adjusted to values just above or below the next most extreme score in the distribution. There were four participants in total with missing data; three of whom were missing all risky driving variables (due to recording loss) and one of whom was missing all socio-demographic variables. Since these data were determined to be missing at random, the cases were removed from the dataset. The final sample size was 57. Violations of linearity, normality, and homogeneity of variance were identified. As such, square root, log, inverse, and Box-Cox transformations were applied according to which fit the data best.

The first hypothesis employed one-way ANOVAs, which tested whether group differences in the means of risky driving variables (mean urban acceleration, mean highway acceleration, mean highway speed, and mean highway merge acceleration) differed significantly. Given the non-specificity of ANOVA as an omnibus test, significance was

determined from the results of planned comparisons, which were conducted regardless of the omnibus ANOVA results (J. Hsu, 1999). Importantly, causal inferences cannot be made from ANOVA. However, ANOVA is robust to small sample sizes in the presence of homogeneity of variance.

The second hypothesis tested how well group membership predicted participants' decision to drive by using logistic regression. Purposeful selection procedures were followed for the selection of covariate and confounding variables (Bursac et al., 2008). Logistic regression is useful for the prediction of dichotomous dependent variables, such as the decision to drive. It assumes linearity and the independence of observations.

For testing the exploratory third hypothesis, a mediated regression analysis was conducted to test whether depressed mood predicted risky driving and whether decision-making, as measured using IGT scores for ambiguity and risk, mediated this relationship as an underlying process. A strength of using mediated regression is that it is a causal model, however, the small sample size of participants in this study was likely insufficient to detect a mediation effect (Fritz & MacKinnon, 2007). As such, mediated regression was conducted as an exploratory analysis only.

Analyses were conducted using SPSS Statistics Subscription (IBM Corp., 2020) and followed by sensitivity analysis using G*Power 3.1 (Faul et al., 2007) to determine whether they were sufficiently powered to minimise Type II error. The PROCESS v3.5 macro for SPSS was additionally employed for the mediated regression analyses (Hayes, 2018).

**Results**

The socio-demographic data are presented in **Table 2-1**. Data for continuous scale variables are described using means and standard deviations and analysed for group differences using ANOVA. Data for categorical variables are reported using percentages and

analysed for group differences using Chi-square. No group differences on any of the socio-demographic variables were found.

***Group Differences in Risky Driving***

With participants randomised into one of four groups, Hypothesis 1 posited that group means on risky driving scores would differ as follows: (a) $D^1A^0 > D^0A^0$ [-1,1,0,0]; (b) $D^0A^1 > D^0A^0$ [-1,0,1,0]; (c) $D^1A^1 > D^0A^0$ [-1,0,0,1]; (d) $D^1A^1 > D^1A^0$ [0,1,0,-1]; and (e) $D^1A^1 > D^0A^1$ [0,0,-1,1]. Results of the omnibus ANOVAs revealed that the differences between groups on each of the risky driving variables – mean urban acceleration, $F(3,53) = 0.52$, $p = .670$, mean highway acceleration, $F(3,53) = 0.77$, $p = .514$, mean highway speed, $F(3,53) = 0.77$, $p = .518$, and mean highway merge acceleration, $F(3,53) = 0.24$, $p = .868$ – were non-significant (**Table 2-2**). Despite these non-significant results, planned comparisons were still conducted to test the hypotheses. The effect sizes of the planned comparisons (**Table 2-3**) were small for mean urban acceleration ($d = -0.19 – 0.35$), small-medium for mean highway acceleration ($d = -0.51 – 0.22$), medium for mean highway speed ($d = 0.54 – 0.49$), and small for mean highway merge acceleration ($d = -0.28 – 0.11$). More specifically, the medium effect sizes in mean highway acceleration were found in contrasts $D^0A^1 > D^0A^0$ [-1,0,1,0] ($d = -.51$) and $D^1A^1 > D^0A^0$ [-1,0,0,1] ($d = -.43$). The medium effect sizes in mean highway speed were found in contrasts $D^1A^1 > D^0A^0$ [-1,0,0,1] ($d = .49$) and $D^1A^1 > D^1A^0$ [0,1,0,-1] ($d = .54$). A sensitivity analysis determined that large effect sizes ($d = 1.14$) were required.

***Group Differences in the Decision to Drive***

Hypothesis 2 posited that the assigned conditions would predict the decision to drive as follows: (a) $D^1A^0 > D^0A^0$ [-1,1,0,0]; (b) $D^0A^1 > D^0A^0$ [-1,0,1,0]; (c) $D^1A^1 > D^0A^0$ [-1,0,0,1]; (d) $D^1A^1 > D^1A^0$ [0,-1,0,1]; and (e) $D^1A^1 > D^0A^1$ [0,0,-1,1]. There were 7 (53.9%) participants in the $D^0A^0$ group, 6 (40.0%) participants in the $D^1A^0$ group, 11 (57.9%) participants in the $D^0A^1$ group, and 5 (50.0%) participants in the $D^1A^1$ group who decided to

drive. Following purposeful selection, age was retained as a covariate. In Model 1, age predicted 8.8% (Nagelkerke $R^2$) of the variance in the decision to drive and correctly predicted 59.6% of cases, $X^2$ (1, $N$ = 57) = 1.08, $p$ = .056. The final logistic regression model, Model 2, predicted 11.3% (Nagelkerke $R^2$) of the variance in decision to drive outcomes and also correctly classified 59.6% of cases. Compared to the $D^0A^0$ condition, the $D^1A^0$ condition (odds ratio [*OR*] = 0.59, 95% confidence interval [*CI*] = [0.13, 2.80]), the $D^0A^1$ condition (*OR* = 1.23, 95% *CI* = [0.29, 5.63]), and the $D^1A^1$ condition (*OR* = 0.00, 95% *CI* = [0.18, 5.42]) did not significantly increase the likelihood of making the decision to drive. The $D^1A^1$ condition was also a non-significant predictor of increased likelihood in the decision to drive when compared to the $D^1A^0$ condition (*OR* = 0.60, 95% *CI* = [0.11, 3.15]) and the $D^0A^1$ condition (*OR* = 1.30, 95% *CI* = [0.27, 6.33]), $X^2$ (3, $N$ = 57) = 1.14, $p$ = .768. These results are summarised in **Table 2-4**.

***Decision-making as a Mediator in the Prediction of Risky Driving***

Hypothesis 3 was exploratory and used mediated regression to test whether decision-making, as measured with IGT scores, would mediate depressed mood's prediction of risky driving. The results did not identify depressed mood as a significant predictor of mean urban acceleration ($B$ = -0.04, $t$ = -0.92, $p$ = 0.363), mean highway acceleration ($B$ = -0.08, $t$ = -0.27, $p$ = 0.787), mean highway speed ($B$ = 2.79, $t$ = 0.85, $p$ = 0.401), or mean highway merge acceleration ($B$ = -0.02, $t$ = -0.65, $p$ = 0.512).

Direct effects and indirect effects for each path are summarised in **Table 2-5** and visually represented in **Figure 2-3**. Only decision-making under risk, $B$ = 0.01, $t$ = 2.83, $p$ = .007, was a significant predictor of mean merge acceleration on the highway, $R^2$ = 0.30, $F$(4,52) = 5.50, $p$ < .001. None of the other direct or indirect effects on any of the risky driving variables were statistically significant.

## Discussion

Male drivers have been identified as high-risk drivers, but less is known about the factors that contribute to their increased risk or the levels of severity at which these factors must be present to exert their effects on risky driving. Males are more likely to experience a dangerous combination of depressed mood and alcohol use, both of which are independent predictors of risky driving, but haven't been investigated for their combined risk potential. This study addresses these gaps by exploring the combined effects of subclinical depressed mood and 0.05% BAC on male drivers' decision-to-drive and risky driving in a simulator.

Hypothesis 1 stated that the $D^1A^1$ group would display the greatest risky driving compared to all other groups, followed by the $D^1A^0$ and $D^0A^1$ groups each exhibiting greater risky driving than the $D^0A^0$ group. Contrary to Hypothesis 1, results of the ANOVAs and planned comparisons did not show any differences between groups on any of the risky driving variables. However, the medium effect sizes found for mean highway acceleration and mean highway speed suggest that these variables should be further examined in future studies. Since the existing literature on depressed mood below the clinical threshold in risky driving is nascent, more targeted measures of depressed mood in males may produce more robust findings. As there is both bottom-up and top-down processing between limbic and prefrontal networks, depressed mood and risky driving may furthermore be mediated by emotion regulation. This may be particularly true for men, as the literature suggests that men may recruit more maladaptive emotion regulation strategies, such as risky driving, than do women (Šeibokaitė et al., 2017). Moreover, despite the wide use of the BDI-II as a measure of depressed mood and its alignment with DSM-IV-TR symptoms, its items are limited to capturing cognitive, affective, and somatic symptoms. Depressed mood in men, however, – particularly those who strongly conform to masculine norms – is often associated with exhibiting externalising behaviours, such as greater alcohol use and risky driving (Rice et al.,

2013). Furthermore, the symptoms measured by the BDI-II overlap with anxiety symptoms, limiting its discriminant validity as a measure of depressed mood (Y.-P. Wang & Gorenstein, 2013). While this may explain the null findings in this study related to depressed mood, the non-significant findings for 0.05% BAC are particularly surprising. Although much of the risky driving literature focuses on higher BACs that meet or exceed the legal *per se* threshold of 0.08% BAC, there is experimental evidence of alcohol's effects on risky driving as low as 0.02% BAC (Schnabel, 2011). As this study was composed of secondary analyses, its sample size was limited to a subset of participants who had been recruited for the parent study.

Hypothesis 2 posited that greater depressed mood and 0.05% BAC would predict a greater likelihood of making the decision to drive. However, results of the logistic regression, found that depressed mood and alcohol use were non-significant predictors of the decision to drive. The momentary subjective experience of acute alcohol intoxication may be a critical factor in the decision to drive since lower subjective intoxication, perceived danger, stimulation, and sedation have been demonstrated to predict a greater willingness to drive further distances (Motschman, Hatz, et al., 2020). Although tested at doses higher than 0.05% BAC (i.e., 0.06-0.10% BAC), evidence also supports that greater acute alcohol intoxication results in greater variability of the decision to drive, with these effects being more marked during the descending limb of the BAC curve (Motschman, Warner, et al., 2020). As the subjective effects of alcohol are less prominent on the descending limb, the likelihood of making the decision to drive while in a depressed mood and below the *per se* legal threshold for alcohol remains a promising focus for continued research. In addition to the limitations of relying on the BDI-II as discussed in relation to Hypothesis 1, logistic regression calls for larger sample sizes than what were available for this study (Hsieh, 1989). Analyses that are more suitable for use on small sample sizes, such as Fisher's exact test may have been more

effective for exploring the effects of depressed mood and 0.05% BAC on the decision to drive.

Hypothesis 3 was exploratory and used mediated regression to test decision-making processes as mediators of the effects of depressed mood on risky driving. Results did not support the role of depressed mood in predicting risky driving (Path A) or decision-making (Path B). Decision-making under risk significantly predicted mean merge acceleration on the highway. None of the other relationships in Path C were statistically significant. The mediated regressions, which included decision-making under ambiguity and risk as potential mediators, were non-significant. Criticisms of the IGT as a measure of decision-making, however, include an argument that performance on the IGT is confounded by reversal learning, an important function of the ventromedial PFC (Fellows, 2011). This criticism arose because, in order to score highly on the IGT, participants must overcome their preference for card selections that they developed at the onset of the game. In light of the much larger sample sizes required for mediated regression analyses (Fritz & MacKinnon, 2007), Hypothesis 3 was established as exploratory due to the limited sample size available.

The potential influence of emotion regulation on the combined effects of depressed mood and alcohol use on risky driving and the decision to drive may contribute to explaining the null findings in this study. In addition to emotion regulation's effects of the expression of depressed mood, a bidirectional relationship may also exist between emotion regulation and alcohol use, whereby alcohol itself may in some cases be used as a maladaptive strategy for emotion regulation (Cooper et al., 2015) and the effects of acute alcohol may, in turn, further deepen the emotion dysregulation (Euser & Franken, 2012). In line with these findings, the risky driving literature also suggests that while adaptive emotion regulation may optimise a driver's ability to remain calm and drive safely while in a depressed mood, a driver with the same depressed mood, but who has a maladaptive ability to regulate their emotions may

exhibit greater risky driving (Sani et al., 2017; Šeibokaitė et al., 2017; Trógolo et al., 2014). This may be particularly relevant for the prediction of risky driving among male drivers who exhibit externalising behaviours as symptoms of depressed mood. Further elaboration on the potential role of emotion regulation is provided in the General Discussion.

***Limitations***

Despite the strong rationale for having conducted this study in a lab setting and using a driving simulator, key differences remain between the lab environment and real-life drinking, deciding to drive, and risky driving. In this context, drinking often takes place socially, making the influences of the drinking environment and peers important factors in risky driving outcomes (Charlton & Starkey, 2015; Rhodes et al., 2015). The lab provides a sterile environment that is devoid of these same environmental and social influences. This allows for more rigorous experimental testing, however, there is also a non-trivial loss in ecological validity, that is particularly relevant when testing the combined effects of mood and alcohol (Dvorak et al., 2014).

The decision to drive is also highly contextual and influenced by numerous factors, including social norms and the availability, accessibility, and convenience of alternative means of transportation (Ouimet et al., 2020). An innovative study design (Ouimet et al., 2020) that more closely simulates the real-life decision to drive is described in Future Directions.

Driving simulators have high relative validity in comparison to other methods of measuring risky driving. However, concerns about the ecological validity of simulators persist. While simulators continue to be the safest method of assessing risky driving, other studies have used closed tracks to assess participants' driving in a vehicle that has been fitted with sensors for measuring specific risky driving outcomes (Helland et al., 2016). Additional safety precautions are required for conducting studies using a closed track, however,

including the presence of a safety driver who may take control of the vehicle in a dangerous situation and, in some jurisdictions, the presence of an on-site police officer (Helland et al., 2016). A drawback of these safety protocols is that they may create a ceiling effect whereby the full extent of risky driving is unable to be measured. Taken as a whole, driving simulators and closed tracks both provide opportunities to measure risky driving, particularly under alcohol. Driving simulation, however, provides an unimpeded method of testing risky driving although its fidelity to driving on the road should be considered in any interpretation of findings from research using a simulator.

### *Future Directions*

This study employs a strong study design and hereby proposes recommendations for an even stronger design, providing the conceptual and methodological groundwork for future studies powered by larger sample sizes to explore the effects of acute alcohol in the context of mood. Importantly, the placebo-controlled design of this study addressed potential effects of alcohol expectancy, whereby changes in brain activation may be amplified by the expectation of alcohol's effects, rather than by the pharmacological effects of alcohol itself (Bodnár et al., 2021; Fillmore & Vogel-Sprott, 1995, 1996). Given the limited sample size for the analyses conducted in the present study, a higher BAC, such as 0.08% BAC, may have increased the power in this study. The added use of a driving simulator to measure risky driving provided safe, objective, and real-time assessment of drivers' behaviours behind the wheel. Although ANOVA is an effective analysis for smaller sample sizes, the inclusion of larger sample sizes in future may provide a more robust basis for the investigation of Hypothesis 1, which investigated whether the means of risky driving in a simulator differed by group. Moreover, with access to these larger sample sizes, regression analyses may also be a suitable means of analysing depressed mood and alcohol use as potential predictors of the variance in risky driving.

Future studies should better align the measurement of depressed mood symptoms with the objectives of the study. In addition to measuring depressed mood symptoms that are more likely to be expressed in men who exhibit externalising behaviours, another alternative to addressing the heterogeneity of depressed mood may be to first isolate the effects of more specific symptoms of interest, such as the emotion of sadness. Sadness, a cardinal symptom of depressed mood, is characterised, in part, by decreased activity in the frontoparietal system that is largely responsible for executive function (Arias et al., 2020; Wager et al., 2015). The measurement of sadness would also allow for the development of an experimental design whereby sadness can be manipulated in the lab by using validated experimental emotion elicitations (Lench et al., 2011; Westermann et al., 1996). Inducing sadness in combination with alcohol intake may provide a more nuanced understanding of the affective aspect of depressed mood on risky driving. Preliminary research on the effects of sadness on risky driving appears mixed and may warrant further study as the operational definitions of sadness and methods of induction vary between studies (Chan & Singhal, 2015; Jeon & Croschere, 2015; Megías, Maldonado, Cándido, et al., 2011; Scott-Parker, 2017).

The measure of the decision-to-drive used in this study has been well-established by previous research (Amlung et al., 2014; Beirness, 1987; Morris et al., 2014). Researchers who still have concerns about its external validity, however, may wish to consider more comprehensive methods of investigating the decision-to-drive. Given the observable nature of the decision to drive, a behavioural measure using a simulated version of the decision to drive was introduced in a recent study (Ouimet et al., 2020). The decision to drive while intoxicated by alcohol was measured using real-time contingencies embedded into the protocol (Ouimet et al., 2020). This allowed for the decision to drive scenario to closely emulate real life, even in an experimental setting, by offering participants different options, including waiting for a safe ride ( ≈ 30 minutes), waiting for a ride from a friend who had

also drank alcohol ( ≈ 23 minutes), and driving themselves to their destination ( ≈ 15 minutes; Ouimet et al., 2020). Although this method of measuring the decision to drive was quite time-consuming, it provided a nuanced simulation of a real-life decision-to-drive situation that may be useful in future experimental studies.

Decision-making remains a likely mediator of the potential effects of depressed mood on risky driving that should be replicated with sufficient power. In addition to decision-making, other areas of executive function may also contribute to the possible effects of depressed mood and risky driving. Advantageous decision-making is dependent, in part, on working memory (Diamond, 2013). Through bottom-up processing, working memory can be impaired when the ruminative thoughts (i.e., mind-wandering; Albert et al., 2018) that typically occur during a depressed mood add to working memory load (Curci et al., 2013). This may reduce the working memory capacity available for tasks requiring executive function, such as safe driving (Curci et al., 2013). Reducing available working memory capacity may increase measures of risky driving, such as speed deviation (Heenan et al., 2014). These findings suggest that depressed mood may have an effect on risky driving whereby the pathway through which depressed mood impacts risky driving may work through its deleterious effect on working memory in addition to decision-making.

Taken together, future research in this area may wish to incorporate a measure of depressed mood that is more sensitive to risky behaviours among men, such as the Male Depression Risk Scale (Rice et al., 2013). Exploring the role of emotion regulation may also provide insight into the relationship between depressed mood and risky driving among male drivers. Alternatively, as depressed mood is comprised of diverse symptoms, future research may instead wish to first explore the effects of more nuanced phenomena, such as sadness, which can be induced in the lab allowing for greater experimental control. Subjective alcohol intoxication may be an additional predictor of the decision to drive that could mediate

alcohol's pharmacological effects. Additionally, the use of a design where the decision to drive can be simulated in the lab may optimise the external validity while maintaining strong experimental control. Another option may be to simply measure decision-making using a continuous scale for the willingness to drive. A measure of working memory, such as the Spatial Working Memory task from the Cambridge Neuropsychological Test Automated Battery (Cambridge Cognition, 2017; Robbins et al., 1998), may also be administered to explore the underlying mechanisms of any emerging effects of depressed mood or sadness on risky driving or the decision to drive.

This study provides insights that appropriately set the stage for future research aiming to gain a more comprehensive understanding of how different human factors may together contribute to risky driving and the decision to drive in male drivers. In addition to proposing methods for future experimental and quasi-experimental cross-sectional studies, observational longitudinal studies on the long-term effects of depressed mood and alcohol are also warranted.

**Ethical Compliance**

All recruitment, informed consent, and experimental procedures were approved by and overseen by the Research Ethics Board of the Douglas Hospital Research Centre.

**Conflict of Interest**

The authors have no conflicts of interest to declare.

**Funding Statement**

This study was conducted with the support of an operating grant, [MOP-137065], from the Canadian Institutes of Health Research, awarded to TGB.

**Acknowledgements**

The authors thank Dr. Marie Claude Ouimet, who developed and provided the use of the driving simulator; Lucie Legault, Laurence Fecteau-Fortin, and Lysiane Robidoux-

Leonard for their coordination of the study; the graduate students and research assistants who contributed to data collection; and the participants.

## References

Albert, D. A., Ouimet, M. C., Jarret, J., Cloutier, M. S., Paquette, M., Badeau, N., & Brown, T. G. (2018). Linking mind wandering tendency to risky driving in young male drivers. *Accident Analysis and Prevention*, *111*(September 2017), 125–132. https://doi.org/10.1016/j.aap.2017.11.019

Amlung, M. T., Morris, D. H., & McCarthy, D. M. (2014). Effects of acute alcohol tolerance on perceptions of danger and willingness to drive after drinking. *Psychopharmacology*, *231*(22), 4271–4279. https://doi.org/10.1007/s00213-014-3579-1

Anderson, B. M., Stevens, M. C., Meda, S. A., Jordan, K., Calhoun, V. D., & Pearlson, G. D. (2011). Functional imaging of cognitive control during acute alcohol intoxication. *Alcoholism: Clinical and Experimental Research*, *35*(1), 156–165. https://doi.org/10.1111/j.1530-0277.2010.01332.x

Arias, J. A., Williams, C., Raghvani, R., Aghajani, M., Baez, S., Belzung, C., Booij, L., Busatto, G., Chiarella, J., Fu, C. H., Ibanez, A., Liddell, B. J., Lowe, L., Penninx, B. W. J. H., Rosa, P., & Kemp, A. H. (2020). The neuroscience of sadness: A multidisciplinary synthesis and collaborative review. *Neuroscience and Biobehavioral Reviews*, *11*, 199–228. https://doi.org/10.1016/j.neubiorev.2020.01.006

Bechara, A. (2004). The role of emotion in decision-making: Evidence from neurological patients with orbitofrontal damage. *Brain and Cognition*, *55*(1), 30–40. https://doi.org/10.1016/j.bandc.2003.04.001

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition, 50*, 7–15. https://doi.org/10.1016/0010-0277(94)90018-3

Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, decision making and the orbitofrontal cortex. *Cerebral Cortex, 10*(3), 295–307.

https://doi.org/10.1093/cercor/10.3.295

Beck, A., Steer, R. A., & Brown, G. K. (1996). *Beck depression inventory-II*. Pearson Canada Assessment, Inc.

Beirness, D. J. (1987). Self-estimates of blood alcohol concentration in drinking-driving context. *Drug and Alcohol Dependence, 19,* 79–90.

Berman, A. H., Bergman, H., Palmstierna, T., & Schlyter, F. (2003). *The drug use disorders identification test: Manual* (1.0). Karolinska Institutet.

Bodnár, V., Nagy, K., Cziboly, Á., & Bárdos, G. (2021). Alcohol and placebo: The role of expectations and social influence. *International Journal of Mental Health and Addiction, 19,* 2292–2305. https://doi.org/10.1007/s11469-020-00321-0

Bouchard, S. M., Brown, T. G., & Nadeau, L. (2012). Decision-making capacities and affective reward anticipation in DWI recidivists compared to non-offenders: A preliminary study. *Accident Analysis and Prevention, 45,* 580–587. https://doi.org/10.1016/j.aap.2011.09.012

Bromet, E., Andrade, L. H., Hwang, I., Sampson, N. A., Alonso, J., de Girolamo, G., de Graaf, R., Demyttenaere, K., Hu, C., Iwata, N., Karam, A. N., Kaur, J., Stanislav, K., Lepine, J. P., Levinson, D., Matschinger, H., Medina Mora, M. E., Browne, M. O., Posada-Villa, J., … Kessler, R. C. (2011). Cross-national epidemiology of DSM-IV major depressive episode. *BMC Medicine, 9*(1), 90. https://doi.org/10.1186/1741-7015-9-90

Brown, T. G., Ouimet, M. C., Eldeb, M., Tremblay, J., Vingilis, E., Nadeau, L., Pruessner, J., & Bechara, A. (2016). Personality, executive control, and neurobiological characteristics associated with different forms of risky driving. *PLOS ONE*, *11*(2), e0150227. https://doi.org/10.1371/journal.pone.0150227

Buelow, M. T., & Suhr, J. A. (2009). Construct validity of the Iowa Gambling Task.

