Exploring the Role of Cannabis in Fatal Car Crashes and A Survey of Canadians' Beliefs, Cannabis Use Behaviours and Decision-Making Processes Related to Cannabis and Driving

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Dedication and Acknowledgements

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Abstract

This mixed-method research project involved two phases investigating relationships between cannabis use and driving. The first phase utilized data from the Fatality Analysis Reporting System (FARS) to determine how much the odds of being responsible for a fatal car crash increased when the driver was under the influence of cannabis. A total of 242,942 fatal crashes met criteria for inclusion. Logistic regression analyses indicated that the presence of THC increased the odds of engaging in unsafe driver actions by 29%. Three driver actions were significantly associated with cannabis use: failure to keep in proper lane, driving too fast for conditions or over the speed limit, and operating the vehicle in an erratic, careless, negligent, reckless manner.

Phase two involved developing a new survey to assess Canadians' knowledge, beliefs and behaviour about cannabis products and driving. This new survey expanded on the existing Canadian Cannabis Survey (CCS), addressing gaps, and adding novel components. After the preliminary survey was developed, three focus groups were conducted. As a result, additional questions and response options were added. The survey was administered to 416 cannabis users across Canada. Results were compared with existing survey data and novel contributions were summarized. The survey identified specific areas where Canadian cannabis users are misinformed or require more information. Taken together, this research has implications for consumers, law enforcement, government agencies and policy makers. Through knowledge dissemination and public health initiatives, this research can help reduce the risk of driving under the influence of cannabis and associated harms. Several recommendations are provided along with suggestions for future research in this area.

Introduction

On June 19, 2018, the Canadian Senate passed Bill C-45, also known as the Cannabis Act, indicating the intent to legalize and regulate the sale of recreational cannabis across the country (Government of Canada, 2018a). Legalization officially came into effect on October 17, 2018 but initially, only dried cannabis and some oils were available for legal sale and purchase (Canadian Centre on Substance Use and Addiction, 2022). Canadians are legally allowed to possess up to 30 grams of cannabis and grow up to four cannabis plants per residence (Government of Canada, 2018b). One year after legalization (October 17, 2019), the Cannabis Act was amended to include the sale and purchase of edible cannabis products, extracts, and topical products (Canadian Centre on Substance Use and Addiction, 2022). Although Canada is the second country to legalize cannabis federally, sales and regulation are managed at a provincial level. Existing laws and legislation were updated to accommodate the shift in legalization while maintaining a commitment to public health and safety (Government of Canada, 2018b).

One major area of concern for federal and provincial policy makers has been the development and enforcement of drug-impaired driving laws (Government of Canada, 2018a). The process of identifying drivers who are impaired due to cannabis is complicated by many factors including tolerance, metabolism, method of administration, and cannabis potency (Beirness & Porath, 2017; Government of Canada, 2019b). Although federal and provincial law has been updated to enforce driving under the influence of cannabis (DUIC), people still engage in this risky behaviour at surprising rates. A report prepared for the Canadian Centre on Substance Use and Addiction considered various data sources and concluded that the legalization of cannabis has resulted in a slight to moderate increase in DUIC (Asbridge et al., 2021).

Following the legalization of cannabis in Canada, past-year prevalence rates of DUIC vary from 3.4% for population-level survey data to 23% for cannabis users with a driver's license (Government of Canada, 2020, 2022a). Although these data are pre-legalization, Canadian youth (i.e., under the age of 18) frequently report much higher rates of DUIC, with 64% of males and 32% of females indicating that they have driven a motor vehicle while intoxicated from cannabis (Leadbeater et al., 2017). No roadside studies have been completed in Canada post-legalization; however, data obtained from hospitals in British Columbia indicate that the proportion of cannabis-positive drivers presenting to emergency departments has significantly increased (Brubacher et al., 2022).

Individual beliefs about cannabis use and driving shape behaviour and decision-making. Therefore, a comprehensive study of these factors can make a valuable contribution to reducing the prevalence of DUIC in Canada.

In this study we seek to maximize Canadian road safety in the context of cannabis legalization by contributing to the knowledge base of cannabis impairment and driving in two ways. First, an existing data set will be analyzed to quantify the risk associated with cannabis use in the context of fatal motor vehicle collisions. Using this dataset, we hope to identify specific driver actions that have contributed to fatal car crashes when the driver was under the influence of cannabis. Secondly, a new survey will be developed and administered to Canadian cannabis users. The survey will explore individual beliefs related to how different types of cannabis affect driving behaviour, how individuals assess impairment in themselves, the specific decision-making process that individuals engage in when contemplating driving after cannabis use, and Canadians' willingness to use assistive tools in this process. Survey development focused on addressing gaps in existing national surveys assessing cannabis use beliefs and behaviour in Canada.

In survey research, cannabis use has been defined as "using cannabis in its dry form or when mixed or processed into another product, such as an edible, a concentrate, including hashish, a liquid, or other product" (Government of Canada, 2022a, para 7). Since the legalization of cannabis, Canadians are using a wider variety of cannabis products at increasing rates (Government of Canada, 2021b; Statistics Canada, 2021). However, most of the research on cannabis and driving has involved the administration of smoked dried cannabis. Little is known about the generalizability of these results to other forms of cannabis such as edible cannabis products. Research on the pharmacodynamics of cannabis highlights very different metabolic pathways for cannabis that is smoked or inhaled, versus cannabis consumed orally (Huestis, 2007; Newmeyer et al., 2016; Reyes et al., 1973).

In this study, we will assess Canadians' beliefs and knowledge about different cannabis products and how these beliefs affect actual driving behaviour. The specific driver actions that are associated with cannabis-attributable fatalities in the first phase of this research will be compared to Canadians' beliefs about the effects of cannabis on cognitive processes and skills relevant to driving. The existing literature on the subjective process of evaluating cannabis-attributable impairment in the context of driving is scarce. The current investigation will help describe how individuals assess impairment, and how this information is used to make decisions about one's ability to drive safely. Overall, this research will help us identify gaps in knowledge as targets for public health intervention and help facilitate the development of tools to promote responsible decision-making as it relates to cannabis use and driving.

Cannabis Use Behaviour in Canada

According to the 2019 Canadian Alcohol and Drugs Survey (CADS), cannabis is the most commonly used drug in Canada; 21% of residents (aged 15+) reported using cannabis in the past year, up from 12% in 2015 (Government of Canada, 2021a). According to the CADS, cannabis use is more common in males (23%) than females (19%), with young adults aged 20-24 reporting the highest prevalence of cannabis use (45%) (Government of Canada, 2021a).

The National Cannabis Study (NCS) was introduced in 2018 and is administered quarterly to monitor changes in cannabis use frequency and behaviour following cannabis legalization (Statistics Canada, 2019). A recent analysis of NCS data revealed that in the first quarter of 2018 (prior to legalization), only 14% of Canadians reported using cannabis in the past three months; this number jumped to 20% by the end of 2020 (Statistics Canada, 2021). Data from the first quarter of 2019 indicated that in this time period, over 640,000 Canadians tried cannabis for the first time with most new users over the age of 45 (Statistics Canada, 2019). This is nearly double the rate of new users from one year prior, indicating that legalization may have contributed significantly to increased prevalence of cannabis use in the Canadian population (Statistics Canada, 2019).

In 2017, the Government of Canada initiated the Canadian Cannabis Survey (CCS) to collect data annually on four themes: 1) knowledge, attitudes and behaviours, 2) cannabis use and products used, 3) driving and cannabis, and 4) cannabis use for medical purposes (Government of Canada, 2018). Although other national surveys such as the CADS and the NCS are used to collect information on Canadians' substance use behaviour, the CCS provides the most in-depth analysis of Canadians' cannabis use behaviour.

Participants are recruited for the CCS using a two step process. First, Canadians are contacted using a random sample of phone numbers, and if deemed eligible, individuals are invited to complete the survey online (Government of Canada, 2018). The most recent survey included over 10,000 respondents with 3,500 (35%) reporting cannabis use within the past 12 months (Government of Canada, 2021b). Cannabis users only represent approximatley one third of respondents; therefore, the survey does not solely reflect the views of cannabis users. Health Canada notes that the "CCS was designed to obtain a sufficient number of respondents from key sub-populations, and minimum sample sizes were determined and met in order to ensure statistical relevance of results and representativeness" (Government of Canada, 2019, p.1). More recent versions of the survey advise that due to the data collection methodology, CCS estimates of prevalence may be higher than those reported in Canadian population level surveys. (Government of Canada, 2021b).

Although the CCS prevalence estimates may be slightly inflated, this annual survey revealed a similar trend of increasing cannabis use post-legalization. The most recent CCS indicates that the proportion of Canadians using cannabis may be stabilizing, staying between 25-27% over the past two years (Government of Canada, 2020, 2021b). Although most cannabis users (52%) report occasional usage (i.e., 1-3 times per month), a significant proportion of cannabis users (18%) report daily usage (Government of Canada, 2022a).

Similar to the data in the CADS, the most recent CCS found that rates of cannabis use vary by age group with younger respondents reporting higher frequency of use. In 2022, 37% of respondents aged 16-19 reported using cannabis in the past year; that number was 50% for those aged 20-24, and 25% for individuals aged 25 and older (Government of Canada, 2022a). There are gender differences in patterns of use as well; 30% of males and 25% of females reported using cannabis in the past 12 months (Government of Canada, 2022a). Interestingly, males are more likely than females to smoke dried cannabis (71% versus 58%) and females were more likely to use edible cannabis products (57% versus 49%) (Government of Canada, 2022a).

The legalization of cannabis has led to a major shift in the types of cannabis products Canadians are using. The percentage of cannabis users who reported using dried cannabis (i.e., smoking) in the last 12 months decreased from 88% in 2017 to 65% in 2022 (Government of Canada 2018, 2022a). On the other hand, the percentage of cannabis users who reported consuming edible cannabis products in the past 12 months increased from 32% in 2017 to 53% in 2022 (Government of Canada, 2018, 2022a).

The increasing rates of cannabis use, combined with the sharp increase in utilization of edible forms of cannabis, suggest there is an urgent need for more research focused on these trends. The effects of edible products are delayed and prolonged due to the absoprtion process; inhaled (i.e., smoked) cannabis reaches peak THC blood plasma concentration within 5-10 minutes, whereas products consumed orally (i.e., edibles) reach peak plasma concentration in 1-2 hours (Huestis, 2007; Reyes et al., 1973). The blood THC concentration returns to baseline much faster when smoking cannabis compared to consuming it orally (Ramaekers et al., 2021).

In 2020, the CCS added a question to assess Canadians' knowledge about the vastly different effects of cannabis products. On the 2022 survey, 53% of respondents were unusure whether smoking or eating/drinking cannabis produces longer lasting effects; this number was 25% for cannnabis users (Government of Canada, 2022a). Although cannabis had been legal for three years by the time of the last CCS, Canadians are still reporting uncertainty, and at times endorsing misinformation, about how different cannabis products affect them. This is a signficiant public health concern because having accurate information is critical to making safe and informed decisions. The current study will expand on the information collected through the

CCS to throughly assess Canadians' beliefs about cannabis effects and impairment and identify specific gaps in knowledge which may contribute to dangerous decision-making.

Neurocognitive Effects of Cannabis/THC

Canadian public health information on the effects of cannabis, and more specifically its psychoactive ingredient (Δ9-tetrahydrocannabinol, THC), indicates that it produces positive feelings of euphoria and relaxation, and that it can negatively affect cognitive processes including: reaction time, divided attention, sense of time, visual function and tracking, short term memory and motor coordination (Beirness & Porath, 2017; Canadian Centre on Substance Use and Addiction, 2015, 2018). The negative effects of cannabis on cognitive processes have been shown to be acute and temporary; chronic cannabis use has not been associated with significant cognitive impairment for adults (Canadian Centre on Substance Use and Addiction, 2015). In fact, when adults abstain from cannabis use for several weeks, impairment on processes such as learning and memory are no longer observable, indicating that these cognitive effects of cannabis are not long-lasting (Canadian Centre on Substance Use and Addiction, 2015). However, early and frequent cannabis use by adolescents can damage the developing brain leading to permanent deficits in executive functioning, decision making and memory (Canadian Centre on Substance Abuse, 2015; Canadian Centre on Substance Use and Addiction, 2022).

Regular cannabis use can increase the risk of psychosis or schizophrenia, especially for those who are predisposed (i.e., have a family history) and engage in heavy cannabis use before the age of 16 or 17 years old (Canadian Centre on Substance Use and Addiction, 2022). A review of Canadian hospitalization data from 2006-2015 investigated the association between psychotic disorders and cannabis use (Maloney-Hall et al., 2020). In this period, the number of hospitalizations for cannabis-related mental or behavioural disorders more than doubled, from

2.11 to 5.18 per 100,000. Males accounted for two thirds of hospitalizations and over 50% of admissions were young Canadians under the age of 25 (Maloney-Hall et al., 2020).

A decade of data (2007-2017) from Ontario inpatient psychiatry admissions reveals a similar trend; more Canadians are using cannabis and the proportion of patients reporting using cannabis prior to admission is increasing (McGuckin et al., 2021). This study also found a significant interaction between gender and schizophrenia; the proportion of males who used cannabis and were diagnosed with schizophrenia was 12.1% higher than males without this diagnosis (McGuckin et al., 2021).

Ramaekers and colleagues (2021) recently published a comprehensive review of the neurocognitive effects of acute cannabis exposure including moderating factors. The cognitive domains that are associated with THC-induced impairment include attention, psychomotor functioning, impulse control, memory, learning and altered consciousness (Ramaekers et al., 2021). The functional deficits that result from impairment in these cognitive domains include: distorted processing in the salience network (responsible for detecting and filtering salient stimuli and generating cognitive and behavioural responses), reduced sustained attention, reduced visuomotor task performance, increased cognitive impulsivity, reduced motor response inhibition, working memory impairment, and altered consciousness which may manifest as increased anxiety, dissociation or unusual thoughts (Ramaekers et al., 2021). The authors integrated available neuroimaging and neurocognitive data to develop a framework proposing that the effects of THC can be attributed to "altered neurotransmission and brain activation in the mesocorticolimbic circuit and the salience network in humans" (Ramaekers et al., 2021, p.441). Although the framework requires further validation, it is promising due to its ability to provide neurobiological explanations for several of the well-established effects of THC.