*Neuropsychology Review*, *19*(1), 102–114. https://doi.org/10.1007/s11065-009-9083-4

Bursac, Z., Gauss, C. H., Williams, D. K., & Hosmer, D. W. (2008). Purposeful selection of variables in logistic regression. *Source Code for Biology and Medicine*, *3*(17). https://doi.org/10.1186/1751-0473-3-17

Cambridge Cognition. (2017). *CANTAB® [Cognitive assessment software]*. Cambridge Cognition. www.cantab.com

Carroll, L. J., & Rothe, J. P. (2014). Viewing vehicular violence through a wide angle lens: Contributing factors and a proposed framework. *Canadian Journal of Criminology & Criminal Justice*, *56*(2), 1–25. https://doi.org/10.3138/cjccj.2014.ES01

Chan, M., & Singhal, A. (2015). Emotion matters: Implications for distracted driving. *Safety Science*, *72*, 302–309. https://doi.org/10.1016/j.ssci.2014.10.002

Charlton, S. G., & Starkey, N. J. (2015). Driving while drinking: Performance impairments resulting from social drinking. *Accident Analysis and Prevention*, *74*, 210–217. https://doi.org/http://dx.doi.org/10.1016/j.aap.2014.11.001

Cooper, M. L., Kuntsche, E., Levitt, A., Barber, L. L., & Wolf, S. (2015). Motivational models of substance use: A review of theory and research on motives for using alcohol, marijuana, and tobacco. In K. Sher (Ed.), *The Oxford handbook of substance use and substance use disorders: Volume 1* (Issue April, pp. 1–53). https://doi.org/10.1093/oxfordhb/9780199381678.013.017

Curci, A., Lanciano, T., Soleti, E., & Rimé, B. (2013). Negative emotional experiences arouse rumination and affect working memory capacity. *Emotion*, *13*(5), 867–880. https://doi.org/10.1037/a0032492

Cyders, M. A., VanderVeen, J. D., Plawecki, M., Millward, J. B., Hays, J., Kareken, D. A., & O'Connor, S. (2016). Gender-specific effects of mood on alcohol-seeking behaviors: Preliminary findings using intravenous alcohol self-administration. *Alcoholism: Clinical*

*and Experimental Research*, *40*(2), 393–400. https://doi.org/10.1111/acer.12955

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750.Executive

Dill, P. L., Wells-Parker, E., Cross, G. W., Williams, M., Mann, R. E., Stoduto, G., & Shuggi, R. (2007). The relationship between depressed mood, self-efficacy and affective states during the drinking driving sequence. *Addictive Behaviors*, *32*(8), 1714–1718. https://doi.org/10.1016/j.addbeh.2006.11.011

Dvorak, R. D., Pearson, M. R., & Day, A. M. (2014). Ecological Momentary Assessment of Acute Alcohol Use Disorder Symptoms: Associations With Mood, Motives, and Use on Planned Drinking Days. *Exp Clin Psychopharmacol*, *22*(4), 285–297. https://doi.org/10.1037/a0037157

Euser, A. S., & Franken, I. H. A. (2012). Alcohol affects the emotional modulation of cognitive control: An event-related brain potential study. *Psychopharmacology*, *222*(3), 459–476. https://doi.org/10.1007/s00213-012-2664-6

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.1088/1755-1315/148/1/012022

Fell, J. C., & Voas, R. B. (2014). The effectiveness of a 0.05 blood alcohol concentration (BAC) limit for driving in the United States. *Addiction*, *109*(6), 869–874. https://doi.org/10.1111/add.12365

Fellows, L. K. (2011). The neurology of value. In J. A. Gottfried (Ed.), *Neurobiology of Sensation and Reward* (pp. 351–568). CRC Press.

Ferrer, R., Klein, W., Lerner, J., Reyna, V., & Keltner, D. (2015). Emotions and health decision making: Extending the appraisal tendency framework to improve health and healthcare. In C. A. Roberto & I. Kawachi (Eds.), *Behavioral Economics and Public*

*Health* (pp. 1–35). Oxford University Press. https://doi.org/10.1093/med/9780199398331.001.0001

Fillmore, M. T., & Vogel-Sprott, M. (1995). Expectancies about alcohol-induced motor impairment predict individual differences in responses to alcohol and placebo. *Journal of Studies on Alcohol*, *56*(1), 90–98.

Fillmore, M. T., & Vogel-Sprott, M. (1996). Evidence that expectancies mediate behavioral impairment under alcohol. *Journal of Studies on Alcohol*, *57*(6), 598–603.

Fisher, H. R., Simpson, R. I., & Kapur, B. M. (1987). Calculation of blood alcohol concentration (BAC) by sex, weight, number of drinks and time. *Canadian Journal of Public Health*, *78*(5), 300–304.

Fritz, M. S., & MacKinnon, D. P. (2007). Required sample size to detect the mediated effect. *Psychological Science*, *18*(3), 233–239.

Gansler, D. A., Jerram, M. W., Vannorsdall, T. D., & Schretlen, D. J. (2011). Comparing alternative metrics to assess performance on the Iowa Gambling Task. *Journal of Clinical and Experimental Neuropsychology*, *33*(9), 1040–1048. https://doi.org/10.1080/13803395.2011.596820

Goldberg, D. P., & Hillier, V. F. (1979). A scaled version of the General Health Questionnaire. *Psychological Medicine*, *9*, 139–145.

Harris, A., Adolphs, R., Camerer, C., & Rangel, A. (2011). Dynamic construction of stimulus values in the ventromedial prefrontal cortex. *PLoS ONE*, *6*(6), e21074. https://doi.org/10.1371/journal.pone.0021074

Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd ed.). The Guilford Press.

Heenan, A., Herdman, C. M., Brown, M. S., & Robert, N. (2014). Effects of conversation on situation awareness and working memory in simulated driving. *Human Factors: The*

*Journal of the Human Factors and Ergonomics Society*, *56*(6), 1077–1092. https://doi.org/10.1177/0018720813519265

Helland, A., Jenssen, G. D., Lervåg, L.-E., Moen, T., Engen, T., Lydersen, S., Mørland, J., & Slørdal, L. (2016). Evaluation of measures of impairment in real and simulated driving: Results from a randomized, placebo-controlled study. *Traffic Injury Prevention*, *17*(3), 245–250. https://doi.org/10.1080/15389588.2015.1065975

Hilton, M. F., Staddon, Z., Sheridan, J., & Whiteford, H. A. (2009). The impact of mental health symptoms on heavy goods vehicle drivers' performance. *Accident Analysis and Prevention*, *41*(3), 453–461. https://doi.org/10.1016/j.aap.2009.01.012

Hsieh, F. Y. (1989). Sample size tables for logistic regression. *Statistics in Medicine*, *8*(7), 795–802. https://doi.org/10.1002/sim.4780080704

Hsu, J. (1999). Abuses and misconceptions in multiple comparisons. In *Multiple comparisons: Theory and methods* (pp. 175–180). https://doi.org/10.1201/b15074-11

IBM Corp. (2020). *IBM SPSS Statistics for Windows* (27.0). IBM Corp.

International Transport Forum. (2020). *Road safety annual report 2020: Canada*. https://www.itf-oecd.org/sites/default/files/canada-road-safety.pdf

Jeon, M., & Croschere, J. (2015). Sorry, I'm late; I'm not in the mood: Negative emotions lengthen driving time. *International Conference on Engineering Psychology and Cognitive Ergonomics*, *9174*, 237–244. https://doi.org/10.1007/978-3-319-20373-7_22

Joly, P., & Bergeron, J. (1987). Étude des comportements de risque au volant à l'aide du questionnaire ACR. *Accident Analysis & Prevention: Proceedings of the Canadian Multidisciplinary Road Safety Conference V*, *20*(2), 156–157.

Jonah, B. A., & Boase, P. (2017). Speeding and other risky driving behavior among young drivers. In *Handbook of teen and novice drivers: Research, practice, policy, and directions* (pp. 145–165). CRC Press.

Khan, A. J., Pedrelli, P., Shapero, B. G., Fisher, L., Nyer, M., Farabaugh, A. I., & Macpherson, L. (2018). The association between distress tolerance and alcohol related problems: The pathway of drinking to cope. *Substance Use & Misuse*, *53*(13), 2199–2209. https://doi.org/10.1080/10826084.2018.1464027

Krain, A. L., Wilson, A. M., Arbuckle, R., Castellanos, F. X., & Milham, M. P. (2006). Distinct neural mechanisms of risk and ambiguity: A meta-analysis of decision-making. *NeuroImage*, *32*, 477–484. https://doi.org/10.1016/j.neuroimage.2006.02.047

Labrie, J. W., Kenney, S. R., & Lac, A. (2010). The use of protective behavioral strategies is related to reduced risk in heavy drinking college students with poorer mental and physical health. *Journal of Drug Education*, *40*(4), 361–378.

Lench, H. C., Flores, S. A., & Bench, S. W. (2011). Discrete emotions predict changes in cognition, judgment, experience, behavior, and physiology: A meta-analysis of experimental emotion elicitations. *Psychological Bulletin*, *137*(5), 834–855. https://doi.org/10.1037/a0024244

Lev, D., Hershkovitz, E., & Yechiam, E. (2008). Decision making and personality in traffic offenders: A study of Israeli drivers. *Accident Analysis and Prevention*, *40*, 223–230. https://doi.org/10.1016/j.aap.2007.05.009

Liljenström, H., & Nazir, A. H. (2016). Neurodynamics of decision making: A computational approach. In R. Wang & X. Pan (Eds.), *Advances in cognitive neurodynamics* (pp. 1–7). Springer Singapore. www.sigtunastiftelsen.se/agoraforbiosystems

Lyvers, M., Mathieson, N., & Edwards, M. S. (2015). Blood alcohol concentration is negatively associated with gambling money won on the Iowa Gambling Task in naturalistic settings after controlling for trait impulsivity and alcohol tolerance. *Addictive Behaviors*, *41*, 129–135. https://doi.org/10.1016/j.addbeh.2014.10.008

Marczinski, C. A., & Fillmore, M. T. (2009). Acute alcohol tolerance on subjective

intoxication and simulated driving performance in binge drinkers. *Psychology of Addictive Behaviors*, *23*(2), 238–247. https://doi.org/10.1037/a0014633

Martin, T. L., M Solbeck, P. A., Mayers, D. J., Langille, R. M., Buczek, Y., & Pelletier, M. R. (2013). A review of alcohol-impaired driving: The role of blood alcohol concentration and complexity of the driving task. *Journal of Forensic Sciences*, *58*(5), 1238–1250. https://doi.org/10.1111/1556-4029.12227

McClure, S. M., & Bickel, W. K. (2014). A dual-systems perspective on addiction: Contributions from neuroimaging and cognitive training. *Annals of the New York Academy of Sciences*, *October*(1327), 62–78. https://doi.org/10.1111/nyas.12561

McDonald, C. C., Sommers, M. S., & Fargo, J. D. (2014). Risky driving, mental health, and health-compromising behaviours: Risk clustering in late adolescents and adults. *Injury Prevention*, *20*(6), 365–372. https://doi.org/10.1136/injuryprev-2014-041150

Meda, S. A., Calhoun, V. D., Astur, R. S., Turner, B. M., Ruopp, K., & Pearlson, G. D. (2009). Alcohol dose effects on brain circuits during simulated driving: An fMRI study. *Human Brain Mapping*, *30*(4), 1257–1270. https://doi.org/10.1002/hbm.20591

Megías, A., Maldonado, A., Cándido, A., & Catena, A. (2011). Emotional modulation of urgent and evaluative behaviors in risky driving scenarios. *Accident Analysis and Prevention*, *43*(3), 813–817. https://doi.org/10.1016/j.aap.2010.10.029

Mezquita, L., Ibáñez, M. I., Moya, J., Villa, H., & Ortet, G. (2014). A longitudinal examination of different etiological pathways to alcohol use and misuse. *Alcoholism: Clinical and Experimental Research*, *38*(6), 1770–1779. https://doi.org/10.1111/acer.12419

Morris, D. H., Treloar, H. R., Niculete, M. E., & Mccarthy, D. M. (2014). Perceived danger while intoxicated uniquely contributes to driving after drinking. *Alcoholism: Clinical and Experimental Research*, *38*(2), 521–528. https://doi.org/10.1111/acer.12252

Motschman, C. A., Hatz, L. E., McCarty, K. N., Merkle, E. C., Trull, T. J., & Mccarthy, D. M. (2020). Event-level predictors of alcohol-impaired driving intentions. *Journal of Studies on Alcohol and Drugs*, *81*(September), 647–654.

Motschman, C. A., Warner, O. M., Wycoff, A. M., Davis-Stober, C. P., & Mccarthy, D. M. (2020). Context, acute tolerance, and subjective response affect alcohol-impaired driving decisions. *Psychopharmacology*, *237*, 3603–3614. https://doi.org/10.1007/s00213-020-05639-0

Ouimet, M. C., Brown, T. G., Corado, L., Paquette, M., & Robertson, R. D. (2020). The effects of alcohol dose, exposure to an in-vehicle alcohol feedback device, and subjective responses to alcohol on the decision to drink-drive in young drivers. *Accident Analysis and Prevention*, *139*, 105495. https://doi.org/10.1016/j.aap.2020.105495

Paaver, M., Eensoo, D., Kaasik, K., Vaht, M., Mäestu, J., & Harro, J. (2013). Preventing risky driving: A novel and efficient brief intervention focusing on acknowledgement of personal risk factors. *Accident Analysis and Prevention*, *50*, 430–437. https://doi.org/10.1016/j.aap.2012.05.019

Paxton, R. J., Valois, R. F., Watkins, K. W., Huebner, E. S., & Drane, J. W. (2007). Associations between depressed mood and clusters of health risk behaviors. *American Journal of Health Behavior*, *31*(3), 272–283. https://doi.org/10.5993/AJHB.31.3.5

Rezaee-zavareh, M. S., Salamati, P., Ramezani-binabaj, M., & Saeidnejad, M. (2017). Alcohol consumption for simulated driving performance: A systematic review. *Chinese Journal of Traumatology*, *20*(3), 166–172. https://doi.org/10.1016/j.cjtee.2017.04.002

Rhodes, N., Pivik, K., & Sutton, M. (2015). Risky driving among young male drivers: The effects of mood and passengers. *Transportation Research Part F-Traffic Psychology and Behaviour*, *28*, 65–76. https://doi.org/10.1016/j.trf.2014.11.005

Rice, S. M., Fallon, B. J., Aucote, H. M., & Möller-Leimkühler, A. M. (2013). Development

and preliminary validation of the male depression risk scale: Furthering the assessment of depression in men. *Journal of Affective Disorders, 151*(3), 950–958. https://doi.org/10.1016/j.jad.2013.08.013

Robbins, T. W., James, M., Owen, A. M., Sahakian, B. J., Lawrence, A. D., McInnes, L., & Rabbitt, P. M. (1998). A study of performance on tests from the CANTAB battery sensitive to frontal lobe dysfunction in a large sample of normal volunteers: Implications for theories of executive functioning and cognitive aging. *Journal of the International Neuropsychological Society*, *4*(5), 474–490. https://doi.org/doi:10.1017/S1355617798455073

Robinson, S. M., Sobell, L. C., Sobell, M. B., & Leo, G. I. (2014). Reliability of the timeline followback for cocaine, cannabis, and cigarette use. *Psychology of Addictive Behaviors*, *28*(1), 154–162. https://doi.org/10.1037/a0030992

Sani, S. R. H., Tabibi, Z., Fadardi, J. S., & Stavrinos, D. (2017). Aggression, emotional self-regulation, attentional bias, and cognitive inhibition predict risky driving behavior. *Accident Analysis and Prevention*, *109*, 78–88. https://doi.org/10.1016/j.aap.2017.10.006

Schnabel, E. (2011). *Alcohol and driving-related performance: A comprehensive meta-analysis focusing the significance of the non-significant* [Julius Maximilian University of Würzburg]. http://hdl.handle.net/20.500.12424/1059913

Scott-Parker, B. (2017). Emotions, behaviour, and the adolescent driver: A literature review. *Transportation Research Part F: Traffic Psychology and Behaviour*, *50*, 1–37. https://doi.org/10.1016/j.trf.2017.06.019

Scott-Parker, B., Watson, B., King, M. J., & Hyde, M. K. (2012). The influence of sensitivity to reward and punishment, propensity for sensation seeking, depression, and anxiety on the risky behaviour of novice drivers: A path model. *British Journal of Psychology*,

*103*(2), 248–267. https://doi.org/10.1111/j.2044-8295.2011.02069.x

Šeibokaitė, L., Endriulaitienė, A., Sullman, M. J. M., Markšaitytė, R., & Žardeckaitė-Matulaitienė, K. (2017). Difficulties in emotion regulation and risky driving among Lithuanian drivers. *Traffic Injury Prevention*, *18*(7), 688–693. https://doi.org/10.1080/15389588.2017.1315109

Starkey, N. J., & Charlton, S. G. (2014). The effects of moderate alcohol concentrations on driving and cognitive performance during ascending and descending blood alcohol concentrations. *Human Psychopharmacology*, *29*(4), 370–383. https://doi.org/10.1002/hup.2415

Stephens, A. N., Bishop, C. A., Liu, S., & Fitzharris, M. (2017). Alcohol consumption patterns and attitudes toward drink-drive behaviours and road safety enforcement strategies. *Accident Analysis and Prevention*, *98*, 241–251. https://doi.org/10.1016/j.aap.2016.10.011

Stoduto, G., Dill, P., Mann, R. E., Wells-Parker, E., Toneatto, T., & Shuggi, R. (2008). Examining the link between drinking-driving and depressed mood. *Journal of Studies on Alcohol and Drugs*, *69*(5), 777–780. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=psyc6&NEWS=N&AN=2008-18392-018

Szuhany, K. L., Mackenzie, D., & Otto, M. W. (2018). The impact of depressed mood, working memory capacity, and priming on delay discounting. *Journal of Behavior Therapy and Experimental Psychiatry*, *60*, 37–41. https://doi.org/10.1016/j.jbtep.2018.03.001

Testa, C. R., & Steinberg, L. (2010). Depressive symptoms and health-related risk-taking in adolescence. *Suicide and Life-Threatening Behavior*, *40*(3), 298–305.

Trógolo, M. A., Melchior, F., & Medrano, L. A. (2014). The role of difficulties in emotion

regulation on driving behavior. *Journal of Behavior, Health & Social Issues*, *6*(1), 107–117. https://doi.org/10.5460/jbhsi.v6.1.47607

Verdejo-Garcia, A., Bechara, A., Recknor, E. C., & Perez-Garcia, M. (2006). Decision-making and the Iowa Gambling Task: Ecological validity in individuals with substance dependence. *Psychologica Belgica*, *46*(1/2), 55–78. https://doi.org/10.5334/pb-46-1-2-55

Vingilis, E., Mann, R. E., Erickson, P., Toplak, M., Kolla, N. J., Seeley, J., & Jain, U. (2014). Attention deficit hyperactivity disorder, other mental health problems, substance use, and driving: Examination of a population-based, representative Canadian sample. *Traffic Injury Prevention*, *15*(sup1), S1–S9. https://doi.org/10.1080/15389588.2014.926341

Wager, T. D., Kang, J., Johnson, J. D., Nichols, T. E., Satpute, A. B., & Barrett, L. F. (2015). A Bayesian model of category-specific emotional brain responses. *PLoS Computational Biology*, *11*(4), 1004066. https://doi.org/10.1371/journal.pcbi.1004066

Wang, Y.-P., & Gorenstein, C. (2013). Psychometric properties of the Beck Depression Inventory-II: A comprehensive review. *Revista Brasileira de Psiquiatria*, *35*, 416–431. https://doi.org/10.1590/1516-4446-2012-1048

Watson, P. E., Watson, I. D., & Batt, R. D. (1981). Prediction of blood alcohol concentrations in human subjects: Updating the Widmark equation. *Journal of Studies on Alcohol*, *42*(7), 547–556. https://doi.org/10.15288/jsa.1981.42.547

Weafer, J., & Fillmore, M. T. (2012). Acute tolerance to alcohol impairment of behavioral and cognitive mechanisms related to driving: Drinking and driving on the descending limb. *Psychopharmacology*, *220*(4), 697–706. https://doi.org/10.1007/s00213-011-2519-6

Wester, A. E., Verster, J. C., Volkerts, E. R., Böcker, K. B. E., & Kenemans, J. L. (2010). Effects of alcohol on attention orienting and dual-task performance during simulated

driving: An event-related potential study. *Journal of Psychopharmacology*, *24*(9), 1333–1348. https://doi.org/10.1177/0269881109348168

Westermann, R., Stahl, G., & Hesse, F. W. (1996). Relative effectiveness and validity of mood induction procedures: A meta-analysis. *European Journal of Social Psychology*, *26*(January), 557–580. https://doi.org/10.1002/(SICI)1099-0992(199607)26:4<557::AID-EJSP769>3.0.CO;2-4

World Health Organization. (2018). *Global status report on alcohol and health 2018*. https://doi.org//entity/substance_abuse/publications/global_alcohol_report/en/index.html

Zhang, Y., & Sloan, F. A. (2014). Depression, alcohol dependence and abuse, and drinking and driving behavior. *Journal of Behavioral Health*, *3*(4), 212–219. https://doi.org/10.5455/jbh.20141115011440

## Supplementary Materials: Results Tables and Figures

**Table 2-1.**

*Sociodemographic characteristics of the sample by group.*

| | $D^0A^0$ (*n* = 13) | | $D^1A^0$ (*n* = 15) | | $D^0A^1$ (*n* = 19) | | $D^1A^1$ (*n* = 10) | | *F* ($X^2$) | $\eta^2$ (Cramér's *V*) | 95% *CI [LL, UL]* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *M* (*n*) | *SD* (%) | *M* (*n*) | *SD* (%) | *M* (*n*) | *SD* (%) | *M* (*n*) | *SD* (%) | | | |
| Age[a] | 39.23 | 7.12 | 38.13 | 8.06 | 38.26 | 8.45 | 37.10 | 6.05 | 0.13 | 0.01 | [.00, .03] |
| Ethnicity | | | | | | | | | 24.93 | 0.38 | |
| White | 9 | 69.23 | 6 | 40 | 13 | 68.42 | 7 | 70.00 | | | |
| Arab | 1 | 7.69 | 4 | 26.67 | 1 | 5.26 | 0 | 0.00 | | | |
| Black | 2 | 15.38 | 1 | 6.67 | 0 | 0.00 | 2 | 20.00 | | | |
| Latino | 1 | 7.69 | 0 | 0 | 3 | 15.79 | 1 | 10.00 | | | |
| Asian | 0 | 0 | 1 | 6.67 | 2 | 10.53 | 0 | 0.00 | | | |
| Other | 0 | 0 | 3 | 20 | 0 | 0.00 | 0 | 0.00 | | | |
| Education | | | | | | | | | 23.58 | 0.37 | |
| Up to Grade 12 | 1 | 7.69 | 1 | 6.67 | 1 | 5.26 | 1 | 10.00 | | | |
| Some or completed college or technical training | 4 | 30.77 | 2 | 13.33 | 2 | 10.53 | 4 | 40.00 | | | |
| Some or completed Bachelor's | 5 | 38.46 | 9 | 60 | 12 | 63.16 | 3 | 30.00 | | | |
| Some or completed Graduate studies | 3 | 23.08 | 3 | 20 | 4 | 21.05 | 2 | 20.00 | | | |

| | $D^0A^0$ (*n* = 13) | | $D^1A^0$ (*n* = 15) | | $D^0A^1$ (*n* = 19) | | $D^1A^1$ (*n* = 10) | | *F* ($X^2$) | $\eta^2$ ('ramer's *V*) | 95% *CI [LL, UL]* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *M* (*n*) | *SD* (%) | *M* (*n*) | *SD* (%) | *M* (*n*) | *SD* (%) | *M* (*n*) | *SD* (%) | | | |
| Annual income | | | | | | | | | 12.83 | 0.27 | |
| <$20 000 | 2 | 15.38 | 4 | 26.67 | 4 | 21.05 | 3 | 30.00 | | | |
| $20 000 – $29 999 | 1 | 7.69 | 3 | 20 | 4 | 21.05 | 3 | 30.00 | | | |
| $30 000 – 39 999 | 1 | 7.69 | 1 | 6.67 | 3 | 15.79 | 1 | 10.00 | | | |
| $40 000 – $49 999 | 4 | 30.77 | 4 | 26.67 | 3 | 15.79 | 2 | 20.00 | | | |
| ≥$50 000 | 5 | 38.46 | 3 | 20 | 5 | 26.32 | 1 | 10.00 | | | |
| Marital status | | | | | | | | | 10.22 | 0.30 | |
| Single, never married | 1 | 7.69 | 9 | 60 | 9 | 47.37 | 5 | 50.00 | | | |
| Married or common law | 10 | 76.92 | 4 | 26.67 | 8 | 42.11 | 3 | 30.00 | | | |
| Separated or divorced | 2 | 15.38 | 2 | 13.33 | 2 | 10.53 | 2 | 20.00 | | | |
| Age received driving license[b] | 18.92 | 4.33 | 19.8 | 3.82 | 20.37 | 6.29 | 20.1 | 4.25 | 0.24 | 0.01 | [.00, .06] |
| Distance driven (km/year in the last 2 years)[b] | 16576.92 | 11470.70 | 20700.00 | 19787.98 | 14268.42 | 12215.29 | 14168.00 | 11605.67 | 1.50 | 0.08 | [.00, .20] |
| Major driving violations (lifetime)[c] | 3.46 | 4.94 | 0.87 | 0.92 | 1.95 | 2.27 | 1.30 | 1.64 | 1.28 | 0.07 | [.00, .18] |

*Note.* $D^0A^0$ = non-depressed mood and placebo beverage group; $D^1A^0$ = depressed mood and placebo beverage group; $D^0A^1$ = non-depressed mood and alcohol beverage group; $D^1A^1$ = depressed mood and alcohol beverage group.

[a] Square root transformation. [b] Inverse transformation. [c] Box-Cox transformation xl1.

**Table 2-2.**

*Hypothesis 1 ANOVAs examining group differences in risky driving outcomes.*

| | $D^0A^0$ (*n* = 13) | | $D^1A^0$ (*n* = 15) | | $D^0A^1$ (*n* = 19) | | $D^1A^1$ (*n* = 10) | | | | 95% *CI [LL, UL]* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *F* | $\eta^2$ | |
| Risky driving | | | | | | | | | | | |
| Mean urban acceleration[a] | 0.08 | 0.03 | 0.08 | 0.04 | 0.11 | 0.08 | 0.09 | 0.04 | 0.52 | 0.03 | [.00, .11] |
| Mean highway acceleration[b] | 0.22 | 0.03 | 0.24 | 0.65 | 0.30 | 0.14 | 0.26 | 0.08 | 0.77 | 0.04 | [.00, .14] |
| Mean highway speed | 81.10 | 11.66 | 79.83 | 14.00 | 82.58 | 13.63 | 88.18 | 17.63 | 0.77 | 0.04 | [.00, .14] |
| Mean highway merge acceleration[b] | 0.28 | 0.11 | 0.31 | 0.16 | 0.37 | 0.29 | 0.35 | 0.28 | 0.24 | 0.01 | [.00, .06] |

*Note.* $D^0A^0$ = non-depressed mood and placebo beverage group; $D^1A^0$ = depressed mood and placebo beverage group; $D^0A^1$ = non-depressed mood and alcohol beverage group; $D^1A^1$ = depressed mood and alcohol beverage group.

[a] Log 10 transformed data. [b] Inverse transformed data.

**Table 2-3.**

*Hypothesis 1 planned comparisons examining group differences in risky driving outcomes.*

| | Mean urban acceleration | | | Mean highway acceleration | | | Mean highway speed | | | Mean highway merge acceleration | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | t | Cohen's d | 95% CI [LL, UL] | t | Cohen's d | 95% CI [LL, UL] | t | Cohen's d | 95% CI [LL, UL] | t | Cohen's d | 95% CI [LL, UL] |
| $D^1A^0$ > $D^0A^0$ | 0.11 | 0.06 | [-.69, .80] | -0.36 | -0.17 | [-.92, .57] | -0.24 | -0.1 | [-.84, .65] | -0.3 | -0.16 | [-.90, .58] |
| $D^0A^1$ > $D^0A^0$ | 1.09 | 0.35 | [-.36, 1.06] | -1.39 | -0.51 | [-1.22, .21] | 0.29 | 0.12 | [-.59, .82] | -0.8 | -0.28 | [-.99, .43] |
| $D^1A^1$ > $D^0A^0$ | 0.48 | 0.25 | [-.58, 1.07] | -0.87 | -0.43 | [-1.26, .41] | 1.2 | 0.49 | [-.36, 1.32] | -0.53 | -0.25 | [-1.07, .59] |
| $D^1A^1$ > $D^1A^0$ | -0.39 | -0.19 | [-.99, .62] | 0.56 | 0.22 | [-.58, 1.02] | -1.45 | -0.54 | [-1.35, .28] | 0.27 | 0.11 | [-.69, .91] |
| $D^1A^1$ > $D^0A^1$ | 0.49 | 0.16 | [-.61, .93] | -0.35 | -0.12 | [-.88, .65] | -1.19 | -0.37 | [-1.14, .40] | -0.17 | -0.05 | [-.82, .71] |

*Note.* $D^0A^0$ = non-depressed mood and placebo beverage group; $D^1A^0$ = depressed mood and placebo beverage group; $D^0A^1$ = non-depressed mood and alcohol beverage group; $D^1A^1$ = depressed mood and alcohol beverage group.

**Table 2-4.**

*Hypothesis 2 logistic regression planned comparisons examining group differences in decision to drive outcomes.*

| | Decision to drive | | | | |
|---|---|---|---|---|---|
| | *B* | *SE* | *Wald* $X^2$ | *OR* | 95% *CI [LL, UL]* |
| Block 1 | | | | | |
| Age | 0.07 | 0.04 | 3.64 | 1.08 | [1.00, 1.16] |
| Block 2 | | | | | |
| Age | 0.07 | 0.04 | 3.66 | 1.08 | [1.00, 1.16] |
| Contrast | | | | | |
| $D^1A^0 > D^0A^0$ | -0.52 | 0.79 | 0.44 | 0.59 | [0.13, 2.80] |
| $D^0A^1 > D^0A^0$ | 0.25 | 0.75 | 0.11 | 1.23 | [0.29, 5.63] |
| $D^1A^1 > D^0A^0$ | -0.01 | 0.87 | 0.00 | 0.99 | [0.18, 5.42] |
| $D^1A^1 > D^1A^0$ | -0.52 | 0.85 | 0.37 | 0.60 | [0.11, 3.15] |
| $D^1A^1 > D^0A^1$ | 0.26 | 0.81 | 0.10 | 1.30 | [0.27, 6.33] |

*Note.* A = Contrast [-1,1,0,0] corresponding with H1a; b = Contrast [-1,0,1,0] corresponding with H1b; c = Contrast [-1,0,0,1] corresponding with H1c; d = Contrast [0,1,0,-1] corresponding with H1d; e = Contrast [-1,1,0,0] corresponding with H1e.

**Table 2-5.**

*Decision-making as a mediator of the effects of depressed mood on risky driving.*

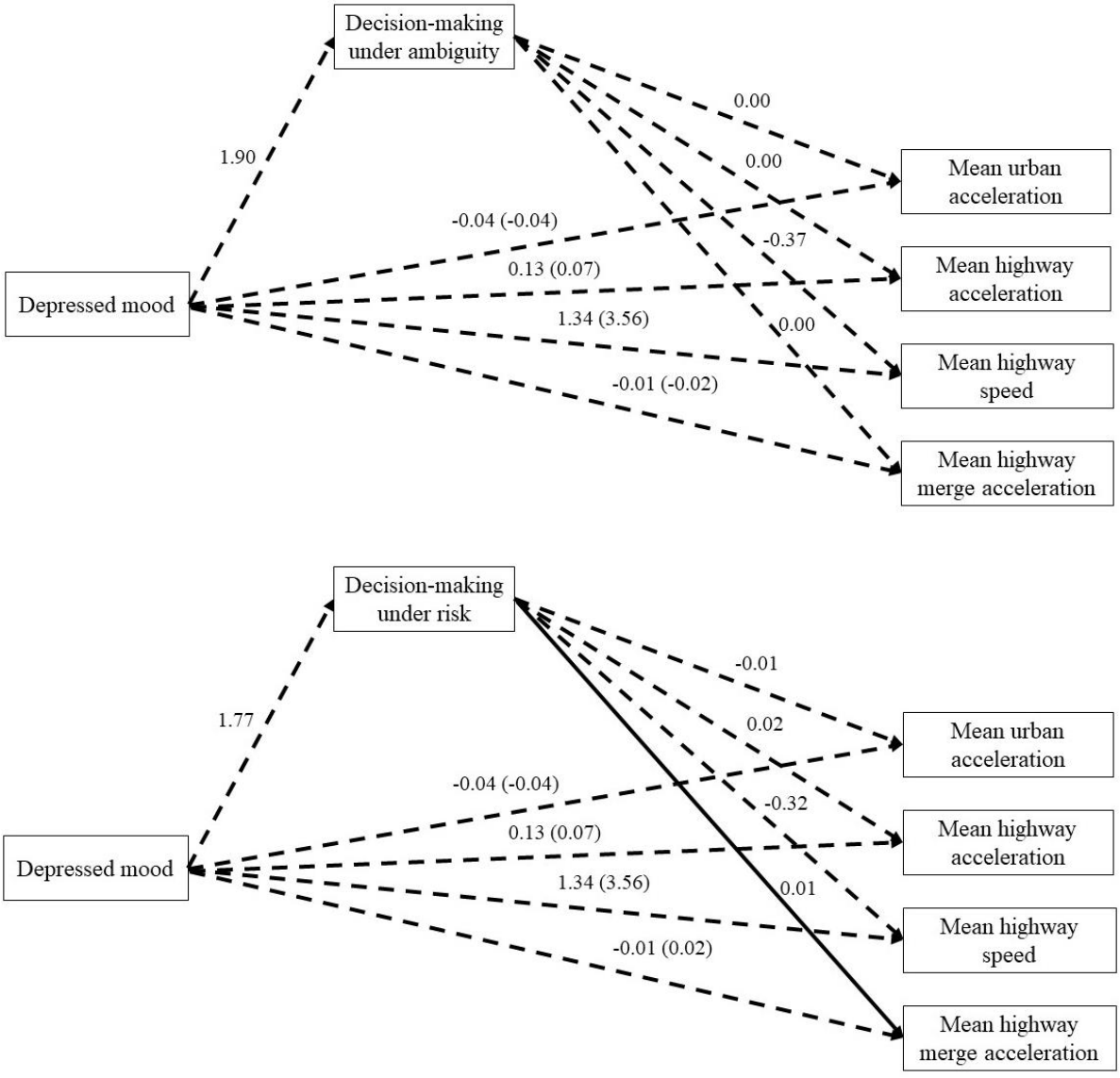
| | | Direct and indirect effects | | | |
|---|---|---|---|---|---|
| | DV | *B* | *SE* | *t* | 95% *CI [LL, UL]* |
| Path A | | | | | |
| BDI-II | Mean urban acceleration | -0.04 | 0.04 | -0.97 | [-0.13, 0.04] |
| | Mean highway acceleration | 0.13 | 0.29 | 0.44 | [-0.45, 0.70] |
| | Mean highway speed | 1.34 | 3.25 | 0.41 | [-5.18, 7.85] |
| | Mean highway merge acceleration | -0.02 | 0.04 | -0.55 | [-0.10, 0.06] |
| Path B | | | | | |
| BDI-II | IGT ambiguity | 1.90 | 1.44 | 1.32 | [-0.99, 4.80] |
| | IGT risk | 1.77 | 1.67 | 1.06 | [-1.59, 5.13] |
| Path C | | | | | |
| IGT ambiguity | Mean urban acceleration | 0.00 | 0.00 | -0.43 | [-0.01, 0.01] |
| | Mean highway acceleration | 0.00 | 0.03 | -0.15 | [-0.06, 0.05] |
| | Mean highway speed | -0.37 | 0.28 | -1.30 | [-0.93, 0.20] |
| | Mean highway merge acceleration | 0.00 | 0.00 | 0.65 | [0.00, 0.01] |
| IGT risk | Mean urban acceleration | -0.01 | 0.00 | -1.51 | [-0.01, 0.00] |
| | Mean highway acceleration | 0.02 | 0.02 | 0.81 | [-0.03, 0.06] |
| | Mean highway speed | -0.32 | 0.24 | -1.33 | [-0.80, 0.16] |
| | Mean highway merge acceleration | 0.01 | 0.00 | 2.83 | [0.00, 0.01] |

| | DV | Direct and indirect effects | | | |
|---|---|---|---|---|---|
| | | *B* | *SE* | *t* | 95% *CI [LL, UL]* |
| Full model | | | | | |
| BDI-II | Mean urban acceleration | -0.04 | 0.04 | -0.79 | [-0.13, 0.05] |
| IGT ambiguity | | 0.00 | 0.00 | 0.59 | [-0.01, 0.01] |
| IGT risk | | -0.01 | 0.00 | -1.58 | [-0.01, 0.00] |
| BDI-II | Mean highway acceleration | 0.07 | 0.30 | 0.24 | [-0.53, 0.67] |
| IGT ambiguity | | -0.03 | 0.03 | -0.88 | [-0.09, 0.03] |
| IGT risk | | 0.04 | 0.03 | 1.37 | [-0.02, 0.09] |
| BDI-II | Mean highway speed | 3.56 | 3.36 | 1.06 | [-3.21, 10.32] |
| IGT ambiguity | | -0.21 | 0.34 | -0.63 | [-0.89, 0.47] |
| IGT risk | | -0.21 | 0.30 | -0.69 | [0.82, 0.40] |
| BDI-II | Mean highway merge acceleration | -0.02 | 0.03 | -0.89 | [-0.08, 0.03] |
| IGT ambiguity | | 0.00 | 0.00 | -0.51 | [-0.01, 0.00] |
| IGT risk | | 0.01 | 0.00 | 2.38 | [0.00, 0.01] |

+ $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

**Figure 2-3.**

*Mediated regression models corresponding with H3.*




*Note.* (A) Decision-making under ambiguity was tested as a mediator of the effects of depressed mood on risky driving outcomes. (B) Decision-making under risk was tested as a mediator of the effects of depressed mood on risky driving outcomes.

Solid line = $p < .05$; Dashed line = $p > .05$

## Transition from Manuscript 1 to Manuscript 2

Manuscript 1 aimed to identify the role of depressed mood and alcohol use on the decision to drive and on risky driving in a simulator among male drivers. While previous studies have separately explored depressed mood and 0.05% BAC in the context of risky driving, this was the first study to investigate the combined effects of subclinical depressed mood and alcohol use below the *per se* legal threshold. Furthermore, previous studies on depressed mood exclusively used self-report questionnaires to measure risky driving. While the use of these self-report questionnaires is valid, Manuscript 1 employed the use of a driving simulator which measured risky driving manoeuvres including acceleration, speed, and merge acceleration in real-time. This study also considered decision-making as a potential underlying mechanism of risky driving. Manuscript 1 provided a robust quasi-experimental, placebo-controlled investigation of the combined effects of depressed mood and 0.05% BAC on the decision to drive and risky driving in an at-risk group.

In balancing the immediate effects of depressed mood and 0.05% BAC that were explored in Manuscript 1, Manuscript 2 widens the scope to become the first study to examine the effects of depressed mood and alcohol misuse on risky driving longitudinally over a period of 3 years and 9 years. This was the first study of its kind in a DWI offender sample. Existing longitudinal studies on DWI offender populations have primarily been within the context of predicting recidivism and often overlooked non-DWI risky driving outcomes. Sensation-seeking was also explored in this study as a potential moderator of alcohol misuse. Manuscript 2 utilises a self-report questionnaire on risky driving and provincial driving record data to elucidate the real-world effects of a combination of depressed mood and alcohol misuse. Presented together, Manuscript 1 and Manuscript 2 provide a well-balanced and comprehensive perspective on the immediate and long-term effects of depressed mood and alcohol on a range of risky driving outcomes.

# Chapter 3: Manuscript 2 – Examining the Predictive Potential of Depressed Mood and Alcohol Misuse on Risky Driving

Case, Nevicia F.[1,2]. Brown, Thomas G.[1,2].

[1]Department of Psychiatry, McGill University, Montreal, QC, Canada

[2]Addiction Research Program, Research Centre of the Douglas Mental Health, University Institute, Montreal, QC, Canada

Correspondence: Thomas Brown, Department of Psychiatry, McGill University, Douglas Mental Health University Institute, 6875 LaSalle Boulevard, Verdun, Montreal, Quebec H4H 1R3, Canada

Email: thomas.brown@mcgill.ca

## Abstract

Male driving while impaired (DWI) offenders are at heightened risk for engaging in risky driving. Males in a depressed mood are also more prone to alcohol misuse, which may further contribute to risky driving. This manuscript investigates the predictive potential of a combination of depressed mood and alcohol misuse on risky driving outcomes 3 and 9 years after baseline in male DWI offenders. At baseline, participants completed questionnaires assessing depressed mood (Major Depression scale of the Millon Clinical Multiaxial Inventory-III), alcohol misuse (Alcohol Use Disorders Identification Test), and sensation-seeking (Sensation Seeking Scale-V). Data on risky driving (Analyse des comportements routiers; ACR3) were collected at a follow-up 3 years after baseline. Driving offence data were obtained for 9 years after baseline. As 50.4% of the sample ($n$ = 129) were missing ACR3 scores, multiple imputation was conducted. In the final regression model, $R^2$ = .34, $F(7,121) = 8.76$, $p < .001$, alcohol misuse significantly predicted ACR3, $B = 0.56$, $t = 1.96$, $p = .05$. Depressed mood, however, did not significantly predict ACR3 and sensation-seeking was not a significant moderator. Although the regression model predicting risky driving offences at Year 9 was significant $R^2 = .37$, $F(10,108) = 6.41$, $p < .001$, neither depressed mood nor alcohol misuse was a significant predictor. These findings identify alcohol misuse as a predictor of risky driving 3 years after baseline among male DWI offenders. This enhances our prediction of risky driving, extending beyond the widely-researched acute impacts of alcohol by exploring chronic patterns.

## Introduction

Road traffic crashes are the leading cause of death among young people aged 5-29 (World Health Organization, 2018b). In addition, road traffic crashes leave many injuries in their wake and are responsible for nearly 68 million disability-adjusted life years worldwide (James et al., 2020). The impact of road traffic crashes is pervasive and extends beyond victims to also impact families, communities, workplaces, healthcare systems, justice systems, and national economies (Bachani et al., 2017). This has led to the declaration of 2021-2030 as the Decade of Action for Road Safety, whereby the target is to prevent 50% of road traffic injuries and deaths by 2030 (United Nations General Assembly, 2020). This study responds to this call to action by aiming to longitudinally identify predictors of risky driving among an at-risk population: male DWI offenders.

Risky driving refers to manoeuvres that increase injury risk, such as speeding, tailgating, and failing to come to a full stop at a stop sign (Joly & Bergeron, 1987). In Québec, these risky driving manoeuvres are recognised offences (Société de l'assurance automobile du Québec [SAAQ], 2020). The risk of engaging in risky driving is heightened among male drivers, particularly those with a history of DWI conviction (T. G. Brown et al., 2020; McDonald et al., 2014; Perreault, 2016; Roidl et al., 2013; World Health Organization, 2018b). Previous research has begun to elucidate a psychological profile of male drivers with convictions for both DWI and risky driving that is distinct from the profile of male drivers with convictions for DWI only (T. G. Brown et al., 2016, 2020; Eensoo et al., 2004, 2005; Paaver et al., 2006). These distinct profiles, therefore, provide a foundation for identifying characteristics that may increase DWI offenders' risk of also engaging in risky driving, paving the way for more targeted interventions.

Repeat DWI offenders have distinct characteristics from non-offenders, including greater alcohol misuse, blunted cortisol stress response, lower platelet monoamine oxidase,

impulsivity, and sensation seeking (T. G. Brown et al., 2016, 2020; Eensoo et al., 2004, 2005; Paaver et al., 2006). Together, these characteristics seem to be indicative of DWI offenders' reduced experience of the aversive responses to risk-taking and their propensity for seeking novel and intense sensations, such as those experienced during risky driving. Drivers with a mixed history of both DWI and risky driving offences also have a unique profile. They are characterised by lower agreeableness, greater alcohol misuse, sensation seeking, sensitivity to reward, blunted cortisol stress responses, and impulsivity (T. G. Brown et al., 2015, 2016, 2017; Constantinou et al., 2011; Scott-Parker & Weston, 2017; Starkey & Isler, 2016). While there is overlap between the two profiles, this cluster of features is distinct from that of repeat DWI offenders. Although analyses have not been conducted to directly compare drivers with a mixed history of DWI offences and risky driving with drivers who have DWI offences only, it is plausible that drivers with a mixed history exhibit greater sensation-seeking and lower agreeableness compared to DWI offenders (T. G. Brown et al., 2016). In order to strengthen the predictive profile of DWI offenders who go on to engage in risky driving, the personality traits and other psychological factors associated with risky driving warrant further investigation.

Depressed mood has been found to contribute to risky driving among male drivers in the general population (Scott-Parker et al., 2012). Despite evidence of this contribution and its association with other risk factors for risky driving, particularly alcohol misuse (Mezquita et al., 2014), there is limited research on depressed mood in a DWI offender population (Lapham et al., 2001; Nelson et al., 2015; Valero et al., 2017). One study found that clinical diagnoses of major depressive disorder and dysthymia were not associated with recidivism among DWI offenders, however, these analyses were only conducted following the participants' involvement in an inpatient treatment program which may have attenuated any possible effects (Nelson et al., 2015). Among drivers who have lost their license, however,

depressed mood identifies drivers at high risk of future driving convictions (Valero et al., 2017). Furthermore, existing research focuses on clinical diagnoses of depression without addressing depressed mood that falls below clinical diagnostic thresholds.

In the context of this study, alcohol misuse refers to drinking behaviour that is hazardous or harmful, but does not meet DSM-IV-TR diagnostic criteria for alcohol dependence (American Psychiatric Association, 2000; Rizer & Lusk, 2017). Since engaging in risky behaviours, such as DWI, is indeed hazardous, it is not surprising that there is a high prevalence of alcohol misuse among DWI offenders (T. G. Brown et al., 2016). What may be less intuitive, however, is how a chronic pattern of alcohol misuse may contribute to risky driving, even when the driver is not acutely intoxicated. Yet, alcohol misuse is predictive of risky driving among both healthy individuals and drivers who have lost their license (Scott-Parker & Weston, 2017; Valero et al., 2017). Alcohol misuse is also elevated among drivers with a mixed history of DWI and risky driving (T. G. Brown et al., 2016). The influence of alcohol misuse may be explained, in part, by the dysregulation of frontolimbic and reward pathways which is also a feature of depressed mood and sensation seeking (Chase et al., 2017; Dillon et al., 2014).

Depressed mood is associated with greater reward seeking, even in the presence of risk (Ferrer et al., 2015). Among DWI offenders, it then follows that depressed mood may co-occur with greater alcohol misuse and may also contribute to the prediction of non-DWI risky driving offences. Consistent with this, depressed mood and alcohol misuse continue to be variables of interest in studies of DWI offenders and risky driving offenders (Lapham et al., 2001; Moxley-Kelly et al., 2019; Nelson et al., 2015; Valero et al., 2017). In adding to the existing body of longitudinal research on various risk factors for driving offences (T. G. Brown et al., 2005, 2020; Moxley-Kelly et al., 2019; Nelson et al., 2015; Ouimet et al., 2013), further investigation into the predictive potential of depressed mood and alcohol

misuse may contribute to more accurate risk assessments, thereby improving injury prevention measures aimed at reducing risky driving.

Sensation-seeking represents the seeking of varied and intense sensations and experiences (i.e., rewards), and the willingness to take risks to obtain these sensations and experiences (Zuckerman, 1994). High sensation-seeking is indicative of an overactive BAS, which is responsible for behaviours that pursue reward and non-punishment (Scott-Parker & Weston, 2017). Among drivers, sensation-seekers have greater thresholds for perceived risk and arousal in comparison to drivers low in sensation-seeking (Zuckerman, 2007b). Thus, they are more susceptible to engaging in risky driving. Findings from a previous study support the high prevalence of both sensation-seeking and alcohol misuse among drivers with a mixed history of both DWI offences and risky driving (T. G. Brown et al., 2016). This is consistent with a meta-analysis which elucidated sensation-seeking as an important predictor of risky driving (Akbari et al., 2019). These findings highlight high sensation-seeking as a critical focal point for research aimed at preventing risky driving (Akbari et al., 2019). Dysregulation of the pathway between the amygdala and orbitofrontal cortex is observed in high sensation-seekers who misuse alcohol (Crane et al., 2018). This pathway is also important for mood processing (Crane et al., 2018). Further support for this cluster of variables suggests that alcohol misuse may even develop as a means of coping with depressed mood in high sensation-seekers (Moreno Padilla et al., 2017). Thus, high sensation-seeking has been identified as a useful predictor of risky driving (Scott-Parker et al., 2012).

***Rationale***

Previous research has defined high risk drivers as those drivers who are statistically most likely to be convicted of future driving offences (Valero et al., 2017). However, to our knowledge, no study has followed drivers longitudinally to obtain data on depressed mood as a predictor of risky driving and real-world driving offences. Despite extensive research

supporting the acute effects of various doses of alcohol on risky driving, the effects of alcohol misuse on risky driving outcomes remain less explored. There is a further paucity of research to identify psychiatric predictors of risky driving and real-world driving offences among DWI offenders.

The present study is a secondary analysis that employs an observational longitudinal cohort research design to examine psychiatric risk factors for future non-DWI risky driving and driving offences; specifically, depressed mood and alcohol misuse. By following the future trajectories of first-time DWI offenders, this study is well-positioned to inform the early prediction of drivers who may become repeat offenders up to 9 years after initial assessment.

The research question asks: Do greater depressed mood severity and alcohol misuse severity predict greater risky driving and the occurrence of a greater number of non-DWI risky driving offence in first-time DWI offenders?

***Hypotheses***

This study hypothesises:

1. Risky driving
    a. Alcohol misuse and depressed mood severity predict greater risky driving among first-time DWI offenders.
    b. Exploratory: Sensation seeking moderates the effect of alcohol misuse severity on non-DWI risky driving.
2. Risky driving offences
    a. Alcohol misuse and depressed mood severity predict an increased likelihood of subsequent driving offences among first-time DWI offenders.
    b. Exploratory: Sensation seeking moderates the effect of alcohol misuse severity on non-DWI risky driving recidivism.

## Methods

The study recruitment, informed consent, and procedures were approved by the Research Ethics Board of the Douglas Hospital Research Centre, where the study was conducted.

### *Participants*

Male participants were drawn from a study designed to examine first-time DWI offenders in relation to a comparison group of non-DWI offenders over a 9-year period (T. G. Brown et al., 2015). Recruitment was conducted between 2007 and 2011. Candidates for participation were obtained through newspaper advertisements; posters in public addiction treatment centres where DWI relicensing evaluations are conducted and agencies where interlock devices are installed; and invitation letters sent to DWI offenders from the SAAQ, the driving authority in Quebec, Canada. Inclusion criteria of the parent study required that DWI offenders were (i) male, (ii) 18-44 years old, (iii) convicted of a DWI within the past 24 months, (iv) without a history of additional previous or subsequent convictions of a DWI, and (v) consenting of access to their provincial driving record for the past 24 months and subsequent 10 years after baseline. Participants were excluded if they: (i) had a reading level below 6$^{th}$ grade in both French and English, (ii) had medical contraindications (the parent study involved measurement of cortisol stress response), and (iii) were under the influence of alcohol or drugs during their visit (this warranted rescheduling).

### *Screening and Consent*

Inclusion and exclusion criteria were verified via telephone using a preliminary screening interview before inviting the candidate to the lab. Eligible candidates were scheduled for Visit 1. Upon arrival, they were asked to provide photo identification and verify their DWI offender status. After receiving a written and oral explanation of the study, candidates were given the opportunity to provide informed consent.