Moderators of Neurocognitive Effects of Cannabis/THC

Tolerance

Individuals who use cannabis heavily demonstrate tolerance, as evidenced by less THC-induced neurocognitive impairment on tasks of attention, memory and impulse control when compared to occasional users (Colizzi & Bhattacharyya, 2018; Foltin, 2013; Ramaekers et al., 2009; Ramaekers et al., 2021). According to the neurocognitive framework proposed by Ramaekers (2021), this effect may be explained by the fact that cannabis-dependent individuals have a reduced availability (10-20% decrease) in receptors for a specific cannabinoid (CB1). The upregulation of these receptors that occurs in prolonged periods of abstinence (e.g., one month) may also help explain why cognitive impairment in regular cannabis users dissipates once individuals cease cannabis use (Bosker et al., 2013; Hirvonen et al., 2012; Pope et al., 2001; Ramaekers et al., 2021; Schreiner & Dunn, 2012).

Method of Consumption

According to the 2022 CCS, the most common methods of cannabis consumption are smoking dried cannabis (70%), followed by oral consumption (52%) (Government of Canada, 2022a). Other methods of consumption include vaporizing using a vape or e-cigarette (31%), ingesting cannabis oil (18%), drinking it (16%), vaporizing using a vaporizer (10%), applying to the skin (7%) and dabbing (6%) (Government of Canada, 2022a). As previously mentioned, smoking and orally consuming cannabis involve very different pathways of absorption and metabolism as reflected in vastly different pharmacokinetic profiles (Newmeyer et al., 2016; Ramaekers et al., 2021; Spindle et al., 2019). Cannabis consumed orally results in lower levels of peak blood THC concentration due to a slower absorption process, with peak effects having a later onset and longer duration (Newmeyer et al., 2016; Poyatos et al., 2020).

The legalization of cannabis has not only resulted in a surge of research involving cannabis, but studies are incorporating a diverse range of cannabis products and methods of administration. Fortunately, several methodologically strong studies have been published over the past few years, allowing researchers, policy makers, and consumers to better understand and differentiate effects for the wide array of products that are available.

A naturalistic study conducted in 2021 was one of the first to assess for potential differences in the physiological, cognitive and subjective effects between smoked (i.e., flower or bud) and edible forms of cannabis (Bidwell et al., 2022). Participants attended experimental sessions in a mobile laboratory where the dosage and cannabis product information were recorded. The researchers collected several measurements including a blood sample, heart rate, ratings of subjective drug effects, and cognitive performance tasks to assess memory, inhibitory control, and attention. Participants using smoked cannabis were required to attend the experimental session immediately post-consumption, whereas edible product users were required to attend the experimental session one hour post-consumption to account for the differences in time required to experience peak effects (Bidwell et al., 2022).

Based on objective and subjective indicators, the two different types of cannabis (i.e., smoked and edible forms) produced similar effects in regular cannabis users after controlling for baseline usage (Bidwell et al., 2022). Significant effects without between-group differences included a dose-response effect, ratings of intoxication, increased heart rate, positive mood changes, decreased tension, increased paranoia, and delayed verbal recall memory deficits (Bidwell et al., 2022). Interestingly, there was no significant effect of cannabis use on cognitive task performance using three brief tasks from the National Institute of Health Cognitive Toolbox (Bidwell et al., 2022).

The researchers also found that participants who smoked cannabis had higher blood THC concentrations than those who consumed edible products (Bidwell et al., 2022). However, based the different pharmacokinetic profiles, it is possible that the one-hour delay was not long enough to capture the peak blood THC concentration for the edible cannabis condition. Another noteworthy finding was that the correlation between self-reported dosage and blood THC levels were much higher for edible cannabis products than smoked cannabis (Bidwell et al., 2022), suggesting that edible products may improve dose standardization and predictability of blood THC concentration.

Additional research has demonstrated that users of edible products often report similar subjective effects and levels of neurocognitive impairment as users of smoked products, despite the fact that with equivalent doses, oral products result in a lower blood THC concentration. (Bidwell et al., 2022; McCartney et al., 2021; Newmeyer et al., 2017). This suggests that perhaps other cannabinoids and/or metabolites may be contributing to subjective or intoxicating effects of edible products. One specific THC metabolite, 11-hydroxy-THC, is found in higher concentrations when products are consumed orally (Newmeyer et al., 2016). It is possible that this metabolite is responsible for some of the impairing effects and may account for the discrepancy between blood plasma THC concentrations and impairment reported by participants (Ramaekers et al., 2021).

A within-participant, double-blind, crossover study conducted at John Hopkins compared the subjective, cognitive and physiological effects of smoked and vaporized cannabis at three different doses (0, 10 and 25 mg) (Spindle et al., 2018). Previous research allowed participants to titrate their doses which threatens the standardization and validity of conclusions drawn; in this study, Spindle and colleagues (2018) required participants to self-administer a fixed amount of cannabis which ensured that the THC dose was more reliable. Another unique aspect of this design was that participants were not regular users; all were required to abstain from cannabis use for 30 days. On average, participants had not used cannabis for one year prior to the study.

Across doses, vaporized cannabis produced significantly greater levels of cognitive impairment, subjective drug effects and higher blood THC concentrations when compared to smoked cannabis (Spindle et al., 2018). Another key finding relates to the correlations between blood THC concentration and outcome variables; there were only modest correlations between blood THC concentration and subjective drug effects (0.38-0.54), and little to no correlations (0.01-0.32) with cognitive and psychomotor performance (Spindle et al., 2018).

Similarly, a recent publication found that levels of THC detected in the blood, and in exhaled breath, do not correlate with impairment (Wurz & DeGregorio, 2022). These conclusions provide support for the notion that blood THC concentration cannot be relied on as a sole indicator of cannabis impairment (Spindle et al., 2018; Wurz & DeGregorio, 2022). Other cannabinoids such as cannabigerol, cannabichromene, and Δ9-tetrahydrocannabivarin were detected in breath samples during the peak impairment window and have been recommended for further study as an indicator of recently inhaled cannabis and potentially, impairment (Wurz & Degregorio, 2022). For edible cannabis, the metabolite 11-hydroxy-THC has been proposed as an indicator of impairment (Ramaekers et al., 2021). Thus, the method of consumption (i.e., inhaled or ingested) may moderate the neurocognitive effects of THC as indicated by the associations with different metabolites or cannabinoids and impairment.

Effects of THC on Driving Performance

Research on the relationship between cannabis use and driving performance is more limited than research on the effects of alcohol for various reasons, including legality, ethics, and safety concerns. The legalization of cannabis in 2018 has resulted in a rapid expansion of research in this area, leading to an improved understanding of the effects of cannabis on driving.

Initial research in this area contained mixed results leading to confusion about the risk associated with driving after using cannabis. It would be easy to assume that cannabis use negatively affects the ability to engage in safety-sensitive tasks, such as driving, given the neurocognitive effects of THC described above (Bondallaz et al., 2016; Hartman & Huestis, 2013; Ramaekers et al., 2021; Ramaekers et al., 2004). However, some early research failed to find an effect of THC on driving or concluded that the effects were only significant at high doses of THC (Lamers & Ramaekers, 2000; Robbe, 1998).

The authors of a comprehensive case-control study conducted under the auspices of the U.S. National Highway Traffic Safety Administration concluded that after controlling for age, gender, ethnicity and alcohol consumption, there was no significant increase in crash risk attributable to cannabis (Lacey et al., 2016). An odds ratio refers to the odds that an outcome will occur given exposure to a variable or factor, compared to the odds of the outcome occurring in the absence of that exposure (Szumilas, 2010). Thus, an odds ratio greater than one indicates that the odds of a specific outcome are increased when the factor is present. While the unadjusted odds ratio for crash risk when the driver tested positive for cannabis was 1.25, it dropped to 1.00 after adjusting for demographic variables and influence of alcohol (Lacey et al., 2016). This study included 3,000 matched cases and all crashes were included regardless of severity; thus, compared to research that only includes fatal crashes or crashes that result in serious injury, the obtained odds ratios are a more accurate representation of *overall* crash risk (Lacey et al., 2016).

Early systematic reviews and meta-analyses concluded that cannabis use translates into a moderate increase in crash risk, with odds ratios ranging from 1.2 to 2.0 (Asbridge et al., 2012;

Drummer et al., 2004; Laumon et al., 2005; Li et al., 2012; Ramaekers et al., 2004; Rogeberg, 2016). Similarly, another review found that as blood THC concentrations increased, drivers were more likely to be declared responsible for the car crash (Hartman & Huestis, 2013).

Different approaches to calculating crash risk have provided more modest estimates; analyses of fatal car crashes found that the risk of making an unsafe driver action (i.e., proxy measure of crash responsibility) increased by 18-29% when the driver tested positive for cannabis (Bédard et al., 2007; Dubois et al., 2015).

Driving Simulator Research

On-road studies investigating the effects of cannabis on driving behaviour are limited due to the costs and methodological issues inherent in the design such as safety and the requirement of a control group to assess the effects of THC. Consequently, a significant proportion of research investigating the relationship between cannabis and driving performance has utilized realistic, validated driving simulators. Driving simulators allow for the introduction of more complex tasks and higher doses of THC administration.

In a unique investigation, researchers sought to compare the sensitivity of simulators and on-road measures for detecting the effects of oral THC consumption (Veldstra et al., 2015). Standard deviation of lateral position (SDLP) is often used to quantify road tracking or the ability to stay within a lane (Sewell et al., 2009). When SDLP was used as the outcome variable, the simulator was as sensitive in detecting the effects of THC as driving performance observed on-road (Veldstra et al., 2015). However, the researchers concluded that assessing the effects of THC on headway distance to a lead car (i.e., a car following task) using a simulator was not comparable to on-road evaluations; thus, simulator sensitivity and convergence with on-road observations may vary based on the specific driver action being considered (Velstra et al., 2015).

SDLP has been proposed as one of the most sensitive indicators of THC-induced impairment (Hartman & Huestis, 2013; Lenné et al., 2010; Ronen et al., 2008; Sexton, Tunbridge, Brook-Carter, & Wright, 2000). However, the impairing effect of THC on SDLP has not been found in all simulator studies (Anderson et al., 2010; Ronen et al., 2008).

Although Anderson and colleagues (2010) failed to find an effect of THC on SDLP, there were some interesting results. In this placebo-controlled, double-blind study, participants completed a series of tasks on the simulator involving collision avoidance and distraction. Driving performance was measured using several indicators. For the distracted driving component, participants were asked to complete a cognitive task (paced auditory serial addition) which was practiced previously. The participants in the THC condition decreased their speed more than participants of the control group, and had a lower mean speed during the distracted sections of the driving simulation (Anderson et al., 2010). Hartman and Huestis (2013), in their review, came to a similar conclusion: With increasing doses of THC, participants tend to reduce their speed in the driving simulator, especially under challenging conditions. Further, participants under the influence of THC failed to show the expected practice effects on the distracted driving task, suggesting that THC may interfere with the ability to use previously acquired information while driving (Anderson et al., 2010).

On-Road Investigations

Although scarce, there are some studies evaluating the effects of cannabis on driving using on-road settings. Prior to the legalization of cannabis, nearly all on-road research was conducted in the Netherlands and involved administration of low to moderate doses of smoked THC (Hartman & Huestis, 2013). In a seminal publication involving four studies, Robbe (1998) administered three doses of smoked THC (100, 200, and 300 µg/kg THC) and observed participants' driving behaviour on closed segments of the highway and in regular traffic. Road tracking (i.e., defined as SDLP) and car following tasks were performed by participants. Robbe (1998) concluded that the low dose of THC (100 µg/kg THC) had little to no effect on these two tasks while the higher doses of THC (200 and 300 µg/kg) had a moderate effect. In these studies, road tracking was negatively affected by THC as indicated by an increase in SDLP. Furthermore, THC significantly increased headway variability (i.e., variability in distance to the car ahead in the car following task). However, no effect of THC on reaction time to movement of the preceding vehicle was observed (Robbe, 1998).

The authors of a different study with similar methodology concluded that on-road driving performance was moderately impaired following administration of smoked THC (100 and 200 µg/kg) with the greatest effects observed on SDLP, time spent out of lane, and mean headway distance (Ramaekers et al., 2004). These results converge with Robbe's (1998) investigation except that Robbe (1998) failed to find an effect of THC at the low dose (100 µg/kg).

In another on-road investigation, participants were to drive a city road test route after smoking a low dose of THC (100 µg/kg) (Lamers & Ramaekers, 2000). Participants' eye movements were tracked using a recording system and driving performance was evaluated by a licensed road test instructor (Lamers & Ramaekers, 2000). The investigators found no effect of THC on driving performance or visual search frequency for traffic at intersections (Lamers & Ramaekers, 2000). This study provides support for the theory that low doses of THC may only have negligible effects on driving performance.

Taken together, results of on-road and simulated driving studies converge to suggest SDLP and headway distance may be sensitive indicators of THC impairment. Investigators using simulators have also detected additional effects of THC on driving performance, albeit not consistently, including increased reaction time and decreased speed (Anderson et al., 2010; Hartman & Huestis, 2013; Lenne et al., 2010; Liguori, Gatto, & Jarrett, 2002; Ronen et al., 2008). It is possible that the advantages of using a driving simulator as opposed to on-road driving scenarios (e.g., reduced safety concerns, higher doses of THC) allowed for the identification of additional effects of THC on driving performance.

Previously cited inconsistencies in research findings have been attributed to methodological differences between studies including THC levels, method of cannabis administration, participant selection and outcome measure (i.e., on-road or driving simulator), reliance on self-report, and the specific drug testing procedure implemented (Ogden & Moskowitz, 2004; Hartman & Huestis, 2013). Fortunately, the publication of comprehensive reviews has helped to resolve these inconsistencies.

Recent Reviews on THC and Driving

Two empirical reviews indicate that THC alters several psychomotor processes and cognitive functions relevant to driving (Bondallaz et al., 2016; Hartman & Huestis, 2013). Bondallaz and colleagues (2016) concluded that reaction time, divided attention, critical tracking, and urgent responding were all negatively affected by cannabis use. Similarly, Hartman and Huestis (2013) concluded that reaction time, divided attention and executive functioning tasks were most sensitive to the effects of cannabis impairment.

McCartney and colleagues (2021) completed a comprehensive meta-analysis summarizing the magnitude of THC-induced cognitive and driving impairment. This review included 80 placebo-controlled studies with over 1500 different outcome variables including cognitive processes relevant to driving and specific driver actions (McCartney et al., 2021).