***Measures***

**MCMI-III.** The Millon Clinical Multiaxial Inventory III (MCMI-III; Millon & Davis, 1997) was developed to correspond with the DSM-IV and has been established as one of the most widely used personality assessments (Piotrowski, 1997). Among the 24 clinical scales included in the MCMI-III is the Major Depression scale, which consists of 17 true/false items. With a base rate score of 60 representing the median score among the normative population (patients seen in clinics, hospitals, and other settings) and a base rate score < 75 indicating no or minimal depressive symptoms that are not severe enough to meet the criteria for Major Depressive Disorder, base rate scores < 75 are more prevalent in the general population than base rate scores ≥ 75 (Craig, 2002). The Major Depression scale had moderate external validity with positive predictive power of .66 (i.e., the conditional probability of the disorder given the symptom) and incremental validity of a positive test diagnosis of .55 (i.e., the extent to which positive test-based diagnoses are more predictive than positive diagnoses assigned at random; L. M. Hsu, 2002). This scale took less than 5 minutes to complete.

**AUDIT.** The AUDIT is validated to detect hazardous and harmful alcohol use and possible dependence in accordance with the DSM-IV-TR (Donovan et al., 2006; Pérula De Torres et al., 2009). Participants were asked to respond to a self-report questionnaire consisting of 10 questions about their alcohol use during the past year. Responses to each item were scored from 0 to 4. Total scores ranging 1-7 were indicative of low-risk consumption, scores of 8-15 were indicative of hazardous alcohol use, scores of 16-19 were indicative of harmful alcohol use, and scores ≥ 20 suggested the possible presence of alcohol dependence. The questionnaire took approximately 5 minutes to complete.

**SSS-V.** The Sensation Seeking Scale V (SSS-V) is a forced-choice questionnaire that assesses the personality trait of sensation-seeking (Zuckerman, 2007a). It has been validated

for use among adults across both clinical and non-clinical populations (Loas et al., 2001; Roberti et al., 2003). It is composed of four subscales – Thrill and Adventure Seeking, Experience Seeking, Disinhibition, and Boredom Susceptibility. With each item being scored as either 0 or 1, total scores represent the sum of these item scores. Completion of its 40 items took about 15 minutes.

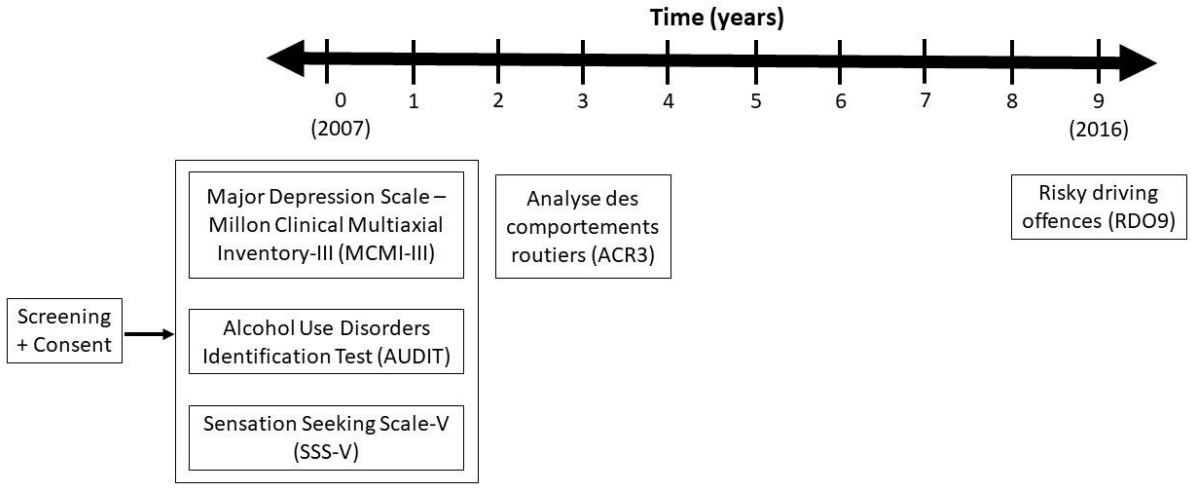
**ACR.** Scale F of the Analyse des comportements routiers (ACR; "Analysis of Driving Behaviour") Version E (Joly & Bergeron, 1987) was used as a measure of risky driving at Visit 3. The scale consists of 19 statements related to their risky driving behaviours during the past year, such as failing to stop at a "Stop" sign, speeding, and driving in adverse weather conditions. If participants had not driven in the past year, they were asked to respond in reference to their last year of driving. Participants were asked to respond to a Likert scale of 1-7 for each statement based on the frequency of their engagement in these behaviours, with the sum of item responses representing the total score on the ACR and higher total scores indicating a greater frequency of engagement in a greater diversity of risky driving behaviours. As this study is measuring risky driving outcomes other than DWI, Question 12, which asked about the past year frequency of driving after consuming 1-2 alcohol beverages, was omitted from the total scoring. This scale was able to be completed in approximately 5 minutes.

**Risky Driving Offences.** Driving offence data represent an important real-world outcome measure of risky driving. Since they were obtained from government sources, attrition rates for driving offence data tend to be much lower compared to attrition rates for measures that require follow-up visits in longitudinal study designs. As such, offence data were used as a measure of risky driving for up to 9 years after initial assessment in this study. All offence data were obtained from a database provided by the SAAQ which included the number, type, and date of risky driving offences each participant received.

***Procedure***

**Figure 3-1.**

*Manuscript 2 procedure.*




Driving offence data for 24 months prior to Visit 1 were obtained from the SAAQ. Upon intake, participants completed an initial assessment which included the MCMI-III, the Michigan Alcoholism Screening Test (MAST), the AUDIT, and the SSS-V. A socio-demographics questionnaire was used to collect information on age, ethnicity, years of education, months of employment in the past year, income in the past year, marital status, age of receiving driver's license, distance driven in the past 5 years, and legal history of non-DWI major driving convictions and criminal arrests since age 18 (e.g., reckless driving, speeding, etc.). The MAST (Selzer, 1971) provided screening for alcohol dependency and was followed by the AUDIT for all participants, regardless of their MAST score. The MCMI-III Major Depression scale assessed the presence and severity of depression symptoms. Self-reported past-year frequency of engagement in 19 non-DWI risky driving manoeuvres was collected using the ACR.

Participants were invited to return to the lab for follow-up assessments at Year 1 to Year 3, where they were asked to complete the ACR. Follow-up data on driving offences

were obtained from the SAAQ from Year 1 to Year 9. A visual representation of the procedure is provided in **Figure 3-1**.

***Statistical Analyses***

Upon review of the raw data, outlier values (+/-3 SD) were identified and adjusted to values just above or below the next most extreme score in the distribution. Given the longitudinal design of this study, missing data were primarily on follow-up self-report assessments – a description of how they were handled is provided in the results. Procedures for the purposeful selection of variables were followed to identify significant covariates and important confounders (Bursac et al., 2008).

Hypotheses 1a and 2a employed multiple regression to test alcohol misuse and depressed mood as predictors of risky driving and risky driving offences, respectively. More specifically, they followed a hierarchical method whereby covariates and confounders were sequentially added to the model and only retained if they significantly improved the prediction of the outcome variable. Use of multiple regression assumed that the risky driving data were continuous, had normally distributed residuals, homogeneity of variance, and were independent.

For testing Hypotheses 1b and 2b, which were exploratory, a moderated regression analysis was conducted to test whether sensation-seeking scores significantly moderate the effects of alcohol misuse on risky driving. Significant results would indicate that the ability of alcohol misuse to predict risky driving significantly differs depending on whether sensation-seeking scores are high or low.

Analyses were conducted using SPSS Statistics Subscription (IBM Corp., 2020) and followed by sensitivity analysis using G*Power 3.1 (Faul et al., 2007) to determine whether they were sufficiently powered to minimise Type II error. The moderation analyses additionally utilised the PROCESS v3.5 macro for SPSS (Hayes, 2018).

## Results

### *Description of the Sample*

The sample ($n$ = 129) consisted of males who received a first-time conviction of DWI within the past year. The average participant had obtained their driving license at age 18 ($M$ = 18.0, $SD$ = 2.4) and was 29 years old at the time of their baseline visit ($M$ = 29.1, $SD$ = 7.4). Within this timespan, they had already accrued more than 4 major driving convictions ($M$ = 4.7, $SD$ = 4.9). Participants were predominantly White ($n$ = 113, 86.82%) and had never married ($n$ = 110, 85.27%). On average, participants' scores on the clinical questionnaires indicated minimal depressed mood ($M$ = 16.9, $SD$ = 24.0), low-risk alcohol consumption ($M$ = 6.3, $SD$ = 3.7), and moderate sensation-seeking ($M$ = 21.1, $SD$ = 6.2). They reported low-moderate risky driving at Visit 3 and had committed 6 offences for risky driving by Year 9. Their sociodemographic, clinical, and risky driving characteristics are found in **Table 1-1**.

### *Missing Data*

Missing data related to Hypothesis 1 accounted for 7.4% of the values for this analysis and the results of Little's missing completely at random (MCAR) test were non-significant, indicating that the data were missing completely at random. As less than 5.0% of the data on race, distance driven in the last 5 years, and depressed mood variables were missing, the means and medians were imputed for these missing values. The study had an attrition rate of 50.4% at Visit 3 and multiple imputation was used to estimate values for ACR scores at Follow-up 3 (ACR3) and time elapsed from baseline to Follow-up 3.

Missing data related to Hypothesis 2 accounted for 0.5% of the data for this analysis and as Little's MCAR test was significant ($X^2$ = 34.28, $df$ = 11, $p$ < .001), the data were not missing completely at random. All 10 of these missing data values were for number of risky driving offences acquired from Baseline to Year 9 (RDO9) and accounted for 7.8% of the data on this variable. These data were determined to be missing at random and their values

were estimated using multiple imputation. Four participants were missing data in their SAAQ records for the entire 9 years and were removed from analyses involving these data. None of the participants with missing data was recorded as having died during the 9-year period of their participation in the study.

***Depressed Mood and Alcohol Misuse as Predictors of Risky Driving***

Hypothesis 1a stated that depressed mood and alcohol misuse would significantly predict ACR3. This was tested using hierarchical regression. All assumptions were met. Covariate and confounding variables were identified using purposeful selection. The potential covariates included baseline measures of age, marital status, age they obtained a driver's license, education, employment, income, race, distance driven in the last 5 years, history of major driving convictions, time elapsed from first offence to Baseline visit, and time elapsed from Baseline to Follow-up 3. When each of these variables was screened for significance in linear regression with ACR3, all except for marital status and income had *p*-values below the suggested threshold of 0.25. Each of the variables with *p*-values below 0.25 was tested in the multiple regression model. Age, distance driven in the last 5 years, education, and race emerged as significant covariates ($p < .10$) and were retained in the model. The time elapsed from Baseline to Follow-up 3 was also included in the model as it was a confounder of depressed mood. The remaining variables were neither significant predictors of ACR3 nor had a significant effect on the independent variables.

In the final model, $R^2 = 0.34$, $F(7, 121) = 8.76$, $p < .001$, AUDIT scores at baseline were a significant predictor of ACR3, $B = 0.56$, $t = 1.96$, $p = .052$. Major Depression scores, $B = -0.01$, $t = -0.22$, $p = .829$, were not significant predictors of ACR3. These results are summarised in **Table 1-2** and visualised in **Figure 1-2**.

***Sensation-seeking as a Moderator in the Prediction of Risky Driving***

Hypothesis 1b was exploratory and built on the findings of Hypothesis 1a by positing that sensation-seeking would moderate the effects of AUDIT scores on ACR3. Moderated regression was used. The same covariates that were included in the hierarchical regression for Hypothesis 1a were entered into the moderated regression model for Hypothesis 1b. The total moderated regression model was significant, $R^2 = 0.38$, $MSE = 114.19$, $p < .001$. However, AUDIT scores, $B = 0.31$, $SE = 0.95$, $p = .741$, Major Depression scores, $B = -0.01$, $SE = 0.04$, $p = .799$, SSS-V scores, $B = 0.48$, $SE = 0.32$, $p = .137$, and the interaction term, $B = 0.01$, $SE = 0.04$, $p = .904$, were non-significant. As such, SSS-V did not emerge as a significant moderator of AUDIT scores in the prediction of ACR3 (**Table 1-2**, **Figure 1-3**).

***Depressed Mood and Alcohol Misuse as Predictors of Risky Driving Offences***

Hypothesis 2a posited that depressed mood and alcohol misuse would predict risky driving offences at Year 9 (RDO9). Although RDO9 consisted of count data, Breusch-Pagan's test determined that the residuals were over-dispersed, thus violating an assumption of Poisson regression, $F(12) = 3.28$, $p < 001$. Following a log(10) transformation of RDO9, the data were suitable for hierarchical multiple regression following the same steps as the previous analysis.

The potential covariates included baseline measures of age, marital status, age they obtained a driver's license, education, employment, income, race, distance driven in the last 5 years, history of major driving convictions, time elapsed from first offence to Baseline visit, and time elapsed from Baseline to the end of SAAQ data. Following purposeful selection, all variables except for income, time elapsed from first offence to baseline visit, and time elapsed from baseline to the end of SAAQ data had *p*-values below the suggested threshold of 0.25. Each of the variables with *p*-values below 0.25 was tested in the multiple regression model. History of major driving convictions, marital status, education, age, age they obtained

a driver's license, and employment emerged as significant covariates ($p < .10$) and were retained in the model. The distance driven in the last 5 years and race were also included in the model as they were confounders of depressed mood. Although the final model was significant, $R^2 = 0.37$, $F(10, 108) = 6.41$, $p < .001$, AUDIT scores, $B = 0.00$, $t = -0.38$, $p = .704$, and Major Depression scores, $B = 0.00$, $t = 0.05$, $p = .957$, at baseline were non-significant predictors of RDO9 (**Table 1-2**, **Figure 1-4**).

***Sensation-seeking as a Moderator in the Prediction of Risky Driving Offences***

Building on Hypothesis 2a, Hypothesis 2b states that sensation-seeking moderates the effects of AUDIT scores on predicting risky driving offences at Year 9. A moderated regression model was used to test this hypothesis. Using the same covariates that were used in the hierarchical regression that tested Hypothesis 2a, the total model was significant, $R^2 = .38$, $MSE = .09$, $p < .001$, but neither AUDIT scores, $B = 0.02$, $SE = 0.03$, $p = .562$, neither Major Depression scores, $B = 0.00$, $SE = 0.00$, $p = .979$, significantly predicted RDO9. SSS-V scores, $B = 0.00$, $SE = 0.01$, $p = .662$ and the interaction term, $B = 0.00$, $SE = 0.00$, $p = .567$, were also non-significant. This model did not identify sensation-seeking as a significant moderator of AUDIT scores in the prediction of RDO9 (**Table 1-2**, **Figure 1-5**).

**Discussion**

While much of the literature on DWI offenders focuses on recidivism, DWI offenders – males in particular – are also at high-risk of engaging in risky driving behaviours unrelated to DWI (T. G. Brown et al., 2020; McDonald et al., 2014; Perreault, 2016; Roidl et al., 2013; World Health Organization, 2018b). Given that these risky driving behaviours occur without the acute influence of alcohol, it is possible that they arise from a chronic pattern of alcohol misuse instead (T. G. Brown et al., 2016; Scott-Parker & Weston, 2017; Valero et al., 2017). Evidence also suggests that males are more likely to experience a maladaptive combination of depressed mood and alcohol misuse (Mezquita et al., 2014). As such, this study examined

how depressed mood and alcohol misuse may contribute to the prediction of non-DWI risky driving and risky driving offences 3 years and 9 years after initial assessment, respectively.

Hypothesis 1a stated that greater depressed mood and alcohol misuse measured at baseline would predict greater risky driving 3 years later. Results of the hierarchical regression identified alcohol misuse, but not depressed mood, as a significant predictor of risky driving, suggesting that alcohol misuse may be a risk factor for risky driving 3 years later. These findings are consistent with findings from a study on individuals who had lost their driving license (Valero et al., 2017). In this study, alcohol misuse (consisting of both alcohol abuse and dependence) was found to be predictive of having a history of engaging in a cluster of high-risk correlates for future traffic violations (OR = 1.63, 95% CI = 1.06, 2.50) – in particular, a history of collisions, having taken driving license recovery courses, losing their driving license, arrests, prison sentences, and legal problems (Valero et al., 2017). Rather than using risk correlates based on previous behaviour as a proxy for future risk, the present study employs a longitudinal design that measures risky driving 3 years after baseline.

While results for alcohol misuse were significant, the model did not find depressed mood to be a significant predictor of risky driving. This may be due to the particular symptoms of depressed mood that have been observed in men. Where some men are more likely to engage in externalising behaviours as symptoms of depressed mood, the MCMI-III measured depressed mood in accordance with DSM-IV-TR criteria, which identifies the depressive symptoms more often observed in women than in men (Bromet et al., 2011; Rice et al., 2013). Furthermore, as reflected in the general population, it is possible that, even in the presence of a depressed mood, emotion regulation among DWI offenders may moderate the effects on risky driving (Šeibokaitė et al., 2017), as discussed further in the General

Discussion. It is also possible that the low severity of depressed mood included in this study may have been insufficient for predicting risky driving longitudinally.

Hypothesis 1b was exploratory and posited that sensation-seeking would moderate the effect of alcohol misuse severity on risky driving. Results of the moderated regression, however, did not identify sensation-seeking as a significant moderator of this relationship. This may be explained by findings that individuals exhibiting greater sensation-seeking also engage in a wider variety of risky behaviours (Lydon-Staley et al., 2020). That is, while sensation-seeking may increase the overall likelihood of engaging in risky behaviours, the types of risky behaviours may not be limited to risky driving (Lydon-Staley et al., 2020).

Hypothesis 2a stated that greater depressed mood severity and alcohol misuse severity would predict a greater number of risky driving offences 9 years after baseline. Findings from the hierarchical regression did not support this, however. Extrapolating from the evidence that depressed mood is predictive of risky driving among the general population (Li et al., 2021; Scott-Parker et al., 2012), a similar pattern may exist among DWI offenders. Alternatively, DWI offenders with a greater severity of depressive symptoms express greater readiness to change their alcohol misuse (Nochajski et al., 2013), indicating that the combination of depressed mood and alcohol misuse may have been successfully treated within the 9 years, alleviating the risk of engaging in risky driving instead of elevating it. Greater alcohol misuse, in particular, was expected as a predictor since alcohol misuse and risky driving are part of a cluster of risky behaviours (McDonald et al., 2014; Paxton et al., 2007). However, greater alcohol misuse is present in both DWI offenders and drivers with a mixed profile of DWI offenses and risky driving (T. G. Brown et al., 2016, 2020). While this study hypothesised that greater alcohol misuse, particularly in the context of depressed mood, would be predictive of DWI offenders' transition to also engage in risky driving, together

with previous research (T. G. Brown et al., 2016), the results indicate that alcohol misuse may instead represent a shared characteristic between these two types of drivers.

Hypothesis 2b was exploratory and stated that greater sensation-seeking would moderate the effect of alcohol misuse severity on risky driving offences. The results of the hierarchical regression used to test Hypothesis 2a provided the basis for the moderated regression that was used to test Hypothesis 2b. The moderated regression results found that the total model was significant, however most of this variability was accounted for by covariates, including having a major driving violation and number of months employed over the past 12 months, rather than being attributed to alcohol misuse. It follows that sensation-seeking also did not emerge as a significant moderator of alcohol misuse. The findings, therefore, suggest that sensation-seeking may not serve to identify DWI offenders at risk for engaging in risky driving. This is likely due to several aspects of the study design. Given that sensation-seeking is predictive of a greater variability of risky behaviours (Lydon-Staley et al., 2020), greater power may have been required to predict risky driving specifically. Furthermore, as a function of time, the prediction of outcomes 9 years after baseline is less likely than prediction 3 years after baseline. These findings may also reflect the attenuation of sensation-seeking with increased age. Rather than representing the true prevalence of risky driving, offences only represent instances where a driver was charged with an offence. Given these limitations, any potential effects of sensation-seeking as a moderator in the prediction of risky driving may have been attenuated in the present study.

The findings in this study build on previous research by establishing alcohol misuse as a predictor of risky driving 3 years after baseline. While greater alcohol misuse in men experiencing a greater depressed mood may be reflective of maladaptive coping strategies (Mezquita et al., 2014), it is also possible that depressed mood may also serve as a protective factor by facilitating readiness to change among DWI offenders (Nochajski et al., 2013).

Evidence from other studies supports that both DWI offenders and drivers who engage in a mixture of DWI offences and risky driving exhibit greater sensation-seeking (T. G. Brown et al., 2016, 2020), suggesting that the non-significant findings in the present study are most likely due to insufficient power.

### *Future Directions*

Male DWI offenders represent a high-risk group for engaging in risky driving (T. G. Brown et al., 2020; McDonald et al., 2014; Perreault, 2016; Roidl et al., 2013; World Health Organization, 2018b), yet research focused on identifying their specific risk profile has been sparse. In identifying characteristics which may increase their risk, the longitudinal design of this study provided a strong foundation for the prediction of risky driving outcomes. However, it was not without areas for improvement.

Adjustments to the threshold for inclusion of depressed mood and the measurement of depressed mood symptoms may provide a more accurate representation of the role of depressed mood in predicting risky driving. In a sample of male first-time DWI offenders, depressed mood may be better assessed using a scale designed to measure externalising behaviour symptoms among males (Rice et al., 2013). Measuring depressed mood in this way may improve the prediction of risky driving, particularly among those who additionally misuse alcohol, which is in itself an externalising behaviour (Rice et al., 2013). Future studies may also wish to first establish the effects of higher severities of depressed mood, particularly to disentangle its nuanced relationship with alcohol misuse in a DWI offender population.

Alternatives in the measurement of sensation-seeking may also allow for the investigation of novel research questions. Although sensation-seeking is generally deemed to be a stable trait, there is a degree of intraindividual variability present (Lydon-Staley et al., 2020). Future research may wish to explore these daily fluctuations in sensation-seeking in relation to the well-established daily fluctuations in mood (Hidalgo et al., 2009) for the

purpose of predicting risky driving within the same day. While 32% of DWI offences occur between the hours of 11 p.m. and 3 a.m. (Perreault, 2021), it is unclear what time of day may be a peak time for DWI offenders who engage in risky driving. Conceptualising these less-stable aspects of sensation-seeking may, therefore, stimulate future research on the relationship between sensation-seeking and depressed mood among DWI offenders. As individuals high in sensation-seeking may also have a higher propensity to engage in a greater diversity of risky behaviours (Lydon-Staley et al., 2020), such as risky sexual behaviour and illicit substance use, these may also serve as important outcome measures for research on other types of risk-taking behaviours.

The ability to predict risky driving outcomes in a DWI offender population has strong clinical significance for the development of interventions for the secondary prevention of risky driving. Where interventions, such as brief motivational interviewing, have been demonstrated to effectively reduce recidivism risk among DWI recidivists, first-time DWI offenders remain a heterogenous population (Moxley-Kelly et al., 2019; Ouimet et al., 2013). Identifying predictors of risky driving in these individuals may lead to the development of interventions targeting first-time DWI offenders. Moreover, existing research has explored the propensity for first-time DWI offenders to become DWI recidivists (T. G. Brown et al., 2009, 2020; Couture et al., 2010). However, research on the risk profile of drivers who commit a mixture of both DWI offences and non-DWI risky driving has highlighted the gravity of identifying these high-risk drivers early. Engaging in both DWI offences and non-DWI risky driving results in drivers being more than twice as likely to commit subsequent DWI offences over a 5-year period compared to drivers who have committed multiple DWI offences, but no non-DWI risky driving offences (Moxley-Kelly et al., 2019). They are also 3 times as likely to reoffend earlier than their DWI recidivist counterparts (Moxley-Kelly et al., 2019). In light of this, prediction of this higher-risk mixed profile extends to represent a

critical step not only in the prevention of risky driving, but also in the prevention of DWI recidivism.

This study identified alcohol misuse as a predictor of risky driving 3 years later among DWI offenders. It also lays the foundation for future research incorporating assessments of important human factors in this population, such as depressed mood and sensation-seeking. The findings may inform the earlier prediction of DWI recidivism as DWI offenders who also engage in risky driving may pose a significant risk of DWI recidivism. Together, this body of research may influence the targeting of interventions, driver education, and relicensing policies for high-risk drivers. With further research and implementation, it is hoped that these findings may contribute to the attenuation of road traffic injuries and fatalities as a result of risky driving.

**Ethical Compliance**

All recruitment, informed consent, and experimental procedures were approved by and overseen by the Research Ethics Board of the Douglas Hospital Research Centre.

**Conflict of Interest**

The authors have no conflicts of interest to declare.

**Funding Statement**

This study was conducted with the support of an operating grant, [MOP-86451], from the Canadian Institutes of Health Research, awarded to TGB.

**Acknowledgements**

The authors thank Lucie Legault for her coordination of the study; Lyne Vezina and Maxime Breault from the Société de l’assurance automobile du Québec for their assistance in retrieving driving records; and the participants.

## References

Akbari, M., Lankarani, K. B., Heydari, S. T., Motevalian, S. A., Tabrizi, R., Asadi-Shekari, Z., & Sullman, M. J. M. (2019). Meta-analysis of the correlation between personality characteristics and risky driving behaviors. *Journal of Injury and Violence Research, 11*(2), 107–122. https://doi.org/10.5249/jivr.v11i2.1172

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders IV TR.* American Psychiatric Association.