Cognitive skills related to driving that were found to be significantly impaired by THC included fluid intelligence, divided attention, tracking performance, information processing, conflict control, reaction time, fine motor function, sustained attention, and working memory. (McCartney et al., 2021). The review provided evidence for an effect of tolerance; regular cannabis use was associated with less THC-induced cognitive impairment across studies (McCartney et al., 2021).

Consistent with previous research, THC was associated with impairment in several driving performance indicators including lateral control (an index variable that includes SDLP, lane crossings, steering deviations, and time out of lane), SDLP-only and reaction time (McCartney et al., 2021). A positive effect of THC on speed was trending towards significance, suggesting that cannabis use may be associated with reduced driving speed (McCartney et al., 2021). Similarly, a recent meta-analysis including 57 studies concluded that cannabis use was associated with decreased speed and impaired lateral control providing further support for SDLP and speed as sensitive indicators of cannabis impairment (Simmons et al., 2022).

In their meta-analysis, McCartney and colleagues (2021) hoped to shed some light on how long individuals should wait to engage in safety-sensitive tasks following cannabis use. However, the authors concluded there is no “universal answer”; the appropriate duration requires consideration of multiple factors (McCartney at al., 2021). Based on the available data that included long post-treatment intervals, the authors provided a conservative estimate of the time required for cognitive skills to “recover”; they recommended 5 hours for smoked cannabis and 8 hours for edible forms of cannabis (McCartney et al., 2021).

Combined Effects of THC/CBD on Driving

Cannabidiol (CBD) is the non-psychoactive cannabinoid in cannabis, which is more broadly linked to medicinal outcomes in relation to pain analgesia and reductions in inflammation (Burstein, 2015; Mlost et al., 2020). Due to the different psychoactive effects of THC and CBD, CBD has received much less attention than THC in the context of impaired driving research.

Research has compared the effects of vaporized cannabis that is THC dominant (11%) and THC/CBD equivalent (10%) on measures of driving performance and cognition (Arkell et al., 2019). The authors found that both types of cannabis were associated with increased SDLP on a driving simulator, suggesting that the presence of CBD in cannabis does not mitigate the impairing effects of THC. In addition, performance on cognitive tasks was worse when participants vaporized cannabis that contained THC and CBD, compared to THC-dominant. Interestingly, peak blood THC levels were significantly higher in the THC/CBD condition, leading the authors to conclude that there may be a pharmacokinetic interaction between the two cannabinoids (Arkell et al., 2019)

In a recent randomized controlled trial (RCT) from the Netherlands, researchers investigated the effects of THC and CBD on driving performance (Arkell et al., 2020). In this double-blind, within-participants crossover study, participants vaporized cannabis (13.75 mg) that was THC-dominant, CBD-dominant, equal parts THC and CBD or placebo cannabis. Participants drove a 100-km highway stretch 40 and 240 minutes post-consumption, and driving performance was operationally defined using SDLP (Arkell et al., 2020). For the cannabis that was THC-dominant and equal parts THC-CBD, SDLP was significantly increased compared to placebo at the first time point (40-100 minutes) but not at the later time point; the observed effect of THC on driving performance was comparable to the effect of a BAC of 0.05 (Arkell et al., 2020). There was no effect of THC or CBD on mean speed or standard deviation of speed as measured by an on-board computer (Arkell et al., 2020).

This body of research points to the diverse ways that THC can impair cognition and, in turn, negatively affect driving performance (McCartney et al., 2021). Driver actions that are consistently associated with cannabis-attributable driving impairment include reaction time, decreased speed and maintaining lateral control of the vehicle (McCartney et al., 2021; Simmons et al., 2022). Although CBD alone has not been associated with driving impairment because this cannabinoid does not produce psychoactive effects, recent research suggests that CBD may slightly exacerbate the subjective effects of THC (Arkell et al., 2019). Future research into the interaction between these two cannabinoids, and how this relates to behavioural outcomes such as driving performance, is warranted.

Combined Neurocognitive Effects of THC and Alcohol

The literature contains mixed findings in terms of the combined effects of THC and alcohol on driving performance. Individually, the two substances demonstrate a clear dose-response relationship but together, it is unclear if THC and alcohol produce additive or multiplicative (i.e., synergistic) effects. In other words, it is possible that the combination of THC and alcohol can interact to produce an effect that is stronger than the combination of each substance individually. Studies have provided support for additive (Bramness et al., 2010; Liguori et al., 2002; J. G. Ramaekers et al., 2004) and multiplicative effects (Downey et al., 2013; Lukas & Orozco, 2001). Two studies found that consumption of alcohol led to increased blood plasma THC levels when compared to participants who were given the same THC dosage with the alcohol placebo; the authors concluded that the alcohol may affect the absorption of

THC leading to a multiplicative effect when combined (Downey et al., 2013; Lukas & Orozco, 2001).

Combined Effects of THC and Alcohol on Driving

A simulator study explored the independent effects of THC and alcohol, and the combined effects of THC and alcohol, on driving performance (Downey et al., 2013). Effects of THC included reduced speed, poor road tracking (i.e., greater SDLP) and greater headway distance (Downey et al., 2013). Alcohol was associated with increased speed (Downey et al., 2013). However, driving impairment was greatest in combination conditions. When alcohol was administered to participants in the low and high doses of THC conditions (cannabis cigarettes containing 1.8% and 3% THC), additive decrements of 21% and 17% were noted in driving performance scores (Downey et al., 2013).

Ramaekers, Robbe and O'Hanlon (2000) investigated the combined effects of THC and alcohol on actual driving performance. Participants were required to complete two tasks in normal traffic: road tracking and car following. Driving performance was operationalized using only SDLP, reaction time, time spent out of lane (TOL), and standard deviation of headway. All individual doses of THC (100 and 200 μg/kg) and alcohol (BAC of 0.04) resulted in impaired performance on the driving tasks. The authors concluded that the impairment was minor for the low alcohol condition, moderate for both THC conditions, and severe when THC and alcohol were combined across conditions.

Based on task performance, the authors proposed the two THC doses (100 and 200 μg/kg), in combination with a low dose of alcohol, produced a level of impairment comparable to BACs of 0.09 and 0.14 respectively (Ramaekers et al., 2000). This study replicates findings from a previous study using a very similar methodology (Robbe, 1998). When evaluating the effects of THC and alcohol in an on-road study, Robbe (1998) concluded that doses of THC alone (100-300 μg/kg) led to small-moderate effects on driving ability, but the combination of THC with a low dose of alcohol led to severe driving impairment (Robbe, 1998).

A group of Canadian researchers used the Fatality Analysis Reporting System (FARS) to examine statistics from over 150,000 fatal car crashes in the United States from 1991-2008 (Dubois et al., 2015). The sample included only drivers for which blood samples were collected to test for the presence of drugs and alcohol. In the FARS database, unsafe driver actions (UDAs) are coded and used by researchers as a proxy measure for crash responsibility (Dubois et al., 2015). Examples of UDAs include failure to keep in proper lane, driving too fast for conditions, failure to yield, obey signs or other traffic laws, making improper turn and erratic, careless, negligent or reckless vehicle operation (Dubois et al., 2010).

After controlling for various factors including driver age, previous driving record, and polydrug use, drivers with a confirmed BAC of zero who tested positive for THC had 16% greater odds of committing an UDA compared to drivers who tested negative. Compared to sober drivers, drivers with BAC of 0.05 and 0.08 had greater odds of committing an UDA by 66% and 117% respectively. Using the same BAC levels (0.05 and 0.08) with drivers who also tested positive for THC, the odds of committing an UDA were 81% and 128% greater respectively, compared to drivers who tested negative for both substances. These results suggest that the combination of THC and alcohol increases the odds of drivers committing UDAs in an additive fashion (Dubois et al., 2015). A noteworthy observation from this analysis was that the THC and alcohol interaction exerted greater effects at lower BAC levels suggesting that "as BAC level increases the impairing effects of alcohol dominate the relationship between THC and alcohol" (Dubois et al., 2015, p.99). The first phase of our study will seek to replicate these results and will add 11 years of new data to the analysis.

Other research using FARS data has produced similar results. The combined effect of THC and alcohol on fatal crash risk is greater than the effect of either substance alone and greater than the sum of their individual effects (Chihuri et al., 2017). In this case-control study, odds ratios were calculated to quantify the increased risk of being in fatal crash when the driver tested positive for THC or alcohol, relative to drivers who tested negative for both substances. Results indicated that alcohol increased the risk of being in a fatal crash 16-fold, THC increased the risk 1.5-fold and the combination of THC and alcohol increased the risk by greater than 25-fold (Chihuri et al., 2017).

A study analyzing fatal crash data from Norway revealed a similar trend; the odds of being involved in a fatal crash was greatest for the combination of alcohol and drugs when compared to a single drug, multiple drugs, or alcohol alone (Gjerde et al., 2011). The combination of alcohol and THC has been associated with increased odds of being responsible for a fatal two-car crash initiation and culpability in cases of injured drivers (Chihuri & Li, 2020; Drummer et al., 2020)

A recent systematic review including over 57 studies concluded that the combination of cannabis and alcohol is more detrimental to driving performance than either substance alone (Simmons et al., 2022). The addition of alcohol resulted in greater decrements in SDLP and time spent out-of-lane than when cannabis was used in isolation (Simmons et al., 2022).

Taken together, this research indicates that the combination of THC and alcohol is associated with significantly greater decrements in driving performance and increased risk of being involved in a car crash, than either substance alone.

Influence of Subjective Evaluation and Compensatory Behaviour

A review of the detrimental effects of cannabis and alcohol on driving found that cannabis shows its greatest impairment on the automatic functions of driving (e.g., maintaining lane position, headway distance), and little impairment on the aspects that require conscious control such as signalling or making required turns (Sewell et al., 2009). On the other hand, alcohol was shown to have the opposite effect, impairing conscious, effortful driving functions more than automatic functions (Sewell et al., 2009). The authors suggested that cannabis users are often more aware of their impairment and make appropriate behavioural compensations, but the introduction of alcohol limits an individual's ability to do so effectively. Therefore, the combination of alcohol and cannabis results in a greater level of driving impairment than would be expected if either substance were consumed alone (Sewell et al., 2009).

There is empirical evidence to support the differential effects of cannabis and alcohol on the ability to engage in compensatory behaviour related to driving impairment (Sewell et al., 2009). In studies investigating the combined effects of THC and alcohol on driving, researchers have noted that alcohol causes individuals to underestimate their level of impairment and over-estimate their driving ability (Ronen et al., 2010). Therefore, drivers under the influence of alcohol often fail to compensate for the impairing effects and engage in risky driving behaviour such as speeding and following other vehicles more closely (Lenne et al., 2010; Ronen et al., 2008, 2010; Smiley, 1999).

On the other hand, researchers have observed compensatory behaviours following THC administration such as decreased speed and increased headway distance (Anderson et al., 2010; Downey et al., 2013; Hartman & Huestis, 2013; McCartney et al., 2021; Robbe, 1998; Ronen et al., 2008; Smiley, 1999). This has led researchers to infer that individuals under the influence of cannabis are more aware of their impairment and are thus more cautious (Anderson et al., 2010; Lamers & Ramaekers, 2000; McCartney et al., 2021; Robbe, 1998; Ronen et al., 2008).

However, not all driving deficits are subject to effective behavioural control. For example, there is a wealth of evidence demonstrating that THC increases SDLP suggesting an inability to mitigate the effect of THC on road tracking (Arkell et al., 2020; Bondallaz et al., 2016; Hartman & Huestis, 2013; Lenne et al., 2010; Robbe, 1998).

Despite research demonstrating the greatest impairment is often observed in conditions involving combinations of alcohol and THC, some researchers have proposed that the opposing effects of the two substances (e.g., alcohol leading to increased speed and THC leading to speed reduction) may cancel each other out (Hartman et al., 2015; Ronen et al., 2010). This suggests that in some instances, driving impairment indicators for THC and alcohol (e.g., variation in speed) may be masked when evaluated in combination due to compensatory processes.

In the real world, low doses of THC could potentially mitigate select dangerous driving actions associated with alcohol such as speeding (Hartman et al., 2015). However, this does not infer that consumption of THC will reduce the risks associated with drinking and driving. There are several variables to consider when evaluating one's ability to drive safely; for example, the amount of THC and alcohol consumed, amount of time passed since consumption, drug and alcohol tolerance, stomach contents, road conditions, time of day, fatigue, age, and driving experience can all affect an individual's driving performance.

Recent prevalence data indicate that alcohol and cannabis are the two most commonly utilized substances in our country (Health Canada, 2018). Since the legalization of cannabis, the prevalence of cannabis use has increased. Therefore, there is a need for more research to understand Canadians' perception of risk associated with driving under the influence of these substances, how they evaluate impairment, and how this information relates to driving decisions.

Impaired Driving in Canada

A recent poll completed for MADD Canada by Ipsos marketing company surveyed 3000 Canadians aged 18-70 with a valid driver's license (Ipsos, 2023). Using quotas and weighting, the survey composition was representative of the Canadian population; using a 95% confidence interval, results are accurate within ± 2.0 percentage points. According to this poll, 68% of Canadians have consumed alcohol within the past 30 days and among those, 6% have driven impaired from at least once in the past six months (Ipsos, 2023). Similarly, 30% of Canadian drivers reported using cannabis in the past 30 days, with 12% indicating that they have driven impaired at least once in the past six months (Ipsos, 2023). Elevated rates of driving under the influence of cannabis (18%) were noted for men and women aged 18-34 (Ipsos, 2023).

According to police reports, impaired driving charges were on a downward trend since 2011 (Perreault, 2019). In 2018, when cannabis was legalized, the Criminal Code was updated which afforded the police increased power when screening for impaired driving. Following this change, impaired driving rates increased by 19% in 2019 for the first time in nearly a decade to a total of 85,673 incidents or 228 incidents per 100,000 population (Perreault, 2019). In 2019, there were 6,543 police reported incidents of drug-impaired driving, a 43% increase from 2018 (Perreault, 2019). This increase is likely attributable to the introduction of new legislation to address drug-impaired driving and a 5-year $161 million investment by the Canadian Government to target this behaviour through enhanced screening and enforcement procedures (Public Safety Canada, 2020). Overall, drug-impaired charges represented 8% of all impaired driving charges in 2019 (Perreault, 2019).

As an indicator of the magnitude of harm caused, the number of impaired driving charges causing death dropped by nearly 50% from 2018 to 2019 (66 incidents, down from 105) and impaired driving causing bodily harm showed little change (457 to 483) (Perreault, 2019). Fortunately, the increase in police-reported impaired driving behaviour is not necessarily translating to more loss of life or serious injury. However, in a recent Canadian analysis, the blood was tested for over 4000 moderately injured drivers who attended a trauma centre in British Colombia (Brubacher et al., 2022) .The authors concluded that the number of injured drivers whose THC blood alcohol concentration was over the legal limit has doubled since cannabis was legalized (Brubacher et al., 2022).

Interestingly, another study from the same Canadian trauma centre concluded that police are much less likely to report drugs as a contributing factor in the crash, when compared to alcohol (Brubacher et al., 2018). For drivers who tested positive for alcohol, alcohol impairment was listed on the police report as a contributing factor in 64% of cases. For drivers who tested positive for THC, drug impairment was only reported in 5% of cases. The authors suggest that impaired driving rates are likely underestimated due to this bias in reporting.

A Canadian public safety report explored drug-impaired driving trends and determined that as a proportion of all impaired driving charges, drug-impaired driving has been increasing over the past ten years. For all drug-impaired driving charges, cannabis is the most frequently detected substance by law enforcement (Public Safety Canada, 2020).

Cannabis and Driving in Canada: Beliefs and Behaviour

In the 2022 CCS, Canadians who reported using cannabis in the past 12 months were asked about their driving behaviour (Government of Canada, 2022a). Among cannabis users, 23% reported that they had driven within two hours of smoking or vaping cannabis and 37% of those did so within the past month. Similarly, 14% of cannabis users reported driving within four hours of consuming an edible cannabis product with 32% of those doing so in the past month (Government of Canada, 2022a). Although it may appear as though users of edible cannabis are more cautious than users of other products, it is important to recall the differences in base rates for the types of products being used by Canadians. More people in the overall sample reported smoking cannabis than using edibles which translates to a higher likelihood of driving after using this specific product.

Respondents who admitted to driving within two hours of smoking cannabis or within four hours of consuming edible cannabis products were asked about driving while under the influence of cannabis and alcohol in combination; 14% indicated that they had done so within the past 30 days (Government of Canada, 2022a).

Among all survey respondents, 21% reported being a passenger in a vehicle with a driver who recently used cannabis; this number jumped to 46% when only cannabis users were considered (Government of Canada, 2022a).

These driving decisions likely reflect a poor understanding of the effects of cannabis. In general, 83% of Canadians think that cannabis use affects driving; however, the CCS did not assess these beliefs in detail (Government of Canada, 2022a). It would be helpful to identify the specific driving behaviours that Canadians believe are positively or negatively affected by cannabis use. For example, it is possible that Canadians think that cannabis use makes it more likely that drivers will swerve, while decreasing the likelihood of other unsafe driver actions such as speeding.

Cannabis users’ beliefs about the effects of cannabis use are more problematic than non-users. In the 2022 CCS, only 76% of cannabis users believe cannabis use negatively affects driving, 13% believe that the effect of cannabis on driving depends on several factors such as tolerance and amount used, and 6% reported that cannabis use does not affect driving. (Government of Canada, 2022a). The fact that 6% of cannabis users do not believe cannabis use affects driving may not seem like an alarming statistic; however, depending on the survey (i.e., Canadian Cannabis Survey or National Cannabis Survey), 20-25% of the Canadian population reports using cannabis (Government of Canada, 2022a; Statistics Canada, 2021). Therefore, these statistics translate to over half a million Canadian cannabis users who do not believe cannabis use affects driving. A better understanding of these belief systems would be extremely valuable in identifying targets for public health campaigns to dispel misconceptions among the Canadian public and keep our roads safe.

Across national surveys, Canadian cannabis users demonstrate more permissive attitudes than non-users which may translate to riskier behaviour. Not only do cannabis users report higher rates of DUIC, they are also two or three times more likely than non-users to ride as a passenger with someone who recently used cannabis (Davis et al., 2016; Fischer et al., 2014; Government of Canada, 2022a)

International survey data reveal similar trends. In Colorado and Washington states, 800 recent cannabis users were surveyed and over 50% agreed or strongly agreed with the statement "I might drive high even though I know I shouldn't" and 43% indicated that they have driven a motor vehicle while high or feeling the effects of cannabis in the past year (Davis et al., 2016). Alarmingly, 23% of participants in this study admitted to driving within an hour of using cannabis five or more times in the past 30 days (Davis et al., 2016). In a survey of regular cannabis users in England, 12% admitted to driving while high even though they felt impaired (Terry & Wright, 2005).

In the CCS, when asked how much time people should wait before driving after using cannabis, 35% of Canadians admitted to being unsure about how much time is required to drive safely following cannabis use (Government of Canada, 2022a). According to the 2019 National Cannabis Survey, nearly half of Canadians (49%) felt individuals should wait three hours before driving after smoking cannabis, while only 6% felt it was safe to drive within three hours (Statistics Canada, 2019). Again, cannabis users held more permissive beliefs with 18% reporting that it was safe to drive within three hours of using cannabis (Statistics Canada, 2019).

In 2020, the CCS added a question about about the perception of time required to drive safely after using different types of cannabis. For smoked and edible cannabis, the most common response was "I don't know" (34% and 36%, respectively) (Government of Canada, 2022a). For smoked cannabis, other responses included: 8 or more hours (21%), 3-5 hours (16%), 5-7 hours (11%) and 7-8 hours (7%) with 2% reporting that it is safe to drive immediately after smoking cannabis (Government of Canada, 2022). For edible cannabis, other responses included: 8 or more hours (31%), 5-7 hours (10%), 7-8 hours (9%) and 3-5 hours (9%), with 2% reporting that it is safe to drive immediately after ingesting cannabis (Government of Canada, 2022a). Unfortunately, the most recent CCS surveys (2020-2022) failed to report on the differences in opinion for Canadians who reported using cannabis versus those who do not.

Canadians who admitted to driving after smoking cannabis or consuming edibles were asked to indicate their reasons for driving. The most common response, reported by 84% of respondents, was that they did not feel impaired (Government of Canada, 2022a). Another common response listed by 19% of respondents was the belief that they could drive carefully following cannabis use (Government of Canada, 2022a). However, very little is known about how individuals assess impairment in themselves and others, and how this assessment relates to the perception of driving ability.

The CCS asked Canadians if they had access to enough trustworthy information about cannabis and 72% reported that they “strongly agreed” or “somewhat agreed” that they do have access to enough information (Government of Canada, 2022a). Thus, a substantial proportion of Canadians do not feel they have access to enough information to make informed decisions. Even within that 72%, not everyone is *fully* satisfied with the currently available information. To address this, our study will seek to understand the sources of information that Canadians prefer and consider trustworthy when it comes to public health knowledge dissemination. In addition, willingness to use different tools to assess cannabis impairment will be explored.

Costs of Driving Under the Influence of Cannabis (DUIC)

At this point, there is clear evidence that cannabis negatively affects driving behaviour and increases crash risk. Epidemiological data has provided evidence of real-world negative outcomes. Based on one year of Canadian data, there were 75 fatalities, 4,407 injuries, and 7,794 reported crashes involving property damage, attributable to cannabis (Wettlaufer et al., 2017). Drivers aged 16-34 appeared over-represented in terms of cannabis-attributable fatalities; this age group represents only 32% of Canada’s population but may have accounted for over 60% of the fatal crashes involving cannabis (Wettlaufer et al., 2017). The authors concluded that driving under the influence of cannabis (DUIC) results in annual social and economic costs exceeding one billion dollars (Wettlaufer et al., 2017). Therefore, any research that contributes to better understanding the factors that contribute to DUIC will benefit Canadians’ health and the economy. No comparable post-legalization data could be located.

Risk Factors for DUIC

Driver Age

Drugs and/or alcohol have been identified as a factor in 55% of fatal crashes in Canada (Solomon et al., 2018). Motor vehicle crashes are the leading cause of death for Canadian youth; in fact, car crashes account for 30% of all deaths for Canadians aged 15-24 (Chamberlain & Solomon, 2006). Young adults aged 20-24 are most likely to be charged with impaired driving, with rates nearly three times higher than the general population (Government of Canada, 2016).

A similar trend is evident in recent data for DUIC. In Canada, individuals aged 16-34 constitute 32% of Canada's population but were responsible for over 60% of fatal car crashes attributable to cannabis (Wettlaufer et al., 2017). This age group was also disproportionally represented in rates of cannabis-attributable car crashes involving serious injury and property damage, comprising 59 and 68 percent of cases, respectively (Wettlaufer et al., 2017).

Data from Ontario suggest higher impaired driving rates for youth (Boak et al., 2017). In 2015, 5.1% of high school students in Ontario reported driving after consuming alcohol and 9.8% admitted to driving under the influence of cannabis (Boak et al., 2017). These rates may appear low, but it is important to consider the previously reported base rates for drug and alcohol use which indicate that rates of cannabis use in these are groups continues to rise. In addition, students may be reluctant to admit to illegal behaviour in a survey despite the assurance of anonymity and confidentiality.

For youth in British Colombia who identified themselves as frequent cannabis users (i.e., using at least once per week), 64% of males and 33% of females reported driving while "intoxicated" from cannabis in the past 30 days (Leadbeater et al., 2017)

Sex/ Gender Differences

Clear gender differences exist in the self-reported rates of impaired driving. According to the CADUMS, for youth aged 15-24, males were three times more likely than females to report driving after drinking or using cannabis (Health Canada, 2014). Data from Ontario high school students reveal a similar trend; males were twice as likely to admit driving while under the influence of cannabis or alcohol (Boak et al., 2017).

Gender differences in self-reported impaired driving mirror the statistics for car crash fatalities in Canada. For all car crashes involving youth aged 15-19, males accounted for 78% of fatalities (Emery et al., 2008).

Interestingly, most experimental studies investigating the effects of cannabis and alcohol on driving performance do not report on gender differences. However, one study tested the hypothesis that THC has differential effects on driving performance based on gender (Anderson et al., 2010). In this double-blind placebo-controlled study, participants were required to smoke a marijuana cigarette, but only half of the cigarettes contained THC, the rest were placebo cigarettes. Immediately following consumption, participants completed three simulated driving tasks: one uneventful baseline drive, and two challenging conditions (i.e., one involving collision avoidance and the other was a distracted driving scenario).

Cannabis consumption had no significant effect on the baseline drive or collision avoidance scenarios. However, participants who smoked cannabis showed significant reductions in speed in the distracted driving tasks and failed to demonstrate the expected practice effects in these scenarios. No gender differences were observed for these effects of cannabis (Anderson et al., 2010). In this study, more females were dropped from the experimental condition analyses (i.e., cannabis consumption) for failing to finish the marijuana cigarette. In the final analysis there were only 9 females and 24 males in the group that smoked marijuana cigarettes with active THC. Therefore, this may have hindered the ability to detect potential gender differences for the effect of THC on driving performance. However, if it is true that there are no gender differences in the effect of cannabis on driving performance, it may be that the gender differences for impaired driving rates and fatalities reflect differences in willingness to drive impaired, as opposed to differential effects of the substance.

This hypothesis is supported by the 2022 CCS which identified clear gender differences in driving after cannabis use. In the 2022 survey, more males than females reported driving within two hours of smoking cannabis (30% versus 18%) and within four hours of ingesting an edible product (16% versus 9%) (Government of Canada, 2022a). The 2022 CCS did report on gender differences for driving under the combined influence of cannabis and alcohol. However, 2019 data reveals a similar pattern with more males reporting driving within two hours of using cannabis in combination with alcohol (24% versus 13%) (Government of Canada, 2019).

Canadian data on drug-impaired driving charges reveals a similar trend. In 2019, 77% of the individuals charged with drug-impaired driving were male (Perreault, 2019).

Personality

Personality traits and characteristics are considered important influences on behaviour. Several personality variables have been found to be associated with DUIC including sensation-seeking and risk-taking (Cook et al., 2017; Richer & Bergeron, 2009). One study failed to detect a relationship between risk-taking and DUIC (Bingham et al., 2008). However, this investigation operationally defined risk-taking propensity using only a 4-item measure (Bingham et al., 2008). The current study explores the relationship the relationship between DUIC and risk-taking using a more comprehensive validated measure that assesses risk taking behaviour in several relevant domains including social, health/safety, ethical, financial and recreational (Blais & Weber, 2006).

Substance Use

Public Health Ontario completed a review exploring different risk and protective factors for DUIC and concluded that substance use (i.e. cannabis, alcohol, and/or other drugs) was associated with increased risk of DUIC (Cadieux & Leece, 2017). Results from two Canadian national surveys (i.e., CCS and NCS) indicate that cannabis users have more permissive beliefs about cannabis use and driving (Government of Canada, 2022; Statistics Canada, 2019). Several studies, including one from Ontario, have demonstrated that this translates into risky behaviour; there is a positive association between frequency of cannabis use and rates of self-reported DUIC (Arterberry et al., 2013; Davis et al., 2016; Fischer et al., 2014). Therefore, regular cannabis use is a risk factor for DUIC, and this relationship is likely explained by the fact that cannabis users generally tend to have more permissive beliefs about driving after using cannabis.

As indicated in the review by Public Health Ontario, other substance use behaviours were also associated with the likelihood of DUIC. Individuals who reported binge drinking and/or using other substances (i.e., not cannabis) were also more likely to self-report DUIC (Fischer et al., 2014; Jones et al., 2007; Lewis et al., 2008; Minaker et al., 2017).

Beliefs

There are several beliefs that have been identified as risk factors for DUIC. A multi-sample research study from Ontario identified factors that distinguished university students who frequently engage in DUIC from those who do not engage in this behaviour (Fischer et al., 2014). Consistent with above, frequency of cannabis use was associated with the odds of reporting DUIC; in addition, students who reported frequent DUIC were more likely to believe that their driving skills were not affected by cannabis use (Fischer et al., 2014). This is consistent with national survey data which found that cannabis users are more likely to report that cannabis has no effect on driving ability (Government of Canada, 2022a).