Bachani, A. M., Peden, M., Gururaj, G., Norton, R., & Hyder, A. A. (2017). Road traffic injuries. In C. N. Mock, R. Nugent, O. Kobusingye, & K. R. Smith (Eds.), *Disease control priorities: Injury prevention and environmental health* (3rd ed., pp. 35–54). The World Bank. https://doi.org/10.1596/978-1-4648-0522-6_ch7

Bromet, E., Andrade, L. H., Hwang, I., Sampson, N. A., Alonso, J., de Girolamo, G., de Graaf, R., Demyttenaere, K., Hu, C., Iwata, N., Karam, A. N., Kaur, J., Stanislav, K., Lepine, J. P., Levinson, D., Matschinger, H., Medina Mora, M. E., Browne, M. O., Posada-Villa, J., … Kessler, R. C. (2011). Cross-national epidemiology of DSM-IV major depressive episode. *BMC Medicine, 9*(1), 90. https://doi.org/10.1186/1741-7015-9-90

Brown, T. G., Gianoulakis, C., Tremblay, J., Nadeau, L., Dongier, M., Ng Ying Kin, N. M. K., Seraganian, P., & Ouimet, M. C. (2005). Salivary cortisol: A predictor of convictions for driving under the influence of alcohol? *Alcohol & Alcoholism, 40*(5), 474–481. https://doi.org/10.1093/alcalc/agh165

Brown, T. G., Ouimet, M. C., Eldeb, M., Tremblay, J., Vingilis, E., Nadeau, L., Pruessner, J., & Bechara, A. (2016). Personality, executive control, and neurobiological characteristics associated with different forms of risky driving. *PLOS ONE, 11*(2), e0150227.

https://doi.org/10.1371/journal.pone.0150227

Brown, T. G., Ouimet, M. C., Eldeb, M., Tremblay, J., Vingilis, E., Nadeau, L., Pruessner, J., & Bechara, A. (2017). The effect of age on the personality and cognitive characteristics of three distinct risky driving offender groups. *Personality and Individual Differences*, *113*, 48–56. https://doi.org/10.1016/j.paid.2017.03.007

Brown, T. G., Ouimet, M. C., Nadeau, L., Gianoulakis, C., Lepage, M., Tremblay, J., & Dongier, M. (2009). From the brain to bad behaviour and back again: Neurocognitive and psychobiological mechanisms of driving while impaired by alcohol. *Drug and Alcohol Review*, *28*(4), 406–418. https://doi.org/10.1111/j.1465-3362.2009.00053.x

Brown, T. G., Ouimet, M. C., Nadeau, L., Tremblay, J., Gianoulakis, C., Couture, S., & Moxley-Kelly, N. (2020). Cortisol stress response predicts 9-year risky driving convictions in male first-time driving-while-impaired offenders. *Psychopharmacology*, *237*, 177–187. https://doi.org/10.1007/s00213-019-05359-0

Brown, T. G., Ouimet, M. C., Nadeau, L., Tremblay, J., & Pruessner, J. (2015). Sex differences in the personality and cognitive characteristics of first-time DWI offenders. *Journal of Studies on Alcohol and Drugs*, *76*(6), 928–934.

Bursac, Z., Gauss, C. H., Williams, D. K., & Hosmer, D. W. (2008). Purposeful selection of variables in logistic regression. *Source Code for Biology and Medicine*, *3*(17). https://doi.org/10.1186/1751-0473-3-17

Chase, H. W., Fournier, J. C., Bertocci, M. A., Greenberg, T., Aslam, H., Stiffler, R., Lockovich, J., Graur, S., Bebko, G., Forbes, E. E., & Phillips, M. L. (2017). A pathway linking reward circuitry, impulsive sensation-seeking and risky decision-making in young adults: Identifying neural markers for new interventions. *Translational Psychiatry*, *7*, e1096.

https://doi.org/10.1038/tp.2017.60

Constantinou, E., Panayiotou, G., Konstantinou, N., Loutsiou-Ladd, A., & Kapardis, A. (2011). Risky and aggressive driving in young adults: Personality matters. *Accident Analysis and Prevention*, *43*(4), 1323–1331. https://doi.org/10.1016/j.aap.2011.02.002

Couture, S., Brown, T. G., Tremblay, J., Ng, N. M. K., Kin, Y., Ouimet, M. C., & Nadeau, L. (2010). Are biomarkers of chronic alcohol misuse useful in the assessment of DWI recidivism status? *Accident Analysis and Prevention*, *42*, 307–312. https://doi.org/10.1016/j.aap.2009.08.016

Craig, R. J. (2002). Essentials of MCMI-III assessment. In S. Strack (Ed.), *Essentials of Millon inventories assessment* (2nd ed., pp. 1–51). John Wiley & Sons.

Crane, N. A., Gorka, S. M., Phan, K. L., & Childs, E. (2018). Amygdala-orbitofrontal functional connectivity mediates the relationship between sensation seeking and alcohol use among binge-drinking adults. *Drug and Alcohol Dependence*, *192*, 208–214. https://doi.org/10.1016/j.drugalcdep.2018.07.044

Dillon, D. G., Rosso, I. M., Pechtel, P., Killgore, W. D. S., Rauch, S. L., & Pizzagalli, D. A. (2014). Peril and pleasure: An RDoC-inspired examination of threat responses and reward processing in anxiety and depression. *Depression and Anxiety*, *31*(3), 233–249. https://doi.org/10.1002/da.22202

Donovan, D. M., Kivlahan, D. R., Doyle, S. R., Longabaugh, R., & Greenfield, S. F. (2006). Correspondence to: Concurrent validity of the Alcohol Use Disorders Identification Test (AUDIT) and AUDIT zones in defining levels of severity among out-patients with alcohol dependence in the COMBINE study. *Addiction*, *101*, 1696–1704. https://doi.org/10.1111/j.1360-0443.2006.01606.x

Eensoo, D., Paaver, M., Harro, M., & Harro, J. (2005). Predicting drunk driving: Contribution of alcohol use and related problems, traffic behaviour, personality and platelet monoamine oxidase (MAO) activity. *Alcohol & Alcoholism, 40*(2), 140–146. https://doi.org/10.1093/alcalc/agh135

Eensoo, D., Paaver, M., Pulver, A., Harro, M., & Harro, J. (2004). Low platelet MAO activity associated with high dysfunctional impulsivity and antisocial behavior: Evidence from drunk drivers. *Psychopharmacology, 172*, 356–358. https://doi.org/10.1007/s00213-003-1664-y

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.1088/1755-1315/148/1/012022

Ferrer, R., Klein, W., Lerner, J., Reyna, V., & Keltner, D. (2015). Emotions and health decision making: Extending the appraisal tendency framework to improve health and healthcare. In C. A. Roberto & I. Kawachi (Eds.), *Behavioral Economics and Public Health* (pp. 1–35). Oxford University Press. https://doi.org/10.1093/med/9780199398331.001.0001

Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd ed.). The Guilford Press.

Hidalgo, M. P., Caumo, W., Posser, M., Coccaro, S. B., Camozzato, A. L., & Chaves, M. L. F. (2009). Relationship between depressive mood and chronotype in healthy subjects. *Psychiatry and Clinical Neurosciences*, *63*(3), 283–290. https://doi.org/10.1111/J.1440-1819.2009.01965.X

Hsu, L. M. (2002). Diagnostic validity statistics and the MCMI-III. *Psychological Assessment*, *14*(4), 410–422. https://doi.org/10.1037/1040-3590.14.4.410

IBM Corp. (2020). *IBM SPSS Statistics for Windows* (27.0). IBM Corp.

James, S. L., Lucchesi, L. R., Bisignano, C., Castle, C. D., Dingels, Z. V., Fox, J. T., Hamilton, E. B., Liu, Z., McCracken, D., Nixon, M. R., Sylte, D. O., Roberts, N. L. S., Adebayo, O. M., Aghamolaei, T., Alghnam, S. A., Aljunid, S. M., Almasi-Hashiani, A., Badawi, A., Behzadifar, M., … Mokdad, A. H. (2020). Morbidity and mortality from road injuries: Results from the Global Burden of Disease Study 2017. *Injury Prevention*, *26*, i46–i56. https://doi.org/10.1136/injuryprev-2019-043302

Joly, P., & Bergeron, J. (1987). Étude des comportements de risque au volant à l'aide du questionnaire ACR. *Accident Analysis & Prevention: Proceedings of the Canadian Multidisciplinary Road Safety Conference V*, *20*(2), 156–157.

Lapham, S. C., Smith, E., C'de Baca, J., Chang, I., Skipper, B. J., Baum, G., & Hunt, W. C. (2001). Prevalence of psychiatric disorders among persons convicted of driving while impaired. *Archives of General Psychiatry*, *58*(10), 943–949. http://www.ncbi.nlm.nih.gov/pubmed/11576032

Li, K., Vaca, F. E., Courtney, J. B., & Haynie, D. L. (2021). Associations of mental health with driving while impaired and risky driving in emerging adults. *Traffic Injury Prevention*, *22*(2), 114–119. https://doi.org/10.1080/15389588.2020.1852225

Loas, G., Verrier, A., Flament, M. F., Perez-Diaz, F., Corcos, M., Halfon, O., Lang, F., Bizouard, P., Venisse, J. L., Guelfi, J. D., & Jeammet, P. (2001). Factorial structure of the Sensation-Seeking Scale-Form V: Confirmatory factorial analyses in nonclinical and clinical samples. *Canadian Journal of Psychiatry*, *46*, 850–855.

Lydon-Staley, D. M., Falk, E. B., & Bassett, D. S. (2020). Within-person variability in sensation-seeking during daily life: Positive associations with alcohol use and self-defined risky

behaviors. *Psychology of Addictive Behavior*, *34*(2), 257–268. https://doi.org/10.31234/osf.io/djb5c

McDonald, C. C., Sommers, M. S., & Fargo, J. D. (2014). Risky driving, mental health, and health-compromising behaviours: Risk clustering in late adolescents and adults. *Injury Prevention*, *20*(6), 365–372. https://doi.org/10.1136/injuryprev-2014-041150

Mezquita, L., Ibáñez, M. I., Moya, J., Villa, H., & Ortet, G. (2014). A longitudinal examination of different etiological pathways to alcohol use and misuse. *Alcoholism: Clinical and Experimental Research*, *38*(6), 1770–1779. https://doi.org/10.1111/acer.12419

Millon, T., & Davis, R. D. (1997). The MCMI-III: Present and future directions. *Journal of Personality Assessment*, *68*(1), 69–85. https://doi.org/10.1207/s15327752jpa6801

Moreno Padilla, M., O'Halloran, L., Bennett, M., Cao, Z., & Whelan, R. (2017). Impulsivity and reward processing endophenotypes in youth alcohol misuse. *Current Addiction Reports*, *4*(4), 350–363. https://doi.org/10.1007/s40429-017-0167-6

Moxley-Kelly, N., Ouimet, M. C., Dongier, M., Chanut, F., Tremblay, J., Marcantoni, W., & Brown, T. G. (2019). The role of behavioural phenotypes on impaired driving recidivism risk and treatment response to brief intervention: A preliminary study. *Alcoholism: Clinical and Experimental Research*, *43*(2), 324–333. https://doi.org/10.1111/acer.13935

Nelson, S. E., Belkin, K., LaPlante, D. A., Bosworth, L., & Shaffer, H. J. (2015). A prospective study of psychiatric comorbidity and recidivism among repeat DUI offenders. *Archives of Scientific Psychology*, *3*(1), 8–17. https://doi.org/10.1037/arc0000009

Nochajski, T. H., Stasiewicz, P. R., & Patterson, D. A. (2013). Depression, readiness for change, and treatment among court-mandated DUI offenders. *Journal of Dual Diagnosis*, *9*(2), 139–148. https://doi.org/10.1080/15504263.2013.779092

Ouimet, M. C., Dongier, M., Di Leo, I., Legault, L., Tremblay, J., Chanut, F., & Brown, T. G. (2013). A randomized controlled trial of brief motivational interviewing in impaired driving recidivists: A 5-year follow-up of traffic offenses and crashes. *Alcoholism: Clinical and Experimental Research*, *37*(11), 1979–1985. https://doi.org/10.1111/acer.12180

Paaver, M., Eensoo, D., Pulver, A., & Harro, J. (2006). Adaptive and maladaptive impulsivity, platelet monoamine oxidase (MAO) activity and risk-admitting in different types of risky drivers. *Psychopharmacology*, *186*, 32–40. https://doi.org/10.1007/s00213-006-0325-3

Paxton, R. J., Valois, R. F., Watkins, K. W., Huebner, E. S., & Drane, J. W. (2007). Associations between depressed mood and clusters of health risk behaviors. *American Journal of Health Behavior*, *31*(3), 272–283. https://doi.org/10.5993/AJHB.31.3.5

Perreault, S. (2016). Impaired driving in Canada, 2015. In *Juristat* (Issues 85-002–X). http://www.statcan.gc.ca/pub/85-002-x/2013001/article/11739-eng.htm#a4

Perreault, S. (2021). Impaired driving in Canada, 2019. In *Juristat* (Issues 85-002–X). https://www150.statcan.gc.ca/n1/pub/85-002-x/2021001/article/00012-eng.htm

Pérula De Torres, L. A., Rebollo, M., Ruiz-Moral, R., Angel Fernández-García, J., Arias Vega, R., & Palomino, M. M. (2009). The European Journal of General Practice Diagnostic usefulness of the Alcohol Use Disorders Identification Test (AUDIT) questionnaire for the detection of hazardous drinking and dependence on alcohol among Spanish patients. *The European Journal of General Practice*, *15*(1), 15–21. https://doi.org/10.1080/13814780902855754

Piotrowski, C. (1997). Use of the Millon Clinical Multiaxial Inventory in clinical practice. *Perceptual and Motor Skills*, *84*(3 Supplemental), 1185–1186.

Rice, S. M., Fallon, B. J., Aucote, H. M., & Möller-Leimkühler, A. M. (2013). Development and

preliminary validation of the male depression risk scale: Furthering the assessment of depression in men. *Journal of Affective Disorders*, *151*(3), 950–958. https://doi.org/10.1016/j.jad.2013.08.013

Rizer, C. A., & Lusk, M. D. (2017). Screening and initial management of alcohol misuse in primary care. *The Journal for Nurse Practitioners*, *13*(10), 660–666. https://doi.org/https://doi.org/10.1016/j.nurpra.2017.08.011

Roberti, J. W., Storch, E. A., & Bravata, E. (2003). Further psychometric support for the Sensation Seeking Scale-Form V. *Journal of Personality Assessment*, *81*(3), 291–292. https://doi.org/10.1207/S15327752JPA8103_12

Roidl, E., Siebert, F. W., Oehl, M., & Höger, R. (2013). Introducing a multivariate model for predicting driving performance: The role of driving anger and personal characteristics. *Journal of Safety Research*, *47*, 47–56. https://doi.org/10.1016/j.jsr.2013.08.002

Scott-Parker, B., Watson, B., King, M. J., & Hyde, M. K. (2012). The influence of sensitivity to reward and punishment, propensity for sensation seeking, depression, and anxiety on the risky behaviour of novice drivers: A path model. *British Journal of Psychology*, *103*(2), 248–267. https://doi.org/10.1111/j.2044-8295.2011.02069.x

Scott-Parker, B., & Weston, L. (2017). Sensitivity to reward and risky driving, risky decision making, and risky health behaviour: A literature review. *Transportation Research Part F: Traffic Psychology and Behaviour*, *49*, 93–109. https://doi.org/10.1016/j.trf.2017.05.008

Šeibokaitė, L., Endriulaitienė, A., Sullman, M. J. M., Markšaitytė, R., & Žardeckaitė-Matulaitienė, K. (2017). Difficulties in emotion regulation and risky driving among Lithuanian drivers. *Traffic Injury Prevention*, *18*(7), 688–693. https://doi.org/10.1080/15389588.2017.1315109

Selzer, M. L. (1971). The Michigan Alcoholism Screening Test: The quest for a new diagnostic instrument. *American Journal of Psychiatry*, *127*(12), 89–94. https://ajp-psychiatryonline-org.proxy3.library.mcgill.ca/doi/pdf/10.1176/ajp.127.12.1653

Société de l'assurance automobile du Québec. (2020). *Offenses and demerit points*. Gouvernement Du Québec. https://saaq.gouv.qc.ca/en/drivers-licences/demerit-points/offences-and-demerit-points/

Starkey, N. J., & Isler, R. B. (2016). The role of executive function, personality and attitudes to risks in explaining self-reported driving behaviour in adolescent and adult male drivers. *Transportation Research Part F: Traffic Psychology and Behaviour*, *38*, 127–136. https://doi.org/10.1016/j.trf.2016.01.013

United Nations General Assembly. (2020). Improving global road safety: Resolution adopted by the General Assembly on 31 August 2020. In *United Nations* (Vol. 74, Issue 299). https://undocs.org/en/A/RES/74/299

Valero, S., Bosch, R., Corominas, M., Giannoni, A., Barrau, V., Ramos-Quiroga, J. A., & Casas, M. (2017). Psychopathology and traffic violations in subjects who have lost their driving license. *Comprehensive Psychiatry*, *76*, 45–55. https://doi.org/10.1016/j.comppsych.2017.03.012

World Health Organization. (2018). *Global status report on road safety 2018*. https://doi.org/10.22201/fq.18708404e.2004.3.66178

Zuckerman, M. (1994). *Behavioral expressions and biosocial bases of sensation seeking*. Cambridge University Press.

Zuckerman, M. (2007a). The sensation seeking scale V (SSS-V): Still reliable and valid. *Personality and Individual Differences*, *43*, 1303–1305.

https://doi.org/10.1016/j.paid.2007.03.021

Zuckerman, M. (2007b). Sensation seeking and risky driving, sports, and vocations. In *Sensation seeking and risky behavior* (pp. 73–106). American Psychological Association. https://doi.org/10.1037/11555-003

## Supplementary Materials: Results Tables and Figures

**Table 1-1.**

*Sociodemographic, clinical, and driving characteristics of DWI offenders.*

| Description of the sample | M ± SD<br>n (%) |
|---|---|
| Sociodemographic Characteristics | |
| Age (years) | 29.1 ± 7.4 |
| Marital status | |
| Married or cohabitating | 10 (7.75) |
| Separated | 2 (1.55) |
| Divorced | 7 (5.43) |
| Never married | 110 (85.27) |
| Age they obtained driving license | 18.0 ± 2.4 |
| Education (years) | 13.9 ± 2.6 |
| Number of months employed (last 12 months) | 8.6 ± 4.3 |
| Income | |
| No personal income | 5 (3.88) |
| $1-$999 | 1 (.78) |
| $1000-$5999 | 5 (3.88) |
| $6000-$11999 | 18 (13.95) |
| $12000-$19999 | 21 (16.28) |
| $20000-$29999 | 26 (20.16) |
| $30000-$39999 | 25 (19.38) |
| $40000-$49999 | 8 (6.20) |
| $50000+ | 20 (15.50) |
| Race | |
| White | 113 (86.82) |
| Black | 4 (3.10) |
| Indigenous | 1 (0.78) |
| Hispanic | 7 (5.43) |
| Other | 4 (3.10) |

| | |
|---|---|
| Number of km driven (last 5 years) | 93281.5 ± 75498.1 |
| Major driving convictions (lifetime) | 4.7 ± 4.9 |

| Description of the sample (cont'd) | M ± SD<br>n (%) |
|---|---|
| **Sociodemographic Characteristics** | |
| Time elapsed from first offence to baseline visit (days) | 13.4 ± 8.2 |
| Time elapsed from baseline visit to FU3 (days) | 1093.7 ± 33.4 |
| Time elapsed from baseline visit to end of driving conviction data (days) | 2597.6 ± 386.1 |
| **Clinical Characteristics** | |
| SSS-V | 21.1 ± 6.2 |
| AUDIT | 6.3 ± 3.7 |
| MCMI-III Major Depression scale | 16.9 ± 24.0 |
| **Risky Driving Characteristics** | |
| ACR3 | 53.4 ± 13.1 |
| RDO9 | 6.2 ± 4.6 |

**Table 1-2.**

*Sensation-seeking as a moderator of the effects of alcohol misuse on risky driving 3 years after baseline and risky driving offences 9 years after baseline.*

| | Risky driving | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model 1 ACR3 | | | | Model 2 RDO9 | | | |
| | *B* | *SE* | *t* | 95% *CI [LL, UL]* | *B* | *SE* | *t* | 95% *CI [LL, UL]* |
| Block 1 | | | | | | | | |
| Age | -0.72 | 0.14 | -5.30 | [-0.99, -0.45] | -0.01 | 0.00 | -1.44 | [-0.01, 0.00] |
| Education | 1.31 | 0.38 | 3.45 | [0.56, 2.07] | -0.02 | 0.01 | -2.03 | [-0.05, 0.00] |
| Marital status | - | - | - | - | 0.04 | 0.03 | 1.48 | [-0.01, 0.09] |
| Race | 1.66 | 0.70 | 2.39 | [0.28, 3.04] | -0.03 | 0.02 | -1.40 | [-0.07, 0.01] |
| Employment | - | - | - | - | 0.02 | 0.01 | 2.60 | [0.00, 0.03] |
| Age of licensing | - | - | - | - | -0.01 | 0.01 | -1.05 | [-0.04, 0.01] |
| Distance driven per year (km) | 0.00 | 0.00 | 3.44 | [0.00, 0.00] | 0.00 | 0.00 | 1.56 | [0.00, 0.00] |
| Major driving convictions | - | - | - | - | 0.02 | 0.01 | 3.79 | [0.01, 0.04] |
| Time since baseline | -0.06 | 0.03 | -1.90 | [-0.12, 0.00] | - | - | - | - |
| $R^2$ | | | 0.31 | | | | 0.37 | |
| $\Delta R^2$ | | | 0.31 | | | | 0.37 | |
| $F$ | | | 11.31 | | | | 8.13 | |
| $\Delta F$ | | | 11.31 | | | | 8.13 | |

| | Risky driving | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model 1 ACR3 | | | | Model 2 RDO9 | | | |
| | *B* | *SE* | *t* | 95% *CI [LL, UL]* | *B* | *SE* | *t* | 95% *CI [LL, UL]* |
| Block 2 | | | | | | | | |
| Age | -0.65 | 0.14 | -4.65 | [-0.93, -0.37] | -0.01 | 0.01 | -1.48 | [-0.02, 0.00] |
| Education | 1.04 | 0.40 | 2.58 | [0.24, 1.84] | -0.02 | 0.01 | -1.75 | [-0.05, 0.00] |
| Marital status | - | - | - | - | 0.04 | 0.03 | 1.46 | [-0.01, 0.09] |
| Race | 1.76 | 0.69 | 2.53 | [0.38, 3.13] | -0.03 | 0.02 | -1.41 | [-0.07, 0.01] |
| Employment | - | - | - | - | 0.02 | 0.01 | 2.61 | [0.00, 0.03] |
| Age of licensing | - | - | - | - | -0.01 | 0.01 | -1.01 | [-0.04, 0.01] |
| Distance driven per year (km) | 0.00 | 0.00 | 3.60 | [0.00, 0.00] | 0.00 | 0.00 | 1.48 | [0.00, 0.00] |
| Major driving convictions | - | - | - | - | 0.02 | 0.01 | 3.74 | [0.01, 0.04] |
| Time since baseline | -0.07 | 0.31 | -2.11 | [-0.13, 0.00] | - | - | - | - |
| MD | -0.01 | 0.04 | -0.22 | [-0.09, 0.07] | 0.00 | 0.00 | 0.06 | [0.00, 0.00] |
| AUDIT | 0.56 | 0.29 | 1.96 | [0.00, 1.13] | 0.00 | 0.01 | -0.38 | [-0.02, 0.01] |
| $R^2$ | | | 0.34 | | | | 0.37 | |
| $\Delta R^2$ | | | 0.02 | | | | 0.00 | |
| $F$ | | | 8.76 | | | | 6.41 | |
| $\Delta F$ | | | 2.55 | | | | 1.72 | |