Additional beliefs were found to be associated with DUIC. There is a relationship between the level of risk perception and the odds of reporting DUIC; individuals who believe that DUIC is dangerous were less likely to report DUIC (Arterberry et al., 2013; Aston et al., 2016; Davis et al., 2016; McCarthy et al., 2007). Similarly, individuals were less likely to report DUIC when they were more cognisant of the negative consequences including being stopped by police, drug tested, being involved in a car crash, or being criminally charged (Aston et al., 2016; Fischer et al., 2014; McCarthy et al., 2007).

Lastly, there is evidence to suggest the normative beliefs of peers may influence the likelihood of DUIC. Drivers were less likely report DUIC if they indicated that their friends disapprove of this behaviour (Aston et al., 2016; McCarthy et al., 2007)

Legality of Driving Under the Influence of Cannabis (DUIC)

Federal and provincial sanctions pertaining to cannabis and driving are similar to those for alcohol. Drivers under the age of 21 and “novice drivers” (i.e., holding only a G1, G2, M1, or M2) are subject to a zero-tolerance rule for cannabis (Government of Canada, 2019b). Similarly, individuals driving commercial vehicles (i.e., holding A-F driver’s licence or Commercial Vehicle Operator’s Registration) are not allowed to have any cannabis in their system. Violation of these laws will lead to license suspensions and monetary fines and repeat offenders will be subject to longer suspensions and mandatory education or treatment programs (Government of Canada, 2019b).

Ahead of cannabis legalization, the government of Canada introduced legislation (i.e., Bill C-46) to amend the Criminal Code of Canada and introduced harsher penalties for impaired driving and new provisions specific to drug use (Beirness & Porath, 2017; Government of Canada, 2018a). Under this new law, police officers can request samples of oral fluid from drivers to test for the presence of drugs, similar to the roadside tests for alcohol impairment (Government of Canada, 2018a).

The new federal impaired driving laws came into effect in December 2018 and included two prohibited levels for THC (Government of Canada, 2019c). A driver found to have between 2 and 5 ng of THC per mL of blood may be fined to a maximum of $1000 fine; drivers who are found to have 5 or more ng of THC per mL of blood may face a minimum fine of $1000 fine and a maximum sentence of ten years in prison (Government of Canada, 2019c). For a second offence with 5 or more ng of THC per mL of blood, impaired drivers receive a minimum of 30 days imprisonment (and a maximum of 10 years), and a minimum of 120 days imprisonment for a third offence (with a maximum of 10 years) (Government of Canada, 2019c). The penalties increase significantly if the driver's impairment results in death or bodily harm (Government of Canada, 2019c).

Further sanctions may occur at the provincial level. For example, in Ontario, if a drug recognition expert determines a driver is impaired from cannabis they will be subject to the same immediate penalties as a driver with a BAC over 0.08 including a 90-day license suspension, 7-day vehicle impoundment, $550 fine and mandatory education and/or treatment programs (Ministry of Transportation of Ontario, 2019).

Driving Under the Influence of Alcohol and Cannabis Combined

The Government of Canada has set limits regarding driving under the combined influence of THC and alcohol (Government of Canada, 2019c). A driver is considered impaired with a BAC of 0.05 (or higher) in combination with 2.5 ng or more of THC per mL of blood (Government of Canada, 2019c). Individually, the levels are consistent with the "warn range" of alcohol and less serious penalties for THC. This suggests that the government considers the combined effects of THC and alcohol as more dangerous than the individual effects of either substance. Individuals should be extremely careful and cautious when making decisions about their ability to drive safely under the influence of both substances. Aside from the fact that judgement is likely impaired, the individualized interactions of alcohol and THC are not fully understood. While the timing of alcohol's effects are well-understood, there is a lack of consensus around the passage of time required for an individual to drive safely after consuming cannabis, especially when the diversity of available cannabis products is taken into consideration (Government of Canada, 2019b).

Evaluating DUIC

Currently, when a driver is suspected of DUIC, law enforcement engages in a two-step process. As a first step, the officer will complete an initial road-side assessment, which often involves administration of the standard field sobriety tests (e.g., walk and turn, eye tracking, pupillary response). Research has called the validity of these tests into question when evaluating cannabis impairment (Bosker et al., 2012; Downey et al., 2012; Papafotiou et al., 2005). This roadside assessment battery was originally developed and validated for determining impairment from alcohol and research has indicated that these same behavioural tests may not be sensitive or specific enough to detect functional impairment attributable to THC (Bosker et al., 2012; Ginsburg, 2019; Ramaekers et al., 2021).

A roadside screening test that has demonstrated superior sensitivity is a mobile application called DRUID (DRiving Under the Influence of Drugs; Richman & May, 2019). The assessment involves a balance task and four short tasks (less than one minute) to measure reaction time, hand-eye coordination, decision-making and time estimation under conditions of divided attention. The data are integrated to provide an overall score for global impairment and preliminary data has found that this tool is more sensitive to cannabis impairment than commonly used standard field sobriety tests (Spindle et al., 2021). This is likely attributable to the fact that the neurocognitive processes measured by the DRUID application are more aligned with the empirically supported predictors of driving impairment associated with cannabis (Spindle et al., 2021)

If impairment is suspected based on roadside testing, the officer will bring the individual to the police station for further examination by a Drug Recognition Expert. This assessment involves additional behavioural assessment and biological confirmation of impairment, using a blood or urine sample to determine blood THC concentration. As previously mentioned, the threshold for charging a driver with DUIC is 5 ng of THC per mL of blood for cannabis alone. These limits are frequently referred to as *per se* limits in recent research literature. In Canada, the limit is lower, 2 ng of THC per mL of blood, when drivers also test positive for alcohol (Government of Canada, 2019b).

These limits have been scrutinized on several accounts including a failure to account for individual differences in genetics, metabolism, and tolerance. There is significant variability in blood THC concentrations based on mode of administration, time elapsed and dosages

(Asbridge, 2006). At the individual level, there is not a clear relationship between self-administered dose and blood THC concentration (Spindle et al., 2021). One study of infrequent users found that for oral consumption of two doses above the proposed threshold, THC levels peaked after two hours but failed to rise above 5 ng. For a 10 mg dose, the mean peak blood THC level was only 1.78 and only 3.06 for a 25 mg dose (Spindle et al., 2021). On the other hand, vaporized cannabis caused blood THC levels to spike immediately after consumption, at levels above the dosage (9.19 for 5 mg dose, and 37.24 for 20 mg dose), but quickly dropping to 5 ng or less within one hour (Spindle et al., 2021).

Arkell and colleagues (2021), leading researchers in this area, recently concluded that the proposed limits failed to discriminate between impaired and unimpaired drivers on a simulated driving task. This study used vaporized cannabis (10% THC dominant, 10% CBD/THC hybrid, and a placebo) and completed measurements at two time points (30 minutes and 3.5 hours) using increases in SDLP as the main outcome variable for driving impairment. At 30 minutes, all participants were well above the recommended limit (5 ng/mL), yet 46% were not classified as impaired. Interestingly, more participants (57%) met the SDLP criteria for impairment at the 3.5 hour time point, although blood and oral THC levels had dropped below the limit for most participants (Arkell et al., 2021). The authors concluded that the relationship between blood THC concentration and driving impairment is weak and inconsistent, indicating an urgent need for more valid impairment detection tools and methods (Arkell et al., 2021).

Evidence-Based Recommendations for Evaluating DUIC

To improve upon the current standards for evaluating DUIC, researchers have made several recommendations to avoid relying on the *per se* limits. As demonstrated above, THC levels in the blood do not reliably predict neurocognitive impairment from cannabis, and the degree of association between these two variables is complicated by several factors (Ramaekers et al., 2021). Although blood THC concentrations are indicative of cannabis *use*, this does not necessarily infer that an individual's abilities are meaningfully *impaired.*

Behavioural field sobriety tests have been proposed as a viable alternative; however, these approaches are introducing additional threats to validity without an individual's baseline performance (Ramaekers et al., 2021). The current SFST battery may not be sufficiently sensitive or specific enough to reliably detect cannabis-attributable impairment, but a behavioural test battery designed specifically to assess for cues of cannabis-impairment may improve the validity if an individual baseline can be established.

In responses to Ramaekers' influential article emphasizing the variability in neurocognitive impairment from cannabis (2021), Arkell (2021) proposed utilization of driver monitoring systems that monitor drivers' behavioural state including eye closure or gaze monitoring. These authors indicate that these sophisticated safety monitoring systems can be built into vehicles or physiological indicators of impairment (e.g., ocular functioning) could be used in roadside assessments in lieu of relying on THC levels and biological matrices (Arkell et al., 2021).

Although an EEG is unlikely to be utilized as a roadside assessment tool in the immediate future, there is evidence to suggest that EEG power in the Theta brain waves (4-7 Hz) is a neurophysiological indicator of cannabis intoxication (Brown et al., 2020). Relative to placebo, brain waves in the Theta frequency band were significantly decreased for participants who vaporized cannabis. Importantly, the theta power was negatively correlated with physiological indicators of cannabis intoxication (i.e., heart rate) and SDLP, a known indicator of cannabis-induced driving impairment (Brown et al., 2020).

The DRUID smartphone application requires further research to validate Spindle's (2021) results which concluded that this brief assessment was the "most sensitive measure of impairment when compared to the other cognitive performance tasks administered, as well as several common standard field sobriety tests" (p.802). With further research and validation, the application can continue to be updated so that the tasks align with assessment of sensitive-indicators of cannabis-attributable impairment. This tool has the potential to strengthen the validity of roadside evaluations.

Overcoming Methodological Inconsistencies in Research on Cannabis and Driving

Recently, researchers have advocated for more standardization in cannabis research methodology including reliable dose administrations (e.g., consistent puffs or titrated doses), and the identification of a "standard dose" (e.g., 5 mg) to enhance validity and allow for comparisons across studies (Arkell et al., 2021; Ramaekers et al., 2021).

In order to better understand the effects of drug-impaired driving in Canada, the Canadian Centre for Substance Use and Addiction (CCSA) completed a multiyear project to identify 34 indicators of drug-impaired driving across nine data sources (Meister & Drug-Impaired Driving Indicators Advisory Committee, 2022). The recommended indicators include data from law enforcement (i.e. incidents and resource use), judicial outcomes, medical and coroner investigations, hospitals, roadside surveys, motor vehicle divisions (i.e. driver records) and national surveys (Meister & Drug-Impaired Driving Indicators Advisory Committee, 2022). Authors of this report suggest that to improve upon the measurement and management of drug-impaired driving in Canada, greater collaboration and data-sharing is required among levels of government and relevant organizations.

For the purposes of research and public consumption, stakeholders in Canada have been discussing the need for quantifying a "standard unit" of THC (Canadian Centre of Substance Use and Addiction, 2023). A virtual session was completed in October 2022 involving four main presenters who discussed how a standard unit of THC would contribute to enhanced research validity, informed public consumption, and an adherence to the goals and objectives of *the Cannabis Act* intended to protect public health and safety.

Driving simulator research is a major contributor to investigating the effects of cannabis on specific driver actions in a controlled and safe manner. A group of Canadian researchers recently published a framework to help support further work this in area by providing evidence-based designs that link cannabis effects (i.e., sensory, motor and cognitive) to specific aspects of driving performance (Thawer et al., 2022). The authors propose several simulated drive components or tasks that can be incorporated to assess specific driver actions that may be negatively affected by cannabis use (Thawer et al., 2022). As an example, processing speed or reaction time can be operationally defined in simulator research as braking or steering reaction time, as measured by simulation components such as the abrupt stopping of a preceding vehicle, or an unexpected pedestrian crossing (Thawer et al., 2022).

Taken together, these recently published recommendations will significantly improve the quality of research involving cannabis and driving by promoting greater standardization, information sharing, and utilization of empirically-informed indicators. This will strengthen the validity of information used by policy makers, decision makers, and public safety practitioners.

Limitations of Previous Research

Although there has been a rapid expansion of research investigating the relationship between cannabis use and driving performance, there are areas in need of further investigation.

A significant majority of existing research on cannabis and driving tends to focus on smoked/inhaled cannabis, excluding other modes of administration that may differentially affect decision-making and driving behaviour. The usage trends observed in Canadian cannabis users suggest a need to further investigate the beliefs, behaviours and decision-making processes of Canadians who are using more diverse types of cannabis at increasing rates.

The current project expands on existing information collected through the CCS and the National Cannabis Survey while addressing gaps in knowledge. Our research will facilitate a deeper level of understanding in terms of Canadians' beliefs and perceptions about the effects of different cannabis products and cannabinoids (e.g., dried cannabis versus edibles and THC versus CBD). One of the most novel contributions to the literature relates to understanding how people evaluate cannabis impairment within themselves in the context of driving. No research could be located that has explored this process. In addition to exploring this notion qualitatively and quantitatively, our research explores Canadians' willingness to use assistive tools for evaluating cannabis impairment to aid in making responsible driving decisions.

The second novel contribution to the literature involves describing the individualized decision-making process people engage in when contemplating driving after cannabis use. Using a survey developed through a two-step process, the subjective process of evaluating cannabis-attributable impairment and weighing other factors in driving decisions is explored. The results contribute to the identification of different risk and protective factors for DUIC.

This project utilizes a mixed-methods design to meet the objectives described below, integrating secondary data with new data collected through focus groups and an online survey. The ensuing data will contribute to the knowledge base about how cannabis use relates to driving behaviour. In addition, this research can be used to inform public health campaigns addressing gaps in knowledge or misinformation to reduce the prevalence DUIC.

Objectives of the Current Study

In this study we seek to add to the knowledge base about cannabis and safe driving by utilizing:

1.) An existing comprehensive dataset (i.e., FARS) to better understand risks associated with driving under the influence of cannabis (DUIC) and the specific driver actions that are associated with cannabis-related fatalities.

2.) A new survey developed to explore individual beliefs and perceptions about the effects of different cannabis products on driving behaviour and the specific decision-making process that individuals engage in when contemplating driving after cannabis use.