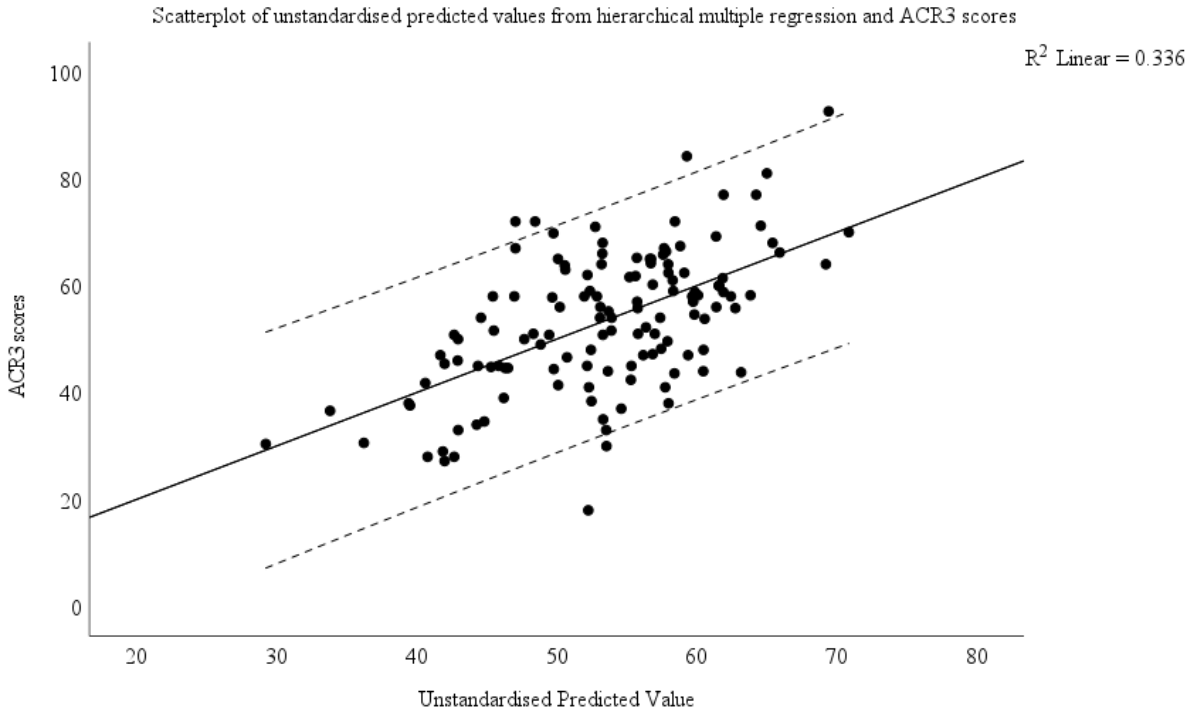
| | Risky driving | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Model 1 ACR3 | | | | Model 2 RDO9 | | | |
| | *B* | *SE* | *t* | 95% *CI [LL, UL]* | *B* | *SE* | *t* | 95% *CI [LL, UL]* |
| Block 3 | | | | | | | | |
| Age | -0.49 | 0.15 | -3.35 | [-0.79, -0.20] | -0.01 | 0.00 | -1.49 | [-0.02, 0.00] |
| Education | 0.69 | 0.41 | 1.67 | [-0.13, 1.51] | -0.02 | 0.01 | -1.60 | [-0.05, 0.01] |
| Marital status | - | - | - | - | 0.05 | 0.03 | 1.75 | [-0.01, 0.11] |
| Race | 2.24 | 0.70 | 3.19 | [0.85, 3.62] | -0.02 | 0.02 | -1.03 | [-0.06, 0.02] |
| Employment | - | - | - | - | 0.02 | 0.01 | 2.67 | [0.00, 0.03] |
| Age of licensing | - | - | - | - | -0.02 | 0.01 | -1.25 | [-0.04, 0.01] |
| Distance driven per year (km) | 0.00 | 0.00 | 3.07 | [0.00, 0.00] | 0.00 | 0.00 | 1.49 | [0.00, 0.00] |
| Major driving convictions | - | - | - | - | 0.02 | 0.01 | 3.56 | [0.01, 0.04] |
| Time since baseline | -0.08 | 0.03 | -2.44 | [-0.14, -0.01] | - | - | - | - |
| MD | -0.01 | 0.04 | -0.25 | [-0.09, 0.07] | 0.00 | 0.00 | -0.03 | [0.00, 0.00] |
| AUDIT | 0.31 | 0.95 | 0.33 | [-1.56, 2.18] | 0.02 | 0.03 | 0.58 | [-0.04, 0.07] |
| SSS-V | 0.48 | 0.32 | 1.50 | [-0.16, 1.12] | 0.00 | 0.01 | 0.44 | [-0.01, 0.02] |
| AUDIT x SSS-V | 0.01 | 0.04 | 0.12 | [-0.08, 0.09] | 0.00 | 0.00 | -0.57 | [0.00, 0.00] |
| $R^2$ | | | 0.38 | | | | 0.38 | |
| $\Delta R^2$ | | | 0.04 | | | | 0.01 | |
| *F* | | | 8.06 | | | | 5.44 | |
| $\Delta F$ | | | 0.70 | | | | 0.97 | |

*Note.* MD = depressed mood; SSS-V = Sensation Seeking Scale; ACR3 = Risky driving scores on the Analyse des comportements routiers at Visit 3; RDO9 = Risky driving offences at Year 9

+ $p < .1$, * $p < .05$, **$p < .01$, ***$p < .001$

**Figure 1-2.**

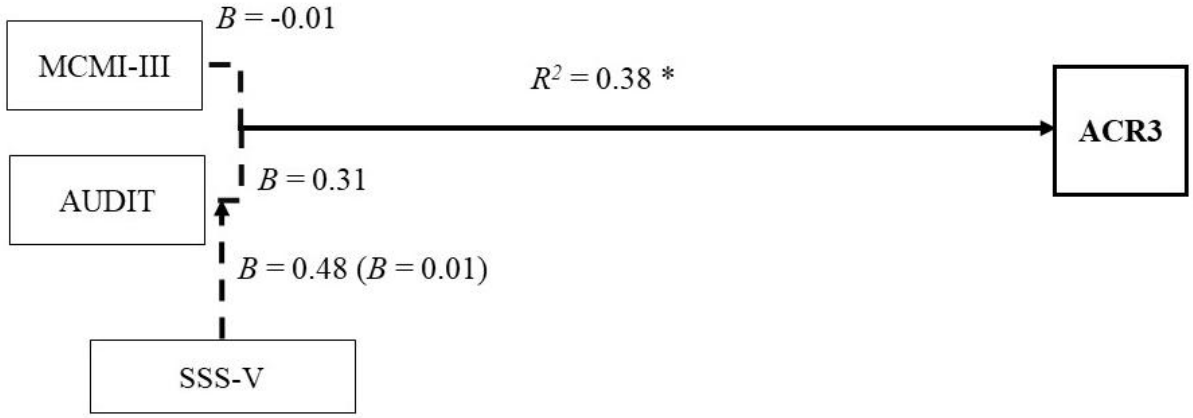
*Scatterplot of unstandardized predicted values from the full hierarchical multiple regression model of ACR3 and observed values of ACR3.*




Solid line = regression line; dashed line = 95% *CI*

**Figure 1-3.**

*Diagram of hierarchical regression for ACR3 and exploratory moderated regression results for sensation-seeking.*

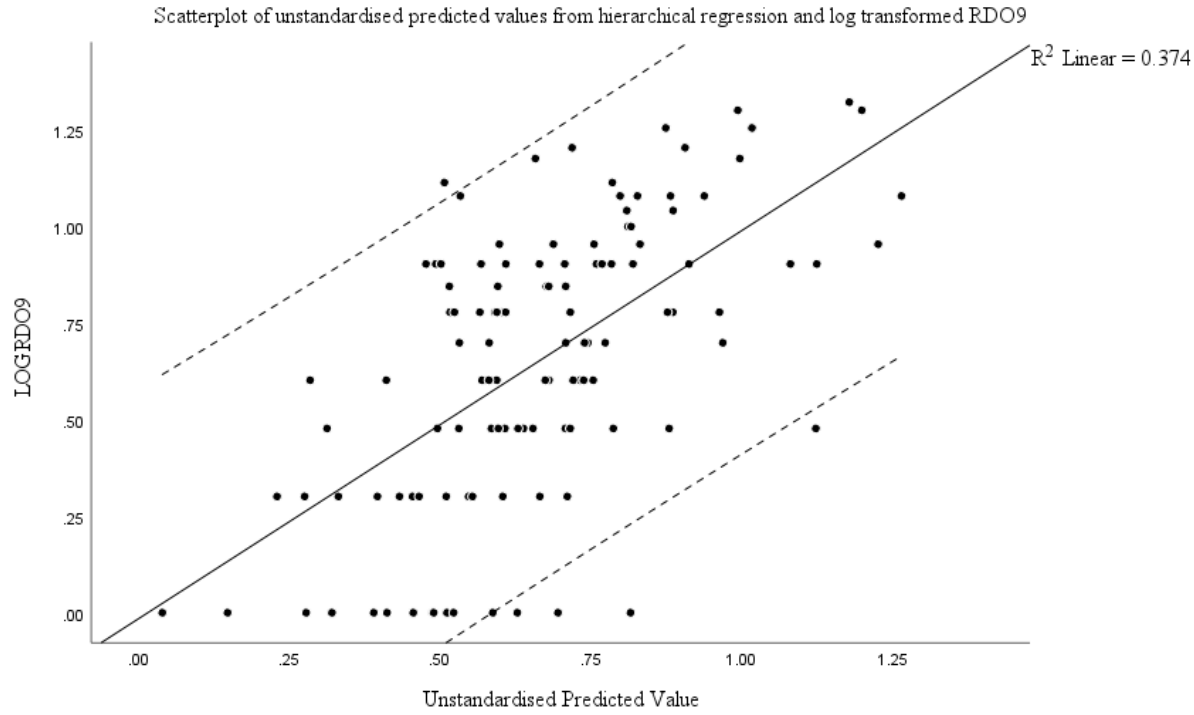



Solid line = significant relationship; dashed line = non-significant relationship; *B* coefficient for interaction term in parentheses.

* $p < .001$

**Figure 1-4.**

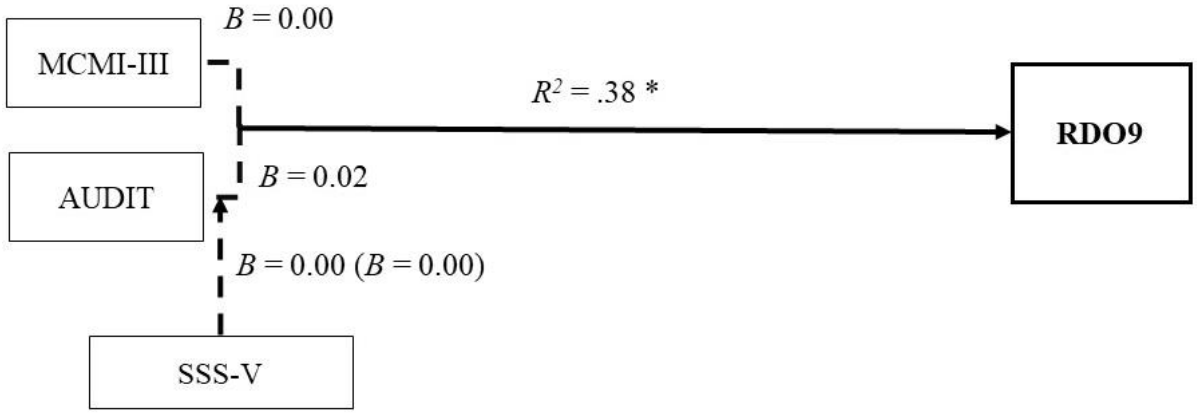
*Scatterplot of unstandardized predicted values from the full hierarchical multiple regression model of RDO9 and the log transformation of observed values of RDO9.*




Solid line = regression line; dashed line = 95% *CI*

**Figure 1-5.**

*Diagram of hierarchical regression for RDO9 and exploratory moderated regression results for sensation-seeking.*




Solid line = significant relationship; dashed line = non-significant relationship

*B* coefficient for interaction term in parentheses.

** $p < .001$

# Chapter 4: General Discussion

Road traffic crashes are responsible for 1.35 million fatalities worldwide each year (World Health Organization, 2018b). Human factors continue to be the largest contributors to these crashes with male drivers and DWI offenders posing a particularly high risk on the road (T. G. Brown et al., 2020; Jafarpour & Rahimi-Movaghar, 2014; McDonald et al., 2014; Perreault, 2016; Roidl et al., 2013; World Health Organization, 2018b). This dissertation identifies the link between depressed mood and alcohol use/misuse among male driver and DWI offender populations and explores their immediate and long-term contributions to risky driving. Two studies were conducted which explored these relationships. Several methodological and conceptual considerations arose from these studies and form the basis of the general discussion.

## Methodological Considerations

### *Risky Driving*

As opposed to closed tracks or on-the-road methods that are common in the broader driving literature, research on depressed mood and alcohol use/misuse in risky driving typically employ self-report questionnaires, driving simulation, and driving offence data (D. L. Fisher et al., 2011). Understanding these methodological differences is important for interpreting the literature in this area. The key differences among these methods relate to their safety, validity, and cost.

Self-report, the most common method of measuring risky driving, can provide additional insights into the underlying beliefs, attitudes, and intentions of drivers that cannot be as easily inferred through behavioural measures, such as driving simulation (Kaye et al., 2018). Self-report measures are, however, prone to biases, such as social desirability, making construct validity studies of particular importance (Kaye et al., 2018). They are also unable to deliver real-time metrics of risky driving manoeuvres. Benefitting from its safety, cost

feasibility, and ease of administration in comparison to more objective measures, self-report is a frequently-used and valid measure of risky driving in the literature.

Driving simulation is another frequently-employed method used as an experimental proxy for real-life driving, particularly in alcohol studies (Helland et al., 2013). Full experimental control and safer manipulation of driver factors (e.g., alcohol or other substance intoxication, distraction, drowsiness), vehicular factors (e.g., dashboard design, navigation system), and driving environment (e.g., road conditions, traffic flow, visibility) that are not feasible or safe on the actual road or on a closed track can be studied using driving simulation. A caveat of driving simulation is that a small but unknown proportion of the population experiences simulation sickness, which may include symptoms such as, eye strain, headache, vertigo, and nausea (Stoner et al., 2011). These participants are typically screened and excluded from driving simulation studies. In general, the use of driving simulation to exercise full experimental control in a laboratory environment, however, raises concerns about the external validity of driving simulation (Mullen et al., 2011).

In addressing validity concerns, driving simulation more often aims for relative validity. Relative validity is established by comparing the specific driving outcomes of interest in a simulator and on the road while also taking driving characteristics and simulator equipment into consideration (Mullen et al., 2011). Several measures derived from driving simulation validly predict on-the-road risky driving through behavioural metrics, such as those associated with SDLP and speed, in a wide range of driver populations, including young adult risky drivers and alcohol-intoxicated drivers (Creaser et al., 2011; Helland et al., 2013; Ouimet et al., 2011).

Driving offence data present another way of measuring risky driving, particularly among driving offender populations. While these data are retrieved from reliable government databases, offences are largely dependent on enforcement practices, which may fluctuate over

time and between jurisdictions (Perreault, 2016). Unless there is a crash resulting in injury or death, risky driving often goes undetected as it does not involve a direct victim (Perreault, 2016). As such, offences are estimated to be a gross underrepresentation of the true prevalence of risky driving. However, offence data remains important as a real-world outcome measure of risky driving in some driving offender samples.

### *Decision to Drive*

The decision to drive has been measured in both sober and alcohol intoxicated individuals primarily in experimental studies using self-report questionnaires. Recent studies have explored new methods of measuring the decision to drive, including incorporating self-report questionnaires into an observational study (Motschman, Hatz, et al., 2020) and using a behavioural measure in an experimental study (Ouimet et al., 2020). However, self-report remains the most well-established method of measuring the decision to drive.

Self-report measures are designed to solicit responses either on a scale of willingness or as a forced-choice decision. Survey questions may include having sober participants indicate the frequencies of their previous decisions to drive and provide "yes/no" forced-choice responses when presented with hypothetical future scenarios where they are given the decision to drive (Stephens et al., 2017). While examining sober participants provides insight into Decision to Drive 1, alcohol's cognitive effects limit the validity of this as a measure of Decision to Drive 2 which is made under the effects of alcohol (see **Figure 1-2**). The Decision to Drive 2 should, therefore, be measured by administering these tests to participants who are intoxicated by alcohol. The Willingness to Drive Rating (Beirness, 1987) has both sober and acutely alcohol-intoxicated participants indicate their willingness to drive in that moment using either a visual analog scale (Marczinski & Fillmore, 2009; Weafer & Fillmore, 2012) or using a dichotomous "yes/no" question (Amlung et al., 2014; Morris et al., 2014). The use of a dichotomous question (as opposed to a scaled question) has stronger

ecological validity as the nature of the resultant behaviour is also dichotomous (i.e., risky driving/not risky driving). These methodological features provide the context for the literature on the decision to drive discussed in this dissertation.

### *Alcohol Use*

**Administration.** Alcohol can be administered either orally or intravenously. Typically consumed orally in recreational and some experimental settings, the concentration of alcohol that travels through the blood and subsequently through the brain is largely dependent on individual differences and pharmacokinetic variables, such as metabolic rates, which may affect the reliability of its measurement (Strang et al., 2015; Wall et al., 2016). Intravenous administration of alcohol reduces the pharmacokinetic variability; however, it is more invasive and reduces the ecological validity compared to the sensory experience of tasting and smelling a beverage as one is drinking it (Zimmermann et al., 2013). Oral alcohol administration was the primary method of administering alcohol among studies which tested alcohol use in relation to risky driving or the decision to drive.

**Measurement.** Acute alcohol use is primarily measured by BAC, which can be sampled in blood or breath. While blood samples are a more direct method of measuring BAC and provide greater accuracy, their collection and processing require phlebotomy and toxicology (Jones, 2019). Breath alcohol concentration is more amenable to roadside testing using portable detection technology, such as Breathalyzer®, and ignition interlock devices as they are less invasive and allow for easier and faster data collection and results (Jones, 2019).

Portable detection of breath alcohol concentration is a typical method of preliminary breath testing (Jones, 2019). When a participant blows through a tube on the device, any ethanol that is present in the breath sample is oxidised, changing the potential of a fuel-cell inside the device, and creating an electronic signal, which can then be read by the experimenter (Jones, 2019). This method of detection produces results that are proportional to

the concentration of ethanol in the breath sample. In a legal context, preliminary breath testing is often followed up using evidential breath testing or blood sampling, however, as BAC measurements derived from breath and blood are highly correlated (r=0.936; Zuba, 2008), preliminary breath testing is often deemed sufficient for experimental testing and is the primary method used in the risky driving literature presented in this dissertation.

### *Alcohol Misuse*

The methods of measuring alcohol misuse vary widely and are critical to understanding the context of the literature. Alcohol misuse can be detected using self-report and through several direct and indirect biomarkers which remain detectable for longer periods of time than indicators of acute alcohol use. Direct biomarkers include alcohol metabolites present in blood, urine, nails, and hair; while indirect biomarkers are present in the blood and liver (Gonzalo et al., 2014). While the collection and processing of these biomarkers require laboratory personnel and resources, self-report measures can be administered more quickly and with minimal training (Couture et al., 2010; Sobell & Sobell, 2003). Self-report measures can also collect rich data on the frequency and patterns of alcohol misuse that are critical for its detection in alignment with diagnostic criteria (American Psychiatric Association, 2000; Rizer & Lusk, 2017; Sobell & Sobell, 2003). While the risky driving literature that are more focused on toxicology often measure alcohol misuse using biomarkers, the literature with a stronger psychiatric focus, such as the literature discussed in this dissertation, more often use self-report measures.

## Discussion of Findings

Manuscript 1 used a quasi-experimental, placebo-controlled design to investigate how a combination of subclinical depressed mood and 0.05% BAC in male drivers affected their decision to drive, and risky driving in a simulator. In order to pinpoint effects that may otherwise remain undetected, the study's thresholds for depressed mood and BAC were

intentionally set lower than the thresholds used in other studies in this area (other studies included participants with clinical diagnoses of depression and tested BACs ranging 0.06-0.10%). Depressed mood has detrimental effects on decision-making that are likely explained by greater reward-seeking and delay discounting (Ferrer et al., 2015; Loganathan et al., 2021; Szuhany et al., 2018). While the literature explores depressed mood as a predictor of risky driving in general, it does not isolate specific measures of risky driving that may be impacted (McDonald et al., 2014; Scott-Parker et al., 2012; Testa & Steinberg, 2010; Vingilis et al., 2014). It also relies exclusively on self-report measures of risky driving. The literature on sadness, however, identifies measures of risky driving, such as increased lane deviation, using driving simulation (Chan & Singhal, 2015; Jeon & Croschere, 2015). Alcohol use is likely to be employed as a maladaptive coping strategy for depressed mood – particularly in males (Mezquita et al., 2014). The literature show that despite falling below the Canadian *per se* legal threshold of 0.08% BAC, drivers who may be inclined to drive after "only a couple of drinks" are still influenced by the dose-dependent effects of alcohol on risky driving (Phillips et al., 2014), including greater SDLP and greater mean speed (T. L. Brown et al., 2019; Jongen et al., 2018; Meda et al., 2009). The non-significant findings across all risky driving and decision-to-drive hypotheses in Manuscript 1, as well as the exploratory hypotheses on the mediating effects of decision-making under risk and ambiguity, were contrary to findings in the literature and likely reflect the insufficient power of the study to detect the hypothesised effects. Several areas of improvement of the study methods were identified and are further discussed here.

In balancing the high granularity of the methods and research design used in Manuscript 1, Manuscript 2 adopted an observational, longitudinal design that investigated the predictive potential of a combination of depressed mood and alcohol misuse at baseline on self-reported risky driving 3 years after baseline and risky driving offences 9 years after

baseline in male DWI offenders. This study maintained the same subclinical threshold for depressed mood that was used in Manuscript 1 and examined alcohol misuse below the threshold for alcohol abuse or dependence (i.e., hazardous or harmful alcohol use). With much of the existing literature focused on participants with alcohol-related disorders, Manuscript 2 explored how chronic patterns of less severe alcohol misuse may affect risky driving outcomes. Risky driving outcomes were measured using: 1) a self-report questionnaire which was administered at baseline and annual follow-up visits for up to 3 years, and 2) risky driving offence data which were obtained from the SAAQ database at baseline and annually for up to 9 years. The findings identified that, among DWI offenders, alcohol misuse was a significant predictor of self-reported risky driving 3 years after baseline. The other results, including the exploratory analyses on the moderating effect of sensation-seeking, were null. A discussion of the study implications and interpretation of the null findings and research methods is presented here.

**Externalising Behaviours**

The non-significant findings for depressed mood for both studies may be partially explained by the use of the BDI-II and the MCMI-III, which measure depressed mood symptoms in accordance with DSM-IV-TR criteria. The BDI-II and MCMI-III are sensitive to the prominent cognitive, affective, and somatic symptoms of depressed mood. However, given that these studies were conducted on male drivers with a higher propensity for risky driving, a measure of depressed mood that is validated for use in this specific population may have been more appropriate. The literature suggests the predominance of externalising behaviours in response to a depressed mood among men who strongly conform to masculine norms (Rice et al., 2013). This profile is consistent with evolutionary theories, which suggest that driving has become a contemporary way for younger males to express their masculinity, particularly in light of media portrayals that idealise risky driving (Constantinou et al., 2011).

Future studies in this area should include conformity to masculine norms as a potential moderator of the effects of depressed mood on risky driving in male drivers. Using a measure of depressed mood that is more sensitive to these behaviours, such as the Male Depression Risk Scale (Rice et al., 2013), may also be beneficial.

**Emotional Intelligence**

Non-significant findings for hypotheses involving depressed mood may have also stemmed from individual differences in emotional intelligence. Emotional recognition and expression, and emotional regulation are two aspects of emotional intelligence that have been shown to influence risky driving. Poorer emotional recognition and expression predict both greater risky driving and negative emotions during driving (Hayley et al., 2017; Šeibokaitė et al., 2017). In other words, when presented with a risky situation, some drivers are less aware of the emotions they experience in response to the risky situation, which can result in risky driving (Hayley et al., 2017). Furthermore, poor use of emotional regulation strategies contributes to risky driving and the ability to control negative emotions during driving (Hayley et al., 2017; Šeibokaitė et al., 2017). This may be exemplified by suppression, a maladaptive strategy of emotional regulation, that is associated with greater externalising behaviour symptoms of depressed mood (Rice et al., 2013). Difficulty in regulating emotions also predicts greater risky driving (Trógolo et al., 2014). These difficulties correspond with the decreased amygdala-orbitofrontal cortex functional connectivity observed among individuals exhibiting high sensation-seeking and alcohol misuse (Crane et al., 2018). As this functional connectivity is critical for deliberate cognitive approaches to emotional regulation, men, in comparison to women, are more likely to rely heavily on automatic emotional regulation, which prioritises immediate rewards (Mcrae et al., 2008; Nigg, 2017). It is therefore likely that, in addition to regulating the effects of depressed mood, emotional regulation may also influence the effects of alcohol misuse on risky driving outcomes in male

drivers. The emotional recognition and expression, and emotional regulation facets of emotional intelligence that lead to risky driving may also affect decision-making processes.

**Sadness**

Another approach to explore depressed mood as a potential predictor of risky driving and the decision to drive may be by isolating the emotion of sadness. Studies on depressed mood in risky driving typically either recruit participants who are already experiencing a depressed mood prior to the study or participants who are experimentally-induced to experience sadness. Naturally-occurring depressed mood provides the benefit of greater generalisability of the results, but its heterogenous symptoms may also introduce greater variability in the sample. In addressing this heterogeneity, exploring the emotion of sadness – a cardinal symptom of depressed mood – may offer the greater specificity that this early research requires.

Pursuing research on the emotion of sadness with the intention of informing the literature on depressed mood, however, requires a nuanced understanding of their differences to avoid conflating them, as is often done. As opposed to moods which may last several days or weeks, emotions last only minutes (Deonna et al., 2015). Among the basic emotions, sadness is characterised by a shift in orientation from the external environment that is critical for safe driving towards internal and somatic states (Wager et al., 2015). Based on a meta-analysis of 148 neuroimaging studies on affect and emotion, sadness is characterised, in part, by increased activity of the Salience Network, Default Mode Network, and visceromotor system in tandem with decreased activity in the frontoparietal system that is largely responsible for executive functions, including stimulus valuation (Arias et al., 2020; Wager et al., 2015). As such, sadness may influence decision-making through its effects on stimulus valuation (similar to cognitive appraisal in the psychology literature, Dixon et al., 2017) and decreased attention to the external environment. In the context of driving, stimulus valuation

can represent decisions, such as deciding to speed or deciding to follow closely behind another vehicle, which are then followed by corresponding behaviours, such as pressing the gas or the brake pedal. These disadvantageous decisions may, therefore, predict risky driving behaviours.

The brief duration of natural experiences of sadness makes it difficult to study its effects on driving, however. As such, emotion induction procedures are used to experimentally induce sadness and allow for greater experimental control (Lench et al., 2011; Westermann et al., 1996). These procedures involve the use of stimuli such as film, pictures, music, and text passages validated to induce sadness (Lench et al., 2011). Studies on sadness in risky driving have elicited sadness experimentally by following these procedures (Chan & Singhal, 2015; Jallais et al., 2014; Jeon & Croschere, 2015; Megías, Maldonado, Catena, et al., 2011). A novel study design for future research may involve combining a sadness induction methodology with alcohol administration to explore their effects on risky driving in a simulator. This more rigid experimental design will provide a stronger foundation for research on sadness which may eventually support research on depressed mood in risky driving.

**Decision-making**

Exploratory hypotheses also did not establish decision-making as a mediator of the effects of depressed mood on risky driving. It remains plausible that decision-making mediates this potential relationship, however. Decision-making involves feedback loops along the corticolimbic pathway responsible for emotion and several different subdomains of executive function (Bechara et al., 2000; Rosenbloom et al., 2012; Z. Wang et al., 2019). Depressed mood promotes high reward-seeking and the prioritisation of immediate rewards, both of which increase disadvantageous decision-making outcomes (Ferrer et al., 2015; Szuhany et al., 2018). By adding to cognitive load, depressed mood makes it more difficult to

switch from automatic decision-making to the more deliberate decision-making that is associated with the inhibition of this pattern of reward-seeking (Kahneman, 2011). The mixed findings in the literature on decision-making in risky driving (T. G. Brown et al., 2016; Lev et al., 2008; Qu et al., 2020) suggests the existence of a more nuanced relationship, whereby having a low tolerance for uncertainty may be the mechanism of action underlying seeking immediate rewards, such as the thrill of risky driving (Kornilova et al., 2018; Qu et al., 2020). In extending this logic, since the decision to drive also represents the choice of an immediate reward as opposed to the delayed reward of safety, a low tolerance for uncertainty in decision-making may also plausibly predict the decision to drive. More specifically, in line with research on preferences for Deck B (Lin et al., 2007), drivers with a stronger preference for Deck B on the IGT (disadvantageous: small rewards at high frequency, but large losses at low frequency) may be more likely to decide to drive.

Further research on the IGT, however, demonstrates that, compared to the original scoring of Decks CD-AB that was proposed by Bechara et al. (1994), alternative scoring metrics of performance on Decks D-A are even more strongly correlated with composite scores on other related neuropsychological measures ($r^2$ = .087 vs. $r^2$ = .059; Gansler et al., 2011). Use of the IGT as a measure of decision-making has also been criticised. The first several card selections in the IGT are designed to give a false impression of the disadvantageous decks as being advantageous. As such, in order to obtain a successful score on the IGT, participants are required to update this learned information through reversal learning. Contrary to performance on the original IGT, when given a shuffled version of the IGT (thereby removing the tasks' dependence on reversal learning), decision-making in patients with ventromedial PFC lesions was no different from decision-making in controls (Fellows & Farah, 2005). Interpretation of the IGT may, therefore, be challenging since decision-making is confounded by reversal learning (Fellows, 2011). Further investigation of

decision-making as a potential underlying mechanism in the prediction of risky driving and the decision to drive by depressed mood and 0.05% BAC is highly encouraged. However, administering it along with another decision-making task, such as the Balloon Analogue Risk Task, may provide a more comprehensive assessment of decision-making (Buelow & Blaine, 2015).

## The Broader Scope of Neuropsychological and Personality Trait Effects on Risky Driving

### *Neuropsychological Function*

Although decision-making was selected as the focus of Manuscript 1, there are other neuropsychological functions that may be pertinent for devising a more holistic model of predictors of risky driving. Previous research has shown that neuropsychological domains, such as executive function and psychomotor function, are critical for safe driving (T. G. Brown et al., 2013). While psychomotor function, such as oculomotor movement and reaction time, can be largely automatic and operate at a more biological level, executive function is the mental effort required for top-down control of other neuropsychological domains, including psychomotor function (Diamond, 2013). It comprises a constellation of more complex neuropsychological abilities, including inhibition, working memory, and cognitive flexibility. These abilities underlie functions, such as decision-making, planning, reasoning, and problem-solving (Diamond, 2013). In addition, executive function is also heavily influenced by mood and cognitive factors (i.e., bottom-up processing), such as the presence of a depressed mood and acute alcohol (Koob & Volkow, 2016; Okon-Singer et al., 2015). Neuropsychological functioning is characterised by dynamic interactions between neural activity, cognition, and behaviour (Parsons & Duffield, 2019). These interactions can be influenced by psychological states and may, therefore, be useful in explaining how depressed mood may dictate its effects on risky driving.

The effects of depressed mood on working memory, in particular, are extensive (Ardila, 2008; Brinker et al., 2013). Individuals with dysphoria, for instance, display lower working memory capacity and impaired filtering of irrelevant information (Owens et al., 2012). This may be explained by the increase in ruminative thoughts (i.e., mind-wandering; Albert et al., 2018; Qu et al., 2015) that typically occur during a depressed mood. These ruminative thoughts add to working memory load, reducing the working memory capacity available for tasks, such as safe driving (Curci et al., 2013). This is also reflected by findings of increased speed deviation in a simulator among healthy drivers who were given a task to reduce their available working memory capacity (Heenan et al., 2014). These findings support a novel hypothesis that, in addition to decision-making, depressed mood likely contributes to risky driving through its deleterious effects on working memory.

***Personality Traits***

The effects of personality traits on risky driving also extend beyond sensation-seeking. Personality traits represent individual differences in an individual's temperament and character (Celikel, 2011) that may help to explain why some drivers intentionally expose themselves and others to danger by engaging in risky driving. Among risky drivers, sensation-seeking is accompanied by a cluster of other personality traits including low agreeableness, high reward sensitivity, and motor impulsivity which may provide additional avenues for future studies on the role of alcohol misuse (T. G. Brown et al., 2015, 2016, 2017; Constantinou et al., 2011; Scott-Parker & Weston, 2017; Starkey & Isler, 2016). Preliminary findings also suggest the role of negative urgency in risky driving (Pearson et al., 2013).

Low agreeableness may be useful for predicting risky driving among DWI offenders. One cross-sectional study identified low agreeableness as a personality trait distinguishing drivers with a history of convictions for both DWI and risky driving from drivers without a

history of driving convictions (T. G. Brown et al., 2016). Notably, drivers with a history of only DWI convictions and drivers with a history of only risky driving convictions were not characterised by low agreeableness, indicating that low agreeableness may be a key characteristic of DWI offenders who may be at high-risk for engaging in risky driving. These findings are consistent with research establishing low agreeableness as a significant predictor of self-reported DWI and risky driving, particularly among males (Luht et al., 2017; Starkey & Isler, 2016).

Alongside sensation-seeking, reward sensitivity is also present in both risky drivers and DWI offenders (T. G. Brown et al., 2015, 2016; Scott-Parker & Weston, 2017). These personality traits are both rooted in the BAS, while motor impulsivity is rooted in the BIS (Scott-Parker & Weston, 2017). BAS is responsible for behaviours that pursue reward and non-punishment and, conversely, BIS is responsible for behaviours that avoid punishment and non-reward (Scott-Parker & Weston, 2017). Risky driving may arise from the dysregulation of these two systems. The high reward sensitivity observed among risky drivers is indicative of an overactive BAS. Reward sensitivity relates to the degree to which rewards, such as “feeling good” while speeding, are motivating and perpetuate repeated behaviours (Scott-Parker & Weston, 2017). Evidence of high sensation-seeking is consistent with the evidence of high reward sensitivity in that it also suggests an overactive BAS. High motor impulsivity is defined as “acting on the spur of the moment” and suggests the underactivity of BIS as individuals are less likely to be deterred from punishment (Patton et al., 1995; Scott-Parker & Weston, 2017). In the context of depressed mood and alcohol misuse, low agreeableness, greater reward sensitivity, and motor impulsivity emerge as additional potential predictors of the effects of alcohol misuse on risky driving.

Depressed mood may give rise to risky driving through negative urgency, a facet of impulsivity. Negative urgency describes the propensity to act impulsively while experiencing

a negative mood (Cyders & Smith, 2008). At a more general level, negative urgency mediates the effects of negative mood valence on risk-taking (Cyders et al., 2015). Preliminary evidence also indicates that negative urgency may specifically predict risky driving (Pearson et al., 2013). Furthermore, negative urgency is a strong predictor of alcohol misuse (explains 34% of the variance in alcohol misuse; Coskunpinar et al., 2013), particularly when motivated by the intention of alleviating negative moods (Wolkowicz et al., 2021). Negative urgency is associated with greater alcohol craving, seeking, area under the alcohol exposure curve, and higher peak BAC (VanderVeen et al., 2016). However, this has not been tested in a DWI offender population and may benefit from research first establishing its usefulness as a characteristic of this population.

***Overlap in the effects of neuropsychological function and personality traits***

For the purposes of this research, decision-making was investigated in the context of depressed mood and sensation-seeking was explored in relation to alcohol misuse. However, it is important to note that the pathways of neuropsychological functioning and personality traits are not mutually exclusive.

A recent study found that sensation-seeking positively predicted risky driving in individuals high in delay discounting (Qu et al., 2020). Interestingly, despite the neuropsychology of greater delay discounting being consistent with increased risky behaviours, these findings indicated that delay discounting negatively predicted risky driving. This suggests that, in addition to links between delay discounting and impulsivity, individuals high in delay discounting may also be driven by a low tolerance for the uncertainty of delayed rewards, therefore preferring the relative certainty of immediate rewards (Qu et al., 2020). Having a low tolerance for uncertainty has been associated with more advantageous decision-making under ambiguity, but poorer overall decision-making compared to individuals with a high tolerance for uncertainty (Kornilova et al., 2018).

The effects of sensation-seeking on risky driving are also likely influenced by inhibition. Findings from a functional magnetic resonance imaging study found that, during a task involving inhibition of risk-taking, individuals high in sensation-seeking (compared to low sensation-seeking) experienced greater activation of the bilateral anterior cingulate cortex and the right anterior insula, areas correlated with cognitive control and negative emotion, respectively (Zheng et al., 2017). This suggests that, for individuals high in sensation-seeking, inhibition may be more effortful.

Taken together, it is likely that a combination of neuropsychological functions and personality traits, in addition to physiological markers and socio-demographic variables form risk clusters for the prediction of risky driving in at-risk populations. The inclusion of each of these factors is important for refining our ability to predict risky driving.

**Implications**

This dissertation investigated predictors of risky driving in two at-risk groups – male drivers and male DWI offenders. The "micro" lens of Manuscript 1 employed a quasi-experimental design, whereby the researchers were able to directly manipulate participants' BAC and test risky driving in real-time. Manuscript 1 was the first investigation conducted on depressed mood using a driving simulator – a method that allows for the safe and direct measurement of driving behaviour. This balanced well with the "macro" lens of Manuscript 2, whereby the researchers observed participants' real-world risky driving outcomes over a period of 9 years. It also expanded beyond conceptions of alcohol's role in driving risk among DWI offenders being limited to acute alcohol use. Through conducting these complementary studies and in the context of the surrounding literature, this dissertation established a more comprehensive understanding of how depressed mood and alcohol use/misuse may contribute to a variety of risky driving outcomes in at-risk groups.

The strong research designs, findings of alcohol misuse as a predictor of risky driving 3 years after baseline, and recommendations for further methodological considerations based on the learnings from these two studies are well-poised to inform future research on depressed mood and alcohol use/misuse in these populations. The medium effect sizes in Manuscript 1 call for increased attention from traffic safety and policy researchers on the effects of 0.05% BAC on the decision to drive and risky driving outcomes. Improving the prediction of risky driving in these at-risk populations also has implications for driver education and awareness and for targeted interventions during the re-licensing process. The findings from Manuscript 2 contribute to a clearer profile of DWI offenders who are likely to engage in non-DWI risky driving and have implications for the identification and/or design of interventions that are tailored toward this subset of DWI offenders. Integrating these targeted interventions to create a more rigorous and effective re-licensing process will further mitigate the risk posed by these DWI offenders.

**Future Studies**

The importance of the research findings and the potential impact of future studies in this field provide strong support for the continuation of this research. Future studies may wish to replicate and build on the findings of alcohol misuse as a predictor of risky driving 3 years later in a DWI offender population. With 34.9% of DWI offenders in Manuscript 2 reporting symptoms of hazardous or harmful alcohol use, this represents a clinically significant proportion of DWI offenders for which interventions may be targeted to reduce risky driving. Further corroboration of these results may then shift the focus of research in this area towards intervention strategies. While brief motivational interviewing has been established as an effective intervention for reducing risky driving among DWI recidivists (Moxley-Kelly et al., 2019; Ouimet et al., 2013), research is needed to determine its effectiveness in predicting risky driving among first-time DWI offenders. Once support for an effective intervention has

been established, this research may then advance to inform criminal justice policies targeting DWI offenders with alcohol misuse who wish to be relicensed.

First and foremost, future studies should prioritise research designs and statistical methods that produce findings with sufficient power to provide more conclusive interpretations of the results. While both study designs presented in this dissertation are subject to a trade-off between internal and external validity, when taken together, they provide a balanced examination of the effects of combined depressed mood and alcohol use on risky driving. Manuscript 1 uses a quasi-experimental design to manipulate and control acute alcohol doses within the lab and assesses decision-making, decision to drive, and risky driving metrics in real-time. Manuscript 2 is an observational study that analyses participants' natural patterns of alcohol use and real-world risky driving offences over a period of 9 years. Building on these secondary analyses, future studies that are designed specifically to test the combined effects of depressed mood and alcohol use on risky driving as their primary analyses may be able to further refine the risk profile of risky drivers. This would strengthen our ability to predict and prevent injury and death as a result of road traffic crashes. In addition to ensuring more adequately powered analyses, future studies seeking to elucidate the effects of depressed mood on risky driving and the decision to drive may benefit from exploring how conforming to masculine norms, emotional recognition and expression, and emotional regulation may affect this relationship. Study designs incorporating sadness may help to lay the groundwork for research on the broader construct of depressed mood. Decision-making may also be considered as a potential mediator of the effects of 0.05% BAC on risky driving and the decision to drive. Guided by the methodological and conceptual considerations outlined in this dissertation, future research will be better equipped to identify the nature of depressed mood's role in risky driving, particularly in the context of alcohol use/misuse.

Attention to demographic disparities between samples and the populations they represent are also critical. For example, 93.0% of the participants in Manuscript 1 had received post-secondary education. This was not a representative sample of the general population of age-matched males in Montreal, of whom only 68.9% have had post-secondary education (Statistics Canada, 2017). Beyond improving the generalisability of the results, ensuring that the sample is representative of the population may contribute to our understanding of socioeconomic determinants of risky driving, informing primary prevention strategies.

Road traffic crashes are an ongoing societal problem that take and permanently change lives, while negatively impacting families, communities, workplaces, and economies. Notably, the DWI offenders included in Manuscript 2 resided in the Montreal metropolitan area. Yet, while the three largest census metropolitan areas in Canada (Toronto, Montreal, and Vancouver) account for 35% of its population, only 8% of DWI offences occur in these areas (Perreault, 2016). Reasons for this disparity likely include the longer travel distances, higher speeds, and lower availability of alternative transportation in rural settings (Perreault, 2016). With similar geographical trends reflected in the United States (Webb, 2020), data show that 54% of American Indians/Alaska Natives live rurally and are 3 times as likely to die from road traffic crashes (First Nations Development Institute, 2017; Governors Highway Safety Association, 2021). Although data on the racial demographics of road traffic crashes are not available in Canada, this is particularly concerning given the similarly high proportion of Canada's Indigenous peoples that live rurally (58.8%). The disproportionate impact of road traffic crashes on rural and Indigenous communities calls for continued research to identify factors contributing to road traffic crashes among DWI offenders in a rural context. This research should be founded by community-specific considerations and guided by the methodological and conceptual considerations presented in this dissertation. With injury

prevention having become even more critical due to the exhaustion of healthcare systems and the death care industry by the current COVID-19 pandemic (Bouthillier et al., 2021), continued research aimed at preventing road traffic crashes also shows strong potential for easing these burdens during future health crises.

# Chapter 5: Conclusion

Road traffic crashes continue to be the leading cause of death among individuals age 5-29 and injury of countless others (World Health Organization, 2018b). The direct impact on injured victims can be devastating, contributing to psychological distress and financial hardship (Bachani et al., 2017). Families are additionally impacted by the additional responsibility of caregiving for injured victims and/or grieving after a death (Bachani et al., 2017). Communities, workplaces, and societies also suffer from the loss of productivity and increased strain on healthcare and justice systems (Bachani et al., 2017).

While much traffic safety research has been rightfully dedicated to alcohol at or exceeding 0.08% BAC, this research conducted analyses of alcohol at 0.05% BAC, studied alcohol misuse, and uniquely incorporated depressed mood. Depressed mood provides the context for increased alcohol use/misuse, particularly among men; thereby likely increasing risk in an already at-risk population. Importantly, the longitudinal analyses of chronic behaviours also expand on the common conceptualisation of alcohol's effects on driving being limited to acute intoxication and DWI outcomes. The influences of decision-making and sensation-seeking were explored as potential neuropsychological functioning and personality trait factors in the prediction of risky driving.

Therefore, by examining the combined effects of depressed mood and alcohol use/misuse on the decision to drive and risky driving, evidence emerged showing alcohol misuse as a significant predictor of risky driving 3 years after baseline among male first-time DWI offenders. With much of the existing research on DWI offenders focusing on their risk for DWI recidivism, these findings call for research examining DWI offenders' risk for committing a broader range of risk-taking behaviours, particularly risky driving. More nuanced methods of measuring the profile of depressed mood with externalising behaviours in this population are discussed.

With the support of replication studies, the improved prediction of risky driving may inform intervention strategies aimed at reducing risky driving among male first-time DWI offenders, thereby better preventing injuries and untimely deaths as a result of road traffic crashes. Important theoretical and methodological considerations, such as the measurement of externalising behaviours associated with depressed mood in males and the addition of measures of emotional intelligence, set the stage for future traffic safety studies on depressed mood. By continuing to improve the prediction of risky driving, we hope to inform the targeting of interventions, driver education, and relicensing policies for high-risk drivers. This research addressed two key risk groups: male drivers and male DWI offenders. It also addressed key factors which contribute to road traffic crashes. As such, this research strongly supports Canada's Road Safety Strategy 2025 which calls for research on high-risk drivers with the long-term aim of zero road traffic crash fatalities and serious injuries. It also builds toward the United Nations' Agenda 2030 target of halving the number of global deaths and injuries resulting from road traffic crashes.

## References

Albert, D. A., Ouimet, M. C., Jarret, J., Cloutier, M. S., Paquette, M., Badeau, N., & Brown, T. G. (2018). Linking mind wandering tendency to risky driving in young male drivers. *Accident Analysis and Prevention*, *111*(September 2017), 125–132. https://doi.org/10.1016/j.aap.2017.11.019

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders IV TR*. American Psychiatric Association.

Amlung, M. T., Morris, D. H., & McCarthy, D. M. (2014). Effects of acute alcohol tolerance on perceptions of danger and willingness to drive after drinking. *Psychopharmacology*, *231*(22), 4271–4279. https://doi.org/10.1007/s00213-014-3579-1

Ardila, A. (2008). On the evolutionary origins of executive functions. *Brain and Cognition*, *68*(1), 92–99. https://doi.org/10.1016/j.bandc.2008.03.003

Arias, J. A., Williams, C., Raghvani, R., Aghajani, M., Baez, S., Belzung, C., Booij, L., Busatto, G., Chiarella, J., Fu, C. H., Ibanez, A., Liddell, B. J., Lowe, L., Penninx, B. W. J. H., Rosa, P., & Kemp, A. H. (2020). The neuroscience of sadness: A multidisciplinary synthesis and collaborative review. *Neuroscience and Biobehavioral Reviews*, *11*, 199–228. https://doi.org/10.1016/j.neubiorev.2020.01.006

Bachani, A. M., Peden, M., Gururaj, G., Norton, R., & Hyder, A. A. (2017). Road traffic injuries. In C. N. Mock, R. Nugent, O. Kobusingye, & K. R. Smith (Eds.), *Disease control priorities: Injury prevention and environmental health* (3rd ed., pp. 35–54). The World Bank. https://doi.org/10.1596/978-1-4648-0522-6_ch7

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition*, *50*, 7–15.

https://doi.org/10.1016/0010-0277(94)90018-3

Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, decision making and the orbitofrontal cortex. *Cerebral Cortex, 10*(3), 295–307. https://doi.org/10.1093/cercor/10.3.295

Beirness, D. J. (1987). Self-estimates of blood alcohol concentration in drinking-driving context. *Drug and Alcohol Dependence, 19*, 79–90.

Bouthillier, M.-E., Lorange, M., Legault, S., Wade, L., Dahine, J., Latreille, J., Germain, I., Grégoire, R., Montpetit, P., Prady, C., Thibault, E., Dumez, V., Opatrny, L., & Bouthillier, M. E. (2021). Prioritizing surgery during the COVID-19 pandemic: The Quebec guidelines. *Canadian Journal of Surgery, 64*(1), E103–E107. https://doi.org/10.1503/cjs.022220

Brinker, J. K., Campisi, M., Gibbs, L., & Izzard, R. (2013). Rumination, mood and cognitive performance. *Psychology, 04*(03), 224–231. https://doi.org/10.4236/psych.2013.43A034

Brown, T. G., Ouimet, M. C., Bhatti, J., Smyth, T., Wells, S., Di Leo, I., & El Amrani, L. (2013). The neuropsychology of risk taking: Driving while impaired by alcohol. In J.-P. Assailly (Ed.), *Psychology of risk-taking* (pp. 27–51). Nova Science Publishers. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=psyc10&NEWS=N&AN=2013-14199-002

Brown, T. G., Ouimet, M. C., Eldeb, M., Tremblay, J., Vingilis, E., Nadeau, L., Pruessner, J., & Bechara, A. (2016). Personality, executive control, and neurobiological characteristics associated with different forms of risky driving. *PLOS ONE, 11*(2), e0150227. https://doi.org/10.1371/journal.pone.0150227

Brown, T. G., Ouimet, M. C., Eldeb, M., Tremblay, J., Vingilis, E., Nadeau, L., Pruessner, J., & Bechara, A. (2017). The effect of age on the personality and cognitive characteristics of

three distinct risky driving offender groups. *Personality and Individual Differences*, *113*, 48–56. https://doi.org/10.1016/j.paid.2017.03.007

Brown, T. G., Ouimet, M. C., Nadeau, L., Tremblay, J., Gianoulakis, C., Couture, S., & Moxley-Kelly, N. (2020). Cortisol stress response predicts 9-year risky driving convictions in male first-time driving-while-impaired offenders. *Psychopharmacology*, *237*, 177–187. https://doi.org/10.1007/s00213-019-05359-0

Brown, T. G., Ouimet, M. C., Nadeau, L., Tremblay, J., & Pruessner, J. (2015). Sex differences in the personality and cognitive characteristics of first-time DWI offenders. *Journal of Studies on Alcohol and Drugs*, *76*(6), 928–934.

Brown, T. L., Lee, J. D., & Fiorentino, D. (2019). Effects of alcohol at 0.05% blood alcohol concentration (BAC) on low speed urban driving. *Traffic Injury Prevention*, *19*(sup2), S175–S177. https://doi.org/10.1080/15389588.2018.1532220

Buelow, M. T., & Blaine, A. L. (2015). The assessment of risky decision making: A factor analysis of performance on the Iowa Gambling Task, Balloon Analogue Risk Task, and Columbia Card Task. *Psychological Assessment*, *27*(3), 777–785. https://psycnet-apa-org.proxy3.library.mcgill.ca/fulltext/2015-00695-001.pdf

Celikel, F. C. (2011). Personality traits: Reflections in the brain. In *Personality traits: Theory, testing and influences* (pp. 161–174).

Chan, M., & Singhal, A. (2015). Emotion matters: Implications for distracted driving. *Safety Science*, *72*, 302–309. https://doi.org/10.1016/j.ssci.2014.10.002

Constantinou, E., Panayiotou, G., Konstantinou, N., Loutsiou-Ladd, A., & Kapardis, A. (2011). Risky and aggressive driving in young adults: Personality matters. *Accident Analysis and Prevention*, *43*(4), 1323–1331. https://doi.org/10.1016/j.aap.2011.02.002

Coskunpinar, A., Dir, A. L., & Cyders, M. A. (2013). Multidimensionality in impulsivity and alcohol use: A meta-analysis using the UPPS model of impulsivity. *Alcoholism: Clinical and Experimental Research*, *37*(9), 1441–1450. https://doi.org/10.1111/acer.12131

Couture, S., Brown, T. G., Tremblay, J., Ng, N. M. K., Kin, Y., Ouimet, M. C., & Nadeau, L. (2010). Are biomarkers of chronic alcohol misuse useful in the assessment of DWI recidivism status? *Accident Analysis and Prevention*, *42*, 307–312. https://doi.org/10.1016/j.aap.2009.08.016

Crane, N. A., Gorka, S. M., Phan, K. L., & Childs, E. (2018). Amygdala-orbitofrontal functional connectivity mediates the relationship between sensation seeking and alcohol use among binge-drinking adults. *Drug and Alcohol Dependence*, *192*, 208–214. https://doi.org/10.1016/j.drugalcdep.2018.07.044

Creaser, J. I., Ward, N. J., & Rakauskas, M. E. (2011). Acute alcohol impairment research in driving simulators. In Donald L Fisher, M. Rizzo, J. K. Caird, & J. D. Lee (Eds.), *Handbook of driving simulation for engineering, medicine, and psychology* (pp. 44-1-44–49). CRC Press.