More specifically, the objectives are:

1.) To determine how much the odds of being responsible for a fatal car crash increases (i.e., odds ratio) when the driver is under the influence of cannabis or alcohol. This will extend the work of Dubois et al., (2015) by adding 11 years of new data to the analysis,

2.) To identify specific driver actions that are implicated in cannabis-related fatalities,

3.) To assess the current level of understanding in Canadians with respect to the different effects of smoked cannabis and edible forms of cannabis,

4.) To explore Canadians' perceptions regarding the impact of cannabis and its different forms on the ability to drive safely (e.g., time required to drive safely after cannabis use, beliefs around how cannabis affects specific driver actions, risk perception compared to alcohol, differences in opinion for different cannabis products), 5.) To understand how individuals evaluate cannabis impairment in themselves in the context of driving,

6.) To identify factors that are considered when individuals contemplate driving after cannabis use and the relative importance of these factors,

7.) To identify the sources of information that Canadian cannabis users rely on for safety information related to cannabis and driving,

8.) To determine if Canadian cannabis users would be willing to use assistive tools to evaluate impairment from cannabis and making decisions about the ability to drive safely. If the focus groups reflect willingness, the survey will identify the preferred type of tools and what factors should be considered in tool development to promote the acceptability and uptake of these tools among cannabis users.

9.) To determine if risk-taking, as measured using the DOSPERT (Blais & Weber, 2006), is associated with impaired driving behaviour. The DOSPERT measures risk-taking in five domains including ethical, financial, health/safety, recreational and social. Associations between general risk-taking, the five risk-taking domains, and self-reported impaired driving are explored.

Hypotheses

1.) Based on previous research, it is hypothesized that the odds of being responsible for a fatal car crash increases when the driver is under the influence of cannabis or alcohol. Specifically, when compared to drivers with a BAC of zero, the odds ratio is predicted to increase by at least 0.1 for every increase of 0.01 in BAC. Relative to drivers who have no drugs or alcohol in their system, it is predicted that the odds ratio of being responsible for a fatal car crash will be 1.25 for drivers who test positive for THC.

2.) The specific unsafe driver actions (UDAs) likely to be implicated in cannabis attributable fatalities will include failure to keep in proper lane (i.e., SDLP or swerving) and improper following (i.e., headway distance).

3.) Canadians will be more knowledgeable about the effects of smoked cannabis than the effects of edible cannabis products. This hypothesis is based on the fact that, post-legalization, the diversity in available edible products increased far faster than the research base and dissemination of information.

   a. It is predicted that cannabis users report being more knowledgeable about products they are more familiar with (i.e., smoked cannabis) than new products (i.e., edible products such as gummy candy, chocolate, or beverages).

   b. Canadians will be more accurate in estimates of time to reach peak effects for smoked cannabis, compared to edible cannabis.

4.) Similar to above, Canadians will be more knowledgeable about how smoked cannabis affects driving behaviour (compared to edible products).

   a. Canadians will report more accurate beliefs about the amount of time required to drive safely after smoking cannabis compared to consuming edible products.

   b. Canadians' beliefs about specific driver actions that are affected by cannabis use will likely be extrapolated from their beliefs about the effects of cannabis in general (e.g., slower reaction time, higher distractibility, fatigue). Thus, it is hypothesized that driver actions Canadians believe are most affected by cannabis will not align with specific UDAs identified through the FARS analyses.

   c. Relative to alcohol, Canadians will perceive a lower level of risk associated with driving under the influence of cannabis.

5.) No existing research could be located relating to how individuals self-evaluate impairment from cannabis in the context of driving; therefore, this hypothesis is exploratory in nature. However, it is predicted that when impairment within themselves, individuals will consider cannabis factors (e.g., amount and type of product used, perception of tolerance, time elapsed), cognitive factors (e.g., fatigue, alertness), and stereotypical cannabis impairment indicators (e.g., redness of the eyes, smell).

6.) It is predicted that individuals will consider various factors when reasoning through the decision-making process of driving after cannabis use. Based on previous research, factors in the decision-making process may include: the amount of cannabis used, the amount of time passed from consumption, availability of other transportation options, driving distance, previous experience driving after using cannabis, risk factors (e.g., time of day, perception of risk relating to law enforcement), consideration of others' opinions (i.e., are others encouraging or discouraging driving), individualized consequences of getting caught (e.g., fear of being in a car crash, career implications, judgement from others) and their own subjective evaluation of impairment (see hypothesis 5).

7.) For accessing information relating to responsible cannabis use and safe driving, it is predicted that Canadians will prefer online information that they can access repeatedly and discreetly as opposed to other sources (e.g., advertisements, social media).

8.) We predict that Canadians would use phone application self-assessment tools to evaluate impairment from cannabis if they were available. Factors that are hypothesized to influence cannabis users' willingness to use the tools include validity and cost.

9.) Participants with higher scores on the DOSPERT will be more likely to report driving under the influence of cannabis and/or alcohol. It is predicted that subscale scores for the health and safety domain of the DOSPERT will have the greatest association with self-reported impaired driving behaviour as assessed using logistic regression models.

Methods

Part 1: Examination of Fatal Car Crash Trends Involving Cannabis: Analysis of Administrative Data

Data Source

In the United States, every time a fatal car crash occurs, trained analysts are responsible for coding detailed information about the crash. These data are recorded in the Fatality Analysis Reporting System (FARS) under the National Center for Statistics and Analysis of the National Highway Traffic Safety Administration. The FARS database includes data for every fatal car crash that occurred since 1975, involving at least one motor vehicle on a public roadway in the United States of America. For inclusion in FARS, the crash must have resulted in at least one fatality within 30 days of the crash and the person who was fatally injured could be an occupant of a motor vehicle, or a non-motorist (e.g., pedestrian or bystander) (Dubois et al., 2010). Data from FARS will be analyzed to address hypotheses one and two.

The crash data are collected and coded from a variety of sources including police reports, vehicle registration and driver licensing files, state highway department data, vital statistics, death certificates, coroner, medical, emergency service, and hospital reports (Dubois et al., 2010; National Center for Statistics and Analysis, 2018). This information is collected using standardized procedures and is organized into three levels: the crash, the vehicle, and the person. At the accident level, information about the crash is recorded such as the time, location, and weather conditions. The vehicle level includes specific information including the number of vehicles involved, type of vehicles, points of impact for the crash, and driver's record history.

Lastly, all relevant information is collected for each person that was involved in the fatal car crash including demographic information, alcohol and drug use, role in the crash and previous driving history (Dubois et al., 2010).

Information on drug testing was introduced in the FARS database in 1991 and for the first two years, drugs were only coded by class (e.g., depressants, stimulants); thus, drug testing data for specific substances is available for fatal crashes that occurred from 1993 onward (Dubois et al., 2015). At present, there are currently eight different codes in the FARS database that correspond to a positive blood test for a drug containing THC including: Delta 9, hashish oil, hashish , marijuana, marinol, tetrahydro cannabinoid, THC, and cannabinoid, type unknown (Dubois et al., 2015). All of these codes were included in our investigation to indicate for the presence of THC. Alcohol and several additional drugs are coded in FARS (e.g., prescription drugs, hallucinogens, depressants, and stimulants).

As a proxy measure of crash responsibility, researchers have identified a subset of codes within FARS that correspond to unsafe driver actions (UDAs); these codes have been used successfully to infer crash responsibility in previous research (e.g., Bédard et al., 2007; Blower, 1988; Dubois et al., 2010, 2015). In total, there are approximately 40 UDAs in the database and for each fatal car crash, specialized FARS analysts read the police report to determine occurrence of any UDA (Dubois et al., 2010, 2015). There are several advantages to using UDAs as opposed to traffic violations or criminal charges when exploring crash responsibility. Importantly, UDAs can be identified through reports and do not rely on the burden of proof or the judicial system (Blower, 1988; Dubois et al., 2015). Furthermore, if the driver was fatally injured, criminal charges may not be pursued depending on the circumstances of the crash, particularly in single-car crashes where the driver was the sole person involved. Lastly, there are UDAs that may have contributed to the crash that don't necessarily correspond to any traffic violations (Blower, 1988; Dubois et al., 2015). Despite its comprehensiveness and popularity among researchers, the FARS dataset is not without limitations. To avoid repetition, these limitations will be summarized in the discussion section of this document.

Data Analysis

Data from the FARS were analysed using SPSS statistical software (Version 28.0.11). The primary analytical strategy to examine hypothesis one was logistic regression with any coded UDA as the dependent variable. The presence of THC was entered as a dichotomous predictor variable to determine if testing positive for THC was associated with increased odds of committing an UDA. To address hypothesis one, the regression model controlled for the presence of other substances (i.e., alcohol and other drugs), as well as identified confounding variables (i.e., age, sex, prior driving record). In FARS, the presence of alcohol is operationally defined as the blood alcohol concentration (BAC) detected and thus, was analysed as a continuous variable.

Based on results of the previous analysis by Dubois and colleagues (2015), several interaction terms were considered in testing different models. Interaction terms that were entered and tested for significance included age by sex, age-squared by sex, age by BAC, age-squared by BAC, age by THC, age by THC-squared, THC by BAC, THC by BAC-squared, THC by sex, BAC by sex, and BAC-squared by sex. Both the linear and quadratic terms for BAC were considered because previous FARS analyses have shown that the BAC data has a curvilinear fit (Dubois et al., 2015). Only significant interaction terms were retained in the final model.

To address the other component of hypothesis one, the odds ratio for alcohol was considered in the final model to determine if the odds of being responsible for a fatal car crash increases significantly when the driver is under the influence of alcohol.

To examine hypothesis two, similar logistic regression models were tested using the process described above for hypothesis one, with different individuals UDAs alternating as the dependent variable. Seven specific UDAs were tested based on previous research. The seven specific UDAs identified for individual analysis are: improper following, improper or erratic lane changing, failure to keep in proper lane (i.e., SDLP), illegal driving on the shoulder, erratic or reckless operation of a motor vehicle, speeding, and driving too slowly.

If THC is a significant predictor in any model, this will suggest that specific driver action is implicated in cannabis-attributable fatal car crashes. For each individual UDA, the influence of cannabis and alcohol were considered separately, and together, by evaluating the relative odds ratios for each substance at various levels of BAC. This step was included as a secondary comparative analysis to quantify the degree of association for alcohol, and cannabis, for each individual UDA.

Part 2: A New Survey of Canadians Beliefs, Cannabis Use Behaviours and Decision-Making Processes Related to Cannabis and Driving

Part two of this dissertation involves developing a new survey to address gaps in existing national surveys. The survey will assess cannabis use behaviour, knowledge of the differential effects for different cannabis products, and how this relates to driving decisions. Novel contributions include describing how individuals evaluate cannabis impairment within themselves, increased understanding of the decision-making process related to driving after cannabis use, and an evaluation of Canadians' willingness to use assistive tools in this process. The influence of dispositional risk-taking will be considered. Survey results will be used to identify areas where public perception may not align with research including results obtained in part one of this project.

Part 2 Phase 1: Focus Groups

Participants

Participants (n = 16) were recruited through several channels including posters distributed throughout the Thunder Bay community, social media posts, and advertisements in cannabis dispensaries. Inclusion criteria required that participants were at least 19 years old (the legal age to use cannabis in Ontario where this research was conducted), drive at least weekly, and have used cannabis at least five times in the past 12 months. This usage criterion could be met with any combination of smoking cannabis and ingesting edible cannabis products but experience with both was required. This criterion ensured that participants had enough experience with these products to provide meaningful feedback. For compensation, participants were entered into a draw for one of three $100 Visa gift cards. A copy of the focus group recruitment materials can be found in Appendix A.

Procedure

The first phase of this research involved holding three virtual focus groups using the Zoom platform. The focus groups allowed researchers to ask open-ended questions, expand on responses provided by participants and use more natural, semi-structured approaches to data collection which was appropriate for the exploratory nature of this phase.

The purpose of the focus groups was to inform survey development by identifying new response options for preliminary questions and potential new survey questions based on the group's contributions. The focus groups included 14 questions assessing beliefs about how cannabis affects driving, the subjective process of determining if you feel "too high" to drive, factors considered in driving decisions, awareness of legal thresholds for impaired driving, willingness to use tools to assist in driving decisions, and factors that may influence tool use.

The focus groups were conducted in September and October 2021. Each focus group had one facilitator and five or six participants. Although conducting the groups online was required due to COVID-19 restrictions, this approach offered additional benefits such as the inclusion of cannabis users from other provinces and the availability of focus group transcription through the Zoom platform.

At the end of each focus group, one volunteer was identified to assist with consultation following the preliminary analyses. The research team shared each volunteer's corresponding interview transcript to ensure that the group discussion content was appropriately represented. In addition, the three volunteers were provided a summary of the themes and new information identified from qualitative analysis to ensure that these ideas transpired directly through these discussions. In other words, this step of verifying the interview transcript and validating the themes confirmed that the data had not been misrepresented by the research team and that no important topics were omitted.

After two focus groups were conducted, the research team met to review the groups' demographics. Our goal was to include participants from diverse demographic groups to try and ensure adequate representation. A second consideration involved data saturation. In qualitative research, data saturation has occurred when it is likely that "no new information or themes are observed in the data" (Guest et al., 2006, p.59). Based on these considerations, it was determined that a third focus group was necessary to increase the sample size and composition. A draft of the focus group script can be found in Appendix B.

Data Analysis

The qualitative data were transcribed first using NVivo. The transcripts were cleaned by the group facilitator to address any errors in transcription and remove any identifying data. The transcripts were coded using the new NVivo interface. Two independent coders were responsible for analyzing the three focus group transcripts.

The purpose of the data analysis for the focus groups was to gain initial insight on cannabis users perspectives relating to the key research questions, but also to assess for the need to add any additional questions or response options to the online survey for phase two. The survey questions were largely developed in response to identified gaps in existing national cannabis surveys. However, it was important to try and limit the number of open-ended responses by providing a thorough and comprehensive list of response options for participants to choose from. This was one of the key objectives for the focus group phase of this research.

The original coding structure was developed from the key research questions. As described by Bingham and Witkowsky (2022), deductive analysis involves utilizing a predetermined set of codes to organize the data based on research questions. Thus, the analysis was mainly deductive since the parent nodes aligned with pre-determined questions of interest and survey items that may require additional response options. More specifically, the initial coding structure included the following parent nodes: does cannabis use affect driving, positive effects of cannabis, negative effects of cannabis, factors that influence the effect of cannabis on driving, specific driver actions, decision making process, DUIC, time to reach peak effects, sources of information, and tools. From these parent nodes, sub nodes (i.e., child nodes) were created based on the transcribed content from the focus groups.