Curci, A., Lanciano, T., Soleti, E., & Rimé, B. (2013). Negative emotional experiences arouse rumination and affect working memory capacity. *Emotion*, *13*(5), 867–880. https://doi.org/10.1037/a0032492

Cyders, M. A., Dzemidzic, M., Eiler, W. J., Coskunpinar, A., Karyadi, K. A., & Kareken, D. A. (2015). Negative urgency mediates the relationship between amygdala and orbitofrontal cortex activation to negative emotional stimuli and general risk-taking. *Cerebral Cortex*, *25*, 4094–4102. https://doi.org/10.1093/cercor/bhu123

Cyders, M. A., & Smith, G. T. (2008). Emotion-based dispositions to rash action: Positive and

negative urgency. *Psychol Bull*, *134*(6), 807–828. https://doi.org/10.1037/a0013341

Deonna, J., Tappolet, C., & Teroni, F. (2015). Emotion, philosophical issues about. *Wiley Interdisciplinary Reviews: Cognitive Science*, *6*(3), 193–207. https://doi.org/10.1002/wcs.1342

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750.Executive

Dixon, M. L., Thiruchselvam, R., Todd, R., & Christoff, K. (2017). Emotion and the prefrontal cortex: An integrative review. *Psychological Bulletin*, *143*(10), 1033–1081. https://doi.org/10.1037/bul0000096

Fellows, L. K. (2011). The neurology of value. In J. A. Gottfried (Ed.), *Neurobiology of Sensation and Reward* (pp. 351–568). CRC Press.

Fellows, L. K., & Farah, M. J. (2005). Different underlying impairments in decision-making following ventromedial and dorsolateral frontal lobe damage in humans. *Cerebral Cortex*, *15*(1), 58–63. https://doi.org/10.1093/cercor/bhh108

Ferrer, R., Klein, W., Lerner, J., Reyna, V., & Keltner, D. (2015). Emotions and health decision making: Extending the appraisal tendency framework to improve health and healthcare. In C. A. Roberto & I. Kawachi (Eds.), *Behavioral Economics and Public Health* (pp. 1–35). Oxford University Press. https://doi.org/10.1093/med/9780199398331.001.0001

First Nations Development Institute. (2017). *Twice invisible: Understanding rural Native America* (Issue April). https://www.usetinc.org/wp-content/uploads/bvenuti/WWS/2017/May 2017/May 8/Twice Invisible - Research Note.pdf

Fisher, D. L., Rizzo, M., Caird, J. K., & Lee, J. D. (2011). Handbook of driving simulation for engineering, medicine, and psychology: An Overview. In *Handbook of driving simulation*

*for engineering, medicine, and psychology* (pp. 1-1-1–16). CRC Press.

Gansler, D. A., Jerram, M. W., Vannorsdall, T. D., & Schretlen, D. J. (2011). Comparing alternative metrics to assess performance on the Iowa Gambling Task. *Journal of Clinical and Experimental Neuropsychology*, *33*(9), 1040–1048. https://doi.org/10.1080/13803395.2011.596820

Gonzalo, P., Radenne, S., & Gonzalo, S. (2014). Biomarkers of chronic alcohol misuse. *Current Biomarker Findings*, *4*, 9–22. https://doi.org/10.2147/cbf.s37239

Governors Highway Safety Association. (2021). *An analysis of traffic fatalities by race and ethnicity*. https://www.ghsa.org/resources/Analysis-of-Traffic-Fatalities-by-Race-and-Ethnicity21

Hayley, A. C., De Ridder, B., Stough, C., Ford, T. C., & Downey, L. A. (2017). Emotional intelligence and risky driving behaviour in adults. *Transportation Research Part F*, *49*, 124–131. https://doi.org/10.1016/j.trf.2017.06.009

Heenan, A., Herdman, C. M., Brown, M. S., & Robert, N. (2014). Effects of conversation on situation awareness and working memory in simulated driving. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *56*(6), 1077–1092. https://doi.org/10.1177/0018720813519265

Helland, A., Jenssen, G. D., Lervåg, L. E., Westin, A. A., Moen, T., Sakshaug, K., Lydersen, S., Mørland, J., & Slørdal, L. (2013). Comparison of driving simulator performance with real driving after alcohol intake: A randomised, single blind, placebo-controlled, cross-over trial. *Accident Analysis and Prevention*, *53*, 9–16. https://doi.org/10.1016/j.aap.2012.12.042

Jafarpour, S., & Rahimi-Movaghar, V. (2014). Determinants of risky driving behavior: A narrative review. *Medical Journal of the Islamic Republic of Iran*, *28*(1), 1–8.

Jallais, C., Gabaude, C., & Paire-ficout, L. (2014). When emotions disturb the localization of road elements: Effects of anger and sadness. *Transportation Research Part F-Traffic Psychology and Behaviour*, *23*, 125–132. https://doi.org/10.1016/j.trf.2013.12.023

Jeon, M., & Croschere, J. (2015). Sorry, I'm late; I'm not in the mood: Negative emotions lengthen driving time. *International Conference on Engineering Psychology and Cognitive Ergonomics*, *9174*, 237–244. https://doi.org/10.1007/978-3-319-20373-7_22

Jones, A. W. (2019). Alcohol, its analysis in blood and breath for forensic purposes, impairment effects, and acute toxicity. *Wiley Interdisciplinary Reviews: Forensic Science*, *1*(e1353), 1–32. https://doi.org/10.1002/wfs2.1353

Jongen, S., Van Der Sluiszen, N. N. J. J. M., Brown, D., & Vuurman, E. F. P. M. (2018). Single- and dual-task performance during on-the-road driving at a low and moderate dose of alcohol: A comparison between young novice and more experienced drivers. *Human Psychopharmacology: Clinical and Experimental*, *33*, e2661. https://doi.org/10.1002/hup.2661

Kahneman, D. (2011). Cognitive ease. In *Thinking, fast and slow* (pp. 59–70). Penguin Books.

Kaye, S.-A., Lewis, I., & Freeman, J. (2018). Comparison of self-report and objective measures of driving behavior and road safety: A systematic review. *Journal of Safety Research*, *65*, 141–151. https://doi.org/10.1016/j.jsr.2018.02.012

Koob, G. F., & Volkow, N. D. (2016). Neurobiology of addiction: A neurocircuitry analysis. *Lancet Psychiatry*, *3*(8), 760–773. https://doi.org/10.1016/S2215-0366(16)00104-8

Kornilova, T. V., Chumakova, M. A., & Kornilov, S. A. (2018). Tolerance and intolerance for uncertainty as predictors of decision making and risk acceptance in Gaming Strategies of The Iowa Gambling Task. *Psychology in Russia: State of the Art*, *11*(3), 86–95.

https://doi.org/10.11621/pir.2018.0306

Lench, H. C., Flores, S. A., & Bench, S. W. (2011). Discrete emotions predict changes in cognition, judgment, experience, behavior, and physiology: A meta-analysis of experimental emotion elicitations. *Psychological Bulletin*, *137*(5), 834–855. https://doi.org/10.1037/a0024244

Lev, D., Hershkovitz, E., & Yechiam, E. (2008). Decision making and personality in traffic offenders: A study of Israeli drivers. *Accident Analysis and Prevention*, *40*, 223–230. https://doi.org/10.1016/j.aap.2007.05.009

Lin, C.-H., Chiu, Y.-C., Lee, P.-L., & Hsieh, J.-C. (2007). Is deck B a disadvantageous deck in the Iowa Gambling Task? *Behavioral and Brain Functions*, *3*(16). https://doi.org/10.1186/1744-9081-3-16

Loganathan, K., Lv, J., Cropley, V., Ho, E. T. W., & Zalesky, A. (2021). Associations between delay discounting and connectivity of the valuation-control system in healthy young adults. *Neuroscience*, *452*, 295–310. https://doi.org/10.1016/j.neuroscience.2020.11.026

Luht, K., Eensoo, D., Tooding, L.-M., & Harro, J. (2017). The association of measures of the serotonin system, personality, alcohol use, and smoking with risk-taking traffic behavior in adolescents in a longitudinal study. *Nordic Journal of Psychiatry*, *72*(1), 9–16. https://doi.org/10.1080/08039488.2017.1368702

Marczinski, C. A., & Fillmore, M. T. (2009). Acute alcohol tolerance on subjective intoxication and simulated driving performance in binge drinkers. *Psychology of Addictive Behaviors*, *23*(2), 238–247. https://doi.org/10.1037/a0014633

McDonald, C. C., Sommers, M. S., & Fargo, J. D. (2014). Risky driving, mental health, and health-compromising behaviours: Risk clustering in late adolescents and adults. *Injury*

*Prevention*, *20*(6), 365–372. https://doi.org/10.1136/injuryprev-2014-041150

Mcrae, K., Ochsner, K. N., Mauss, I. B., Gabrieli, J. J. D., & Gross, J. J. (2008). Gender differences in emotion regulation: An fMRI study of cognitive reappraisal. *Group Processes & Intergroup Relations*, *11*(2), 143–162. https://doi.org/10.1177/1368430207088035

Meda, S. A., Calhoun, V. D., Astur, R. S., Turner, B. M., Ruopp, K., & Pearlson, G. D. (2009). Alcohol dose effects on brain circuits during simulated driving: An fMRI study. *Human Brain Mapping*, *30*(4), 1257–1270. https://doi.org/10.1002/hbm.20591

Megías, A., Maldonado, A., Catena, A., Di Stasi, L. L., Serrano, J., & Cándido, A. (2011). Modulation of attention and urgent decisions by affect-laden roadside advertisement in risky driving scenarios. *Safety Science*, *49*(10), 1388–1393. https://doi.org/10.1016/j.ssci.2011.06.001

Mezquita, L., Ibáñez, M. I., Moya, J., Villa, H., & Ortet, G. (2014). A longitudinal examination of different etiological pathways to alcohol use and misuse. *Alcoholism: Clinical and Experimental Research*, *38*(6), 1770–1779. https://doi.org/10.1111/acer.12419

Morris, D. H., Treloar, H. R., Niculete, M. E., & Mccarthy, D. M. (2014). Perceived danger while intoxicated uniquely contributes to driving after drinking. *Alcoholism: Clinical and Experimental Research*, *38*(2), 521–528. https://doi.org/10.1111/acer.12252

Motschman, C. A., Hatz, L. E., McCarty, K. N., Merkle, E. C., Trull, T. J., & Mccarthy, D. M. (2020). Event-level predictors of alcohol-impaired driving intentions. *Journal of Studies on Alcohol and Drugs*, *81*(September), 647–654.

Moxley-Kelly, N., Ouimet, M. C., Dongier, M., Chanut, F., Tremblay, J., Marcantoni, W., & Brown, T. G. (2019). The role of behavioural phenotypes on impaired driving recidivism risk and treatment response to brief intervention: A preliminary study. *Alcoholism: Clinical*

*and Experimental Research*, *43*(2), 324–333. https://doi.org/10.1111/acer.13935

Mullen, N., Charlton, J., Devlin, A., & Bedard, M. (2011). Simulator validity: Behaviors observed on the simulator and on the road. In D. L. Fisher, M. Rizzo, J. Caird, & J. D. Lee (Eds.), *Handbook of driving simulation for engineering, medicine, and psychology* (pp. 13.1-13.18). CRC Press.

Nigg, J. T. (2017). Annual research review: On the relations among self-regulation, self-control, executive functioning, effortful control, cognitive control, impulsivity, risk-taking, and inhibition for developmental psychopathology. *Journal of Child Psychology and Psychiatry*, *58*(4), 361–383. https://doi.org/10.1111/jcpp.12675

Okon-Singer, H., Hendler, T., Pessoa, L., & Shackman, A. J. (2015). The neurobiology of emotion-cognition interactions: Fundamental questions and strategies for future research. *Frontiers in Human Neuroscience*, *9*(February), 1–14. https://doi.org/10.3389/fnhum.2015.00058

Ouimet, M. C., Brown, T. G., Corado, L., Paquette, M., & Robertson, R. D. (2020). The effects of alcohol dose, exposure to an in-vehicle alcohol feedback device, and subjective responses to alcohol on the decision to drink-drive in young drivers. *Accident Analysis and Prevention*, *139*, 105495. https://doi.org/10.1016/j.aap.2020.105495

Ouimet, M. C., Dongier, M., Di Leo, I., Legault, L., Tremblay, J., Chanut, F., & Brown, T. G. (2013). A randomized controlled trial of brief motivational interviewing in impaired driving recidivists: A 5-year follow-up of traffic offenses and crashes. *Alcoholism: Clinical and Experimental Research*, *37*(11), 1979–1985. https://doi.org/10.1111/acer.12180

Ouimet, M. C., Duffy, C. W., Simons-Morton, B. G., Brown, T. G., & Fisher, D. L. (2011). Understanding and changing the younger driver problem: A review of the randomized

controlled trials conducted with driving simulation. In *Handbook of driving simulation for engineering, medicine and psychology* (pp. 24-1-24–16). CRC Press.

Owens, M., Koster, E. H. W., & Derakshan, N. (2012). Impaired filtering of irrelevant information in dysphoria: an ERP study. *Social Cognitive and Affective Neuroscience*, *7*(7), 752–763. https://doi.org/10.1093/scan/nsr050

Parsons, T. D., & Duffield, T. (2019). National Institutes of Health initiatives for advancing scientific developments in clinical neuropsychology. *The Clinical Neuropsychologist*, *33*(2), 246–270. https://doi.org/10.1080/13854046.2018.1523465

Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt Impulsiveness Scale. *Journal of Clinical Psychology*, *51*(6), 768–774. https://doi.org/10.1002/1097-4679(199511)51:6<768::AID-JCLP2270510607>3.0.CO;2-1

Pearson, M. R., Murphy, E. M., & Doane, A. N. (2013). Impulsivity-like traits and risky driving behaviors among college students. *Accident Analysis and Prevention*, *53*, 142–148. https://doi.org/10.1016/j.aap.2013.01.009

Perreault, S. (2016). Impaired driving in Canada, 2015. In *Juristat* (Issues 85-002–X). http://www.statcan.gc.ca/pub/85-002-x/2013001/article/11739-eng.htm#a4

Phillips, D. P., Sousa, A. L. R., & Moshfegh, R. T. (2014). Official blame for drivers with very low blood alcohol content: There is no safe combination of drinking and driving. *Injury Prevention*, *3*, 1–8. https://doi.org/10.1136/injuryprev-2013-040925

Qu, W., Ge, Y., Xiong, Y., Carciofo, R., Zhao, W., & Zhang, K. (2015). The relationship between mind wandering and dangerous driving behavior among Chinese drivers. *Safety Science*, *78*, 41–48. https://doi.org/10.1016/j.ssci.2015.04.016

Qu, W., Zhang, W., & Ge, Y. (2020). The moderating effect of delay discounting between

sensation seeking and risky driving behavior. *Safety Science*, *123*(February 2019), 104558. https://doi.org/10.1016/j.ssci.2019.104558

Rice, S. M., Fallon, B. J., Aucote, H. M., & Möller-Leimkühler, A. M. (2013). Development and preliminary validation of the male depression risk scale: Furthering the assessment of depression in men. *Journal of Affective Disorders*, *151*(3), 950–958. https://doi.org/10.1016/j.jad.2013.08.013

Rizer, C. A., & Lusk, M. D. (2017). Screening and initial management of alcohol misuse in primary care. *The Journal for Nurse Practitioners*, *13*(10), 660–666. https://doi.org/https://doi.org/10.1016/j.nurpra.2017.08.011

Roidl, E., Siebert, F. W., Oehl, M., & Höger, R. (2013). Introducing a multivariate model for predicting driving performance: The role of driving anger and personal characteristics. *Journal of Safety Research*, *47*, 47–56. https://doi.org/10.1016/j.jsr.2013.08.002

Rosenbloom, M. H., Schmahmann, J. D., & Price, B. H. (2012). The functional neuroanatomy of decision-making. *The Journal of Neuropsychiatry and Clinical Neurosciences*, *24*, 266–277.

Scott-Parker, B., Watson, B., King, M. J., & Hyde, M. K. (2012). The influence of sensitivity to reward and punishment, propensity for sensation seeking, depression, and anxiety on the risky behaviour of novice drivers: A path model. *British Journal of Psychology*, *103*(2), 248–267. https://doi.org/10.1111/j.2044-8295.2011.02069.x

Scott-Parker, B., & Weston, L. (2017). Sensitivity to reward and risky driving, risky decision making, and risky health behaviour: A literature review. *Transportation Research Part F: Traffic Psychology and Behaviour*, *49*, 93–109. https://doi.org/10.1016/j.trf.2017.05.008

Šeibokaitė, L., Endriulaitienė, A., Sullman, M. J. M., Markšaitytė, R., & Žardeckaitė-

Matulaitienė, K. (2017). Difficulties in emotion regulation and risky driving among Lithuanian drivers. *Traffic Injury Prevention, 18*(7), 688–693. https://doi.org/10.1080/15389588.2017.1315109

Sobell, L. C., & Sobell, M. B. (2003). Alcohol consumption measures. In J. P. Allen & V. B. Wilson (Eds.), *Assessing alcohol problems: A guide for clinicians and researchers clinic* (2nd ed., pp. 75–99). National Institute on Alcohol Abuse and Alcoholism. https://www.researchgate.net/publication/313670911

Starkey, N. J., & Isler, R. B. (2016). The role of executive function, personality and attitudes to risks in explaining self-reported driving behaviour in adolescent and adult male drivers. *Transportation Research Part F: Traffic Psychology and Behaviour, 38,* 127–136. https://doi.org/10.1016/j.trf.2016.01.013

Statistics Canada. (2017). *Montréal [Census metropolitan area], Quebec and Canada [Country] (table). Census Profile. 2016 Census.* Statistics Canada Catalogue No. 98-316-X2016001. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E

Stephens, A. N., Bishop, C. A., Liu, S., & Fitzharris, M. (2017). Alcohol consumption patterns and attitudes toward drink-drive behaviours and road safety enforcement strategies. *Accident Analysis and Prevention, 98,* 241–251. https://doi.org/10.1016/j.aap.2016.10.011

Stoner, H. A., Fisher, D. L., & Mollenhauer, M. (2011). Simulator and scenario factors influencing simulator sickness. In D. L. Fisher, M. Rizzo, J. K. Caird, & J. D. Lee (Eds.), *Handbook of driving simulation for engineering, medicine, and psychology* (pp. 14.1-14.24). CRC Press.

Strang, N. M., Claus, E. D., Ramchandani, V. A., Graff-Guerrero, A., Boileau, I., & Hendershot, C. S. (2015). Dose-dependent effects of intravenous alcohol administration on cerebral

blood flow in young adults. *Psychopharmacology*, *232*, 733–744. https://doi.org/10.1007/s00213-014-3706-z

Szuhany, K. L., Mackenzie, D., & Otto, M. W. (2018). The impact of depressed mood, working memory capacity, and priming on delay discounting. *Journal of Behavior Therapy and Experimental Psychiatry*, *60*, 37–41. https://doi.org/10.1016/j.jbtep.2018.03.001

Testa, C. R., & Steinberg, L. (2010). Depressive symptoms and health-related risk-taking in adolescence. *Suicide and Life-Threatening Behavior*, *40*(3), 298–305.

Trógolo, M. A., Melchior, F., & Medrano, L. A. (2014). The role of difficulties in emotion regulation on driving behavior. *Journal of Behavior, Health & Social Issues*, *6*(1), 107–117. https://doi.org/10.5460/jbhsi.v6.1.47607

VanderVeen, J. D., Plawecki, M. H., Millward, J. B., Hays, J., Kareken, D. A., O'Connor, S., & Cyders, M. A. (2016). Negative urgency, mood induction, and alcohol seeking behaviors. *Drug and Alcohol Dependence*, *165*, 151–158. https://doi.org/10.1016/j.drugalcdep.2016.05.026

Vingilis, E., Mann, R. E., Erickson, P., Toplak, M., Kolla, N. J., Seeley, J., & Jain, U. (2014). Attention deficit hyperactivity disorder, other mental health problems, substance use, and driving: Examination of a population-based, representative Canadian sample. *Traffic Injury Prevention*, *15*(sup1), S1–S9. https://doi.org/10.1080/15389588.2014.926341

Wager, T. D., Kang, J., Johnson, J. D., Nichols, T. E., Satpute, A. B., & Barrett, L. F. (2015). A Bayesian model of category-specific emotional brain responses. *PLoS Computational Biology*, *11*(4), 1004066. https://doi.org/10.1371/journal.pcbi.1004066

Wall, T. L., Luczak, S. E., Hiller-Sturmhöfel, S., & Diego, S. (2016). Biology, genetics, and environment: Underlying factors influencing alcohol metabolism. *Alcohol Research:*

*Current Reviews*, *38*(1), 59–68. www.ncbi.nlm.nih.gov/snp

Wang, Z., Yue, L., Cui, C., Liu, S., Wang, X., Li, Y., & Ma, L. (2019). Top-down control of the medial orbitofrontal cortex to nucleus accumbens core pathway in decisional impulsivity. *Brain Structure and Function*, *224*, 2437–2452. https://doi.org/10.1007/s00429-019-01913-w

Weafer, J., & Fillmore, M. T. (2012). Acute tolerance to alcohol impairment of behavioral and cognitive mechanisms related to driving: Drinking and driving on the descending limb. *Psychopharmacology*, *220*(4), 697–706. https://doi.org/10.1007/s00213-011-2519-6

Webb, C. N. (2020). *Geospatial summary of crash fatalities (Report No. DOT HS 812 607)* (Issue May). www.ntis.gov.

Westermann, R., Stahl, G., & Hesse, F. W. (1996). Relative effectiveness and validity of mood induction procedures: A meta-analysis. *European Journal of Social Psychology*, *26*(January), 557–580. https://doi.org/10.1002/(SICI)1099-0992(199607)26:4<557::AID-EJSP769>3.0.CO;2-4

Wolkowicz, N. R., Ham, L. S., Perrotte, J. K., & Byron, L. (2021). Negative urgency and alcohol-related problems: Indirect links with alcohol expectancies and drinking motives. *Journal of Addictive Diseases*, *39*(2), 199–207. https://doi.org/10.1080/10550887.2020.1847993

World Health Organization. (2018). *Global status report on road safety 2018*. https://doi.org/10.22201/fq.18708404e.2004.3.66178

Zheng, Y., Li, Q., Tian, M., Nan, W., Yang, G., Liang, J., & Liu, X. (2017). Deficits in voluntary pursuit and inhibition of risk taking in sensation seeking. *Human Brain Mapping*, *38*(12), 6019–6028. https://doi.org/10.1002/hbm.23807

Zimmermann, U. S., O'Connor, S., & Ramchandani, V. (2013). Modeling alcohol self-administration in the human laboratory. *Current Topics in Behavioral Neurosciences Series*, *13*, 315–354. http://www.springer.com/series/7854

Zuba, D. (2008). Accuracy and reliability of breath alcohol testing by handheld electrochemical analysers. *Forensic Science International*, *178*, e29–e33. https://doi.org/10.1016/j.forsciint.2008.03.002

# Appendix

**Table A-1.**

*The variables and their corresponding measures for both Manuscript 1 and Manuscript 2.*

| | | | Manuscript | |
|---|---|---|---|---|
| Variable | Measure | Description | 1 | 2 |
| Depressed mood | | | | |
| | BDI-II | A scale consisting of statements corresponding with symptoms of depression; total scores < 14 indicating no or minimal symptoms | ✓ | x |
| | MCMI-III, Major Depression scale | A scale consisting of true/false statements corresponding with symptoms of depression; base rate scores < 75 indicating no or minimal symptoms | x | ✓ |
| Alcohol use | | | | |
| | Breathalyzer | A portable device used for the detection of breath alcohol concentration obtained by blowing through the tube of the device; used as a proxy for blood alcohol concentration | ✓ | x |
| Alcohol misuse | | | | |
| | AUDIT | A scale consisting of statements corresponding with symptoms of alcohol misuse; total scores < 20 indicating no, hazardous, or harmful alcohol use | x | ✓ |
| Decision to drive | | | | |
| | Decision to drive scenario | A contingency scenario presenting the decision to drive or not drive while possibly impaired by alcohol | ✓ | x |
| Risky driving | | | | |
| | Speed deviation | The position of the accelerator in a driving simulator ranging from 0 to 1 | ✓ | x |

| | | | | |
|---|---|---|---|---|
| | | throughout the full duration of both highway and urban scenarios | | |
| | Mean speed | Km/h travelled in a driving simulator throughout the full duration of a highway scenario | ✓ | x |
| | Speed change in response to a car merging | The position of the accelerator in a driving simulator ranging from 0 to 1 in a highway scenario when another car is merging | ✓ | x |
| | ACR | A scale consisting of questions related to the frequency of engaging in risky driving behaviours | x | ✓ |
| | Driving offence data | Number of risky driving offences an individual receives as reflected by government records | x | ✓ |
| Decision-making | | | | |
| | IGT | A computerised card task measuring decision-making under risk and ambiguity | ✓ | x |
| Sensation-seeking | | | | |
| | SSS-V | A forced-choice scale measuring different aspects of sensation-seeking including thrill- and adventure-seeking, experience-seeking, disinhibition, and boredom susceptibility | x | ✓ |