A data dictionary was provided to the research assistants to ensure that coding was consistent, and the key terms and parent nodes were clearly defined. In the first wave of coding, the two research assistants coded the first focus group independently. An inter-rater coding comparison was run through NVivo to assess the inter-rater reliability, or consistency of the coding structure, between raters (i.e., raw agreement) as recommended by Belotto (2018). If agreement was less than 85% for a text section or coding node, the research team met to resolve coding discrepancies and finalize the coding structure. Only one discrepancy was identified and was easily resolved through further clarification of the data dictionary. This process of verification continued throughout coding of the two subsequent transcripts, and inter-rater agreement was found to be above 95% for all codes within the finalized structure.

Part 2 Phase 2: Online Survey

Participants

The recruitment strategy and inclusion criteria for this phase of the project were planned to be consistent with phase one. We aimed to collect a minimum of 500 responses as this would allow us to have confidence intervals around our response estimates of no more than ± 5%. Initial recruitment efforts included posters distributed throughout the Thunder Bay community, social media posts, and advertisements in cannabis dispensaries. All survey participants were entered into a draw for one of three $100 VISA gift cards as compensation for survey completion. Copies of the survey recruitment flyers and social media advertisements can be found in Appendix C.

To protect the integrity of the data, recruiting participants through paid means (e.g., MTurk) was avoided. Similarly, the Lakehead undergraduate participant pool was not utilized due to fears of skewing the demographics of the sample by overrepresenting undergraduate students from northwestern Ontario. Consequently, recruitment efforts were maintained for 5-6 months and included dropping off flyers in dispensaries around Canada and posting on social media groups that were developed specifically for Canadian cannabis users. An online forum called Reddit was included in the final round of recruitment. Survey advertisements were posted in Reddit subcommunities that focused on uniting Canadian cannabis users and growers, at federal and provincial levels. This was a successful recruitment strategy that resulted in a diverse group of survey participants, with higher rates of completion than other recruitment channels.

Procedure

The second phase of data collection involved the online survey. The survey was developed using RedCAP and took approximately 30 minutes to complete. The survey remained active for 6 months with ongoing advertisements to reach the target sample size.

The first set of questions assessed cannabis use behaviour such as about the types of cannabis used, frequency of use, average dose, whether cannabis is used medicinally or recreationally, and perception of knowledge about the effects of cannabis products.

The following sets of questions related to the main research questions. Specifically, we asked participants to report on their perception of how different types of cannabis affect driving, how specific driver actions are affected by cannabis use, how individuals assess impairment from cannabis, the factors that influence decision-making about driving after cannabis use, sources of information relied on for safety information related to cannabis use, and the willingness to use tools to aid in assessing impairment.

In addition to addressing the main research questions, the survey included questions about demographic information, a measure of risk-taking behaviour, and driving history using tools from the Centre of Research on Safe Driving at Lakehead University. A copy of the online survey questions can be found in Appendix D.

Materials

Although most of the online survey is original content that was developed based on gaps in existing national surveys and focus group results, a section of the survey included a validated measure to assess individual differences in risk-taking propensity.

Domain-Specific Risk-Taking Scale (DOSPERT)

A propensity towards risk-taking was measured in this study using the Domain-Specific Risk-Taking Scale (DOSPERT). The DOSPERT was originally developed by Weber, Blais and Betz (2002) to assess risk-taking attitudes and risk perception across five domains: ethical, financial, social, health/safety and recreation. For each item, respondents are asked to indicate how likely they are to engage in a particular behaviour (i.e., risk-taking) on a 7-point Likert scale ranging from "extremely unlikely" to "extreme likely" with "not sure" as a midpoint (Blais & Weber, 2006). General risk-taking is represented by the total score on the DOSPERT. This approach has been validated in research supporting a general risk factor that predicts real world behaviour (Highhouse et al., 2017). Total scores can range from 30 to 210, and higher scores represent a stronger propensity towards risk-taking. Each risk-taking domain, or subscale, is comprised of six items from the DOSPERT and subscale scores range from 6 to 42.

Since its introduction, the DOSPERT has demonstrated moderate test-retest reliability and convergent/divergent validity with associated constructs including sensation seeking, dispositional risk-taking, intolerance for ambiguity, and social desirability (Blais & Weber, 2006; Weber et al., 2002). A review of a large number of risk-taking instruments identified the DOSPERT as one of three measures relevant to clinical populations because it captures risk-taking propensity across a variety of everyday situations including health-related decisions (Harrison et al., 2005). Understanding the dimensional and situational variation in risk-taking behaviour has applications for fields such as medicine, psychology, and public health and the DOSPERT allows researchers and clinicians to quantify these differences.

The DOSPERT was revised in 2006, reducing the number of items from 40 to 30 without compromising the psychometric properties (Blais & Weber, 2006). Further, the items were slightly adapted to apply to a wider range of ages, cultures and educational backgrounds (Blais & Weber, 2006). In this version, the five factor structure was retained, reflecting risk-taking attitudes in the same five domains as the original (Blais & Weber, 2006). For the five subscales, Cronbach's alpha ranged from .66 to .84 (Blais & Weber, 2006). Interestingly, the authors concluded that there is seven times more variation across the domains within individuals than between individuals (Blais & Weber, 2006). The revised version will be utilized in the online survey to determine if dispositional risk-taking or risk reception relates to cannabis use behaviours and driving decisions. The DOSPERT can be found within the survey in Appendix D and the corresponding subscale for each item is identified in brackets (omitted from survey).

Data Analysis

The survey data were analysed using SPSS statistical software (Version 28.0.11). The analyses primarily involved descriptive statistics to summarize participants' cannabis use behaviour and beliefs. Where relevant, the influence of demographic information, such as age and gender, was considered. For open ended responses, qualitative analyses were conducted to identify themes in responses to address the specific research objective. For open-ended questions that asked participants to report on numeric information (e.g., the amount of time it takes smoked cannabis to reach peak levels in the blood), frequencies were calculated, and the mode was reported to minimize the influence of outliers and negate the issue of participants reporting numerical ranges in their responses.

To address hypothesis nine, a series of binary logistic regression analyses were conducted to determine whether risk-taking behaviour was associated with driving under the influence of cannabis, alcohol, or the combination of both. In these models, age and gender were used as co-variates.

Ethical Considerations

Benefits of Participation

For participants, the direct benefit for participation is the compensation (entry into a draw for a $100 VISA gift card). There are additional benefits to society for advancing the knowledge base related to cannabis use and safe driving. Phase one of this project will allow for a better understanding of the risk level associated with DUIC and the specific driver actions that are associated with cannabis-attributable fatalities. Phase two makes a novel contribution to the literature by identifying targets for public health campaigns in terms of misperceptions or gaps in knowledge of Canadians' beliefs about the effects of different cannabis products as they relate to driving decisions. In addition, phase two evaluates how individuals self-assess impairment and the factors that individuals consider when making driving decisions. An important component will be soliciting information on Canadians' willingness to use assistive tools in this process, which type of tools people would use (e.g., phone application) and factors that would influence tool utilization. Taken together, this research balances Canadians' legal right to use cannabis with the main objective of the *Cannabis Act* (i.e., protecting public health and safety).

Potential Risks of Participation

There are no significant risks to participants physical or psychological well-being resulting from study participation. Focus group participants will be discouraged from sharing information discussed in the focus group. However, the investigators cannot guarantee confidentiality on behalf of the other participants. This risk is outlined in the focus group consent form. By indicating consent to participate, individuals are accepting this small risk.

In the online survey, participants were asked about engagement in illegal behaviour such as driving under the influence. However, all responses are confidential, so honest reporting does not translate to any legal or social risk to participants. Letters of information and consent forms for the focus groups and surveys can be found in Appendix E.

Storage of Materials

All participant data are treated as confidential. Electronic data is stored on password-protected computers. Files with identifiable information were encrypted and the files will never be transferred without encryption. Only the research team had access to the data from this investigation. All data will be kept for a minimum of 5 years.

Results

Phase 1: FARS Analyses

Description of Dataset Characteristics

For the FARS analyses, the dataset included information from 1,100,883 fatal crashes that occurred between the years of 1991 and 2019. To address the research questions, only drivers whose blood was tested for the presence of THC and alcohol were included in the analysis, reducing the dataset to 242,924 drivers. Of these, 142,479 were alcohol- and THC-free, 80,755 tested positive for alcohol only, 9,449 tested positive for THC only, and 10,241 drivers tested positive for both THC and alcohol. Drivers who tested positive for THC, alcohol or both were more likely to be male, younger in age, and have previous driving charges than drivers who tested negative for both substances. Detailed descriptive statistics for the final dataset can be found in Table 1.

Table 1

Demographic information by group

Characteristic	Alcohol- and THC-free (N= 142479)	Alcohol only (N=80755)	THC only (N= 9449)	Alcohol + THC (N= 10241)	$F/\chi^{2\,*}$	Sig. (*p*)
Age, mean (*SD*)	47.55 (19.38)	36.62 (13.64)	33.92 (12.8)	31.82 (10.84)	9,401.25	< .001
Male (%)	90,798 (63.7)	65,516 (81.1)	7,148 (75.6)	8,443 (82.4)	8,388.14	< .001
Previous driver history						
Crashes (%)	22,261 (15.6)	13,495 (16.7)	1,932 (20.4)	2,005 (16.3)	256.68	< .001
DWI (%)	2,610 (1.8)	7,941 (9.8)	434 (4.6)	1,074 (10.5)	7,686.64	< .001
Other convictions (%)	22,525 (15.8)	18,451 (22.8)	2,748 (29.1)	2,942 (28.7)	2,941.52	< .001
Speeding (%)	26,046 (18.3)	18,755 (23.2)	2,649 (28.0)	2,760 (27.0)	1,376.42	< .001
Suspended License (%)	15,251 (10.7)	21,251 (26.3)	2,541 (26.9)	3,396 (33.2)	11,236.58	< .001
Any of the above (%)	56,682 (39.8)	43,926 (54.4)	5,634 (59.6)	6,398 (62.5)	6,312.64	< .001
Other drugs/medications						
Depressants (%)	8,720 (6.1)	4,563 (5.7)	1,270 (13.4)	962 (9.4)	1,031.38	< .001
Narcotic (%)	9,091 (6.4)	3,027 (3.7)	1,020 (10.8)	501 (4.9)	1,177.06	< .001
Stimulants (%)	8,812 (6.2)	7,607 (9.4)	2,003 (21.2)	1,638 (16.0)	3,849.83	< .001
Other (%)	11,019 (7.7)	5,442 (6.7)	836 (8.8)	696 (6.8)	108.90	< .001
Any of the above (%)	28,819 (20.2)	16,763 (20.8)	4,043 (42.8)	3,217 (31.4)	3,259.67	< .001

* *F*-statistic given for age; Chi-square reported for all other variables

Odds of Engaging in Any Unsafe Driver Action

To address hypothesis one, a series of logistic regression models were constructed. For each model, the dependent variable was committing *any* unsafe driver action (UDA), which is used as a proxy measure of driver responsibility for the crash. The first model (Model 1) included only THC exposure and data year. The data year variable was used to account for the variance attributable to the change in frequency of drug testing over time. As time progressed, more testing for substances, including cannabis, was conducted in context of fatal crash investigations.

In the FARS database, THC exposure was coded dichotomously (i.e., yes or no) to indicate whether the driver in the fatal crash tested positive for cannabis in blood test analyses. Actual blood THC concentration is not reported in FARS so this could not be analyzed as a continuous variable. According to Model 1, cannabis increased the odds of committing an UDA by 54% (Adjusted OR: 1.54; 95% CI: 1.49; 1.59, $p < .001$). In this model, no additional covariates were included.

The second model (Model 2) included several covariates that have been shown to influence the likelihood of engaging in unsafe driver actions (Dubois et al., 2015) including age, sex, alcohol consumption, other medications (depressants, stimulants, narcotics and other) and unsafe driver history variables (previous crashes, DUI charges, speeding infractions, licence suspensions and other driving convictions). In this model, quadratic terms including age-squared and BAC-squared were included to account for the fact that these variables did not demonstrate a linear distribution in previous research using this dataset (Dubois et al., 2015). If either quadratic term is significant, both the linear and quadratic terms will be retained in the model.

In Model 2, several interactions were added to determine which interactions were statically significant for retention in the final model. Alcohol exposure is defined by the variable BAC. Interaction terms added to Model 2 included age by sex, age-squared by sex, age by BAC, age-squared by BAC, age by THC, age-squared by THC, THC by BAC, THC by BAC-squared, THC by sex, BAC by sex, and BAC-squared by sex.

The final model (Model 3) retained the key variables of interest (THC and alcohol exposure), year of data collection, covariates that influence the likelihood of committing a UDA, and all significant quadratic terms and interactions. The coefficients and odds ratios for each variable in the model are reported in Table 2. Both the linear and quadratic terms for BAC were included because the data have a curvilinear fit (i.e., statistically significant quadratic term). The odds of committing an UDA did not steadily increase with age but were highest for younger and older drivers. Similarly, the age by sex interaction was significant (Wald Statistic = 31.77, $p <$ .001) which suggests that sex follows a similar pattern to age in terms of risk of committing unsafe driver actions. Men commit more UDAs and this risk is highest for young and old drivers; it follows then that this gender difference for increased risk of UDAs leading to fatal crashes is most pronounced for young and old drivers.

The key variable of interest for this analysis was THC exposure. After adjusting for age, sex, alcohol consumption, the presence other drugs and previous driver history, the odds ratio for THC exposure was 1.29 (95% CI: 1.23, 1.34, $p < .001$), relative to drivers who tested negative for THC and alcohol. In other words, THC increased the odds of committing any UDA by 29% relative to sober drivers.

The influence of alcohol in fatal crashes was another key variable of interest. For each increase of 0.01 in BAC, the odds of committing an unsafe driver action increased by 9% (OR: 1.09; 95% CI:1.09, 1.10, $p < .001$). Most often, BAC is considered at the level of 0.05 or 0.08 (the legal limit). After controlling for age, sex, THC exposure, other drugs and previous driver history, the odds ratio for a BAC of 0.05 was 1.56 (95% CI: 1.53, 1.58) and the odds ratio for a BAC of 0.08 was 1.96 (95% CI: 1.93, 2.00). Additional odds ratios for BAC at intervals of 0.01 are reported in Table 3.

The influence of covariates on unsafe driver actions are reported in Table 2. After controlling for age, sex, previous driver history and exposure to THC and alcohol, results indicate that the presence of stimulant medication is associated with higher odds of an unsafe driver action (OR = 1.66; 95% CI: 1.60, 1.72, $p < .001$), as is the presence of depressant medication (OR = 1.41; 95% CI: 1.36, 1.47, $p < .001$), narcotics (OR = 1.22; 95% CI: 1.18, 1.27, $p < .001$) or other medication (OR = 1.12; 95% CI: 1.08, 1.16, $p < .001$). For previous driver history, the only previous conviction that was not associated with increased odds of an UDA was a previous DUI conviction (referred to as a DWI [Driving While Intoxicated] in the United States and in the table). For previous driver history, the most pronounced effects were observed for previous crashes and licence suspensions. For one previous crash, the odds of an UDA increased by 8%, followed by 14% for two previous crashes and 28% for three or more crashes. If the driver had one previous licence suspension, the odds of committing an UDA increased by 22%, and 28% for two or more previous suspensions.

Table 2

Model 3: Coefficients and odds ratios with 95% CI for the final model predicting any unsafe driver action.

Variable, referent	*B* (S.E.)	Odds ratio (95% CI)	Sig (*p*)
Year of data collection	-.043 (.001)	0.96 (0.96; 0.96)	< .001
Age (decades, centred at 45 years)	-. 006 (.005)	0.99 (0.98; 1.00)	.22
Age^2	.064 (.002)	1.07 (1.06; 1.07)	<.001
BAC, 0.01g/100ml	.088 (.002)	1.09 (1.09; 1.10)	< .001
BAC^2	-.001 (.000)	1.00 (1.00; 1.00)	< .001
Sex, female	-.060 (.015)	0.94 (0.92; 0.97)	< .001
Sex x BAC	.007 (.001)	1.01 (1.00; 1.01)	< .001
Age x BAC	-.003 (.000)	1.00 (1.00; 1.00)	< .001
Age^2 x BAC	-.003 (.000)	1.00 (1.00; 1.00)	< .001
Age x sex	-.080 (.006)	0.92 (0.91; 0.93)	< .001
Age^2 x sex	.016 (.003)	1.02 (1.01; 1.02)	< .001
THC exposure, none	.252 (.022)	1.29 (1.23; 1.34)	< .001
THC exposure x BAC	-.027 (.004)	0.97 (0.97; 0.98)	< .001
THC exposure x BAC^2	.001 (.000)	1.00 (1.00; 1.00)	< .001

Depressants, none		.346 (.020)	1.41 (1.36; 1.47)	< .001
Narcotics, none		.203 (.020)	1.23 (1.18; 1.27)	< .001
Stimulants, none		.505 (.018)	1.66 (1.60; 1.72)	< .001
Other drugs, none		.115 (.017)	1.12 (1.08; 1.16)	< .001
Crashes	One	.076 (.014)	1.08 (1.05; 1.11)	< .001
	Two	.127 (.030)	1.14 (1.07; 1.20)	< .001
	Three or more	.248 (.054)	1.28 (1.15; 1.42)	< .001
DWI	One	-.026 (.028)	0.97 (0.92; 1.03)	.35
	Two	.022 (.066)	1.02 (0.90; 1.16)	.74
	Three or more	-.048 (.145)	0.95 (0.72; 1.27)	.74
Speeding	One	.057 (.013)	1.06 (1.03; 1.09)	< .001
	Two	.103 (.024)	1.11 (1.06; 1.16)	< .001
	Three or more	.104 (.033)	1.11 (1.04; 1.18)	.02
Suspension	One	.202 (.018)	1.22 (1.18; 1.27)	< .001
	Two	.243 (.027)	1.28 (1.21; 1.34)	< .001
	Three or more	.245 (.025)	1.28 (1.22; 1.34)	< .001
Other	One	.104 (.014)	1.11 (1.08; 1.14)	< .001
	Two	.148 (.026)	1.16 (1.10; 1.22)	< .001
	Three or more	.183 (.032)	1.20 (1.13; 1.28)	< .001

The interaction between THC and BAC was considered. The interaction was significant (Wald Statistic = 13.48, $p < .001$) which suggests that the effect of THC depends on BAC. Using the BAC levels of 0.01, 0.05 and 0.08 reported above for comparison, the odds ratios for drivers who also tested positive for THC were 1.38 (95% CI: 1.32, 1.43), 1.77 (95% CI: 1.70, 1.84) and 2.11 (95% CI: 2.01, 2.20), respectively. In the presence of THC, as BAC increases, the odds of committing an unsafe driver action increase. The interaction attenuates at higher levels of BAC. Table 3 includes the predicted odds and odds ratios for alcohol and THC alone, and the combination of THC and alcohol at various BAC levels. Odds ratios in Table 3 have been adjusted to account for the increase in drug testing over the period of data collection.

Table 3

Predicted odds and adjusted odds ratios for any unsafe driver action by BAC and THC detection

BAC	Predicted Odds	Predicted Odds	Odds Ratio (95% CI)	Odds ratio (95% CI)
	No THC	THC Detected	No THC	Alcohol and THC
0.00	1.69 (1.64, 1.73)	2.17 (2.06, 2.28)	1.00 (N/A)	1.29 (1.23, 1.34)

0.01	1.85 (1.81, 1.90)	2.32 (2.21, 2.43)	1.10 (1.09, 1.10)	1.38 (1.32, 1.43)
0.02	2.03 (1.98, 2.08)	2.48 (2.37, 2.59)	1.20 (1.20, 1.21)	1.47 (1.41, 1.53)
0.03	2.21 (2.16, 2.27)	2.64 (2.52, 2.76)	1.31 (1.30, 1.32)	1.57 (1.51, 1.63)
0.04	2.41 (2.35, 2.47)	2.81 (2.69, 2.94)	1.43 (1.42, 1.45)	1.67 (1.60, 1.73)
0.05	2.62 (2.56, 2.69)	2.99 (2.85, 3.13)	1.56 (1.53, 1.58)	1.77 (1.70, 1.84)
0.06	2.84 (2.77, 2.92)	3.17 (3.02, 3.32)	1.69 (1.66, 1.71)	1.88 (1.80, 1.96)
0.07	3.07 (2.99, 3.16)	3.36 (3.20, 3.52)	1.82 (1.79, 1.85)	1.99 (1.91, 2.08)
0.08	3.31 (3.22, 3.41)	3.55 (3.38, 3.73)	1.96 (1.93, 2.00)	2.11 (2.01, 2.20)

Exploring the Influence of THC on Individual Unsafe Driver Actions

Hypothesis two sought to identify specific driver actions that are implicated in fatal car crashes where the driver tested positive for THC. Based on the literature review, seven specific UDAs were selected for individual analysis. The individual analyses will consider how THC affects the odds of committing specific unsafe driver actions in the context of fatal crashes. In the FARS database, the seven specific UDAS identified for further analysis are coded as driver responsibility factors (DRF) number 26 (Following Improperly), 27 (Improper or Erratic Lane Changing), 28 (Failure to Keep in Proper Lane or Running off Road), 29 (Illegal Driving on Road Shoulder, in Ditch, on Sidewalk, on Median), 36 (Operating the Vehicle in Other Erratic, Reckless, Careless or Negligent Manner [or Operating at Erratic or Suddenly Changing Speeds, Since 1995]), 44 (Driving Too Fast for Conditions or in Excess of Posted Speed Limit) and 45 (Driving Less than Posted Maximum).

A descriptive summary of the distribution of cases for each individual UDA is provided in Table 4. This table indicates how many cases were included in each analysis the relevant conditions (i.e., alcohol only, THC only, and the combination of THC and alcohol).

Table 4

Summary of cases for each individual unsafe driver action

Unsafe Driver Action	Total N	Alcohol and THC Free	Alcohol Only	THC Only	Alcohol + THC
DRF 26: Improper Following	1,927	1,297	481	86	63
DRF 27: Improper or Erratic Lane Change	3,297	1,775	1,123	190	209
DRF 28: Failure to Keep in Proper Lane	65,489	32,092	28,668	2,093	2,636
DRF 29: Illegal Driving on Road Shoulder, in Ditch, on Sidewalk, on Median	1,006	396	495	40	75
DRF 36: Operating the Vehicle in Erratic, Reckless, Careless or Negligent Manner	14,533	5,463	7,421	605	1,044
DRF 44: Driving Too Fast for Conditions or in Excess of Posted Speed Limit	63,680	22,895	33,410	2,492	4,883
DRF 45: Driving Less than Posted Maximum	129	84	35	5	5

A series of logistic regressions were constructed based on Model 3 with the individual UDAs alternating as the dependent variable. For readability, an abbreviated version of Table 2 will be provided below for each individual UDA analysed. Although the same covariates (i.e., age, sex, other medications, driver history) and interaction terms from Model 3 were entered into each regression, odds ratios for THC and alcohol are the key components and will be the focus of the reported results for individual UDAs.

DRF 26: Improper Following

The influence of THC and alcohol on improper following are depicted in Table 5. Testing positive for THC does not have a significant effect on the odds of committing this driver action (OR = 0.89; 95% CI: 0.71, 1.10, p = .28), and the interaction terms with BAC did not reach statistical significance. Alcohol did not have a significant effect on improper following (OR= 0.99; 95% CI: 0.97, 1.00, $p = .09$).

Table 5

Coefficients and odds ratios with 95% CI for predicting DRF 26: Improper Following.

Variable, referent	*B*	S.E.	Wald	Significance (*p*-value)	Odds ratio	95% CI (Lower)	95%CI (Upper)
THC +	-0.120	0.112	1.15	.28	0.89	0.71	1.10
BAC, 0.01 g/100 mL	-0.014	0.008	2.91	.09	0.99	0.97	1.00
BAC^2	0.001	0.001	11.22	< .001	1.00	1.00	1.00
THC x BAC	0.019	0.026	0.53	.47	1.02	0.97	1.07
THC x BAC^2	-0.001	0.001	0.45	.50	1.00	1.00	1.00

DRF 27: Improper or Erratic Lane Change

The influence of THC and alcohol on improper or erratic lane changes are reported in Table 6. Testing positive for THC does not have a significant effect on the odds of committing this driver action (OR = 1.12; 95% CI: 0.96, 1.30, $p = .16$). For alcohol, the linear term was significant suggesting that as BAC increases, the odds of engaging in improper or erratic lane changes increases (OR= 1.02; 95% CI: 1.00, 1.03, $p = .01$). To further highlight the influence of alcohol on this driver action, odds ratios are presented for various BAC levels in Table 12 which includes all UDAs. Table 12 is presented at the end of this section.

Table 6

Coefficients and odds ratios with 95% CI for predicting DRF 27: Improper or Erratic Lane Change.

Variable, referent	*B*	S.E.	Wald	Significance (*p*-value)	Odds ratio	95% CI (Lower)	95%CI (Upper)
THC +	0.109	0.077	1.98	.16	1.12	0.96	1.30
BAC, 0.01 g/100 mL	0.017	0.007	6.55	.01	1.02	1.00	1.03
BAC^2	0.000	0.000	1.01	.31	1.00	1.00	1.00
THC x BAC	0.012	0.014	0.84	.36	1.01	0.99	1.04
THC x BAC^2	0.000	0.000	0.05	.83	1.00	1.00	1.00

DRF 28: Failure to Keep in Proper Lane

The influence of THC and alcohol on a driver's ability to maintain lane position are reported in Table 7. THC has a significant effect on the odds of committing this driver action (OR = 1.11; CI 95%: 1.06, 1.17 $p < .001$). After controlling for age, sex, alcohol consumption, other drugs, and previous driver history, testing positive for THC increased the odds of failing to keep in proper lane by 11%. The influence of BAC is demonstrated by the main effect of BAC (OR = 1.05; 95% CI: 1.05, 1.05, $p < .001$). For each 0.01 increase in BAC, the odds of failing to keep in proper lane increases by 5%. Thus, at a presumed BAC of 0.05, an individual is 25% more likely to swerve out of lane.

For this driver action, all interaction terms were statistically significant. As shown in Table 12, the combined effect of THC and alcohol is additive at low levels of BAC. However, at higher levels of BAC, the presence of THC does not result in increased odds of failing to maintain lane position. Interestingly, for higher BACs, the odd ratios decrease when THC is present. Given that all odds ratios for this UDA are above one, this does not necessarily indicate that THC is protective when combined with alcohol.

Table 7

Coefficients and odds ratios with 95% CI for predicting DRF 28: Failure to Keep in Proper Lane

Variable, referent	*B*	S.E.	Wald	Significance (*p*-value)	Odds ratio	95% CI (Lower)	95%CI (Upper)
THC +	0.108	0.026	17.98	< .001	1.11	1.06	1.17
BAC, 0.01 g/100 mL	0.048	0.002	778.30	< .001	1.05	1.05	1.05
BAC^2	-0.001	0.000	195.88	< .001	1.00	1.00	1.00
THC x BAC	-0.029	0.004	53.38	< .001	0.97	0.96	0.98
THC x BAC^2	0.001	0.000	18.85	< .001	1.00	1.00	1.00

DRF 29: Illegal Driving on Road Shoulder, in Ditch, on Sidewalk, on Median

Table 8 includes the odds ratios for THC and alcohol for predicting the unsafe driver action of illegal driving on the shoulder, in a ditch, on the sidewalk or on a median. This will be referred to as driving off the road. The effect of THC on the odds of driving off the road did not reach statistical significance (OR= 1.29, 95% CI: 0.95, 1.76, p = 0.10).

Alcohol significantly increased the odds of driving off the road with a 7% increase in odds for each increase of 0.01 BAC, relative to drivers with a BAC of zero and a negative test for THC (OR= 1.07, 95% CI: 1.04, 1.09, $p < .001$). The BAC-squared term was statistically significant, indicating that the effect of BAC is attenuated with increasing BAC.

Table 8

Coefficients and odds ratios with 95% CI for predicting DRF 29: Illegal Driving on Road Shoulder, in Ditch, on Sidewalk, on Median

Variable, referent	*B*	S.E.	Wald	Significance (*p*-value)	Odds ratio	95% CI (Lower)	95%CI (Upper)
THC +	0.257	0.157	2.69	.10	1.29	0.95	1.76
BAC, 0.01 g/100 mL	0.066	0.011	34.45	< .001	1.07	1.04	1.09
BAC^2	-0.001	0.000	10.41	< .001	1.00	1.00	1.00
THC x BAC	-0.026	0.018	2.20	.14	0.97	0.94	1.01
THC x BAC^2	0.001	0.000	3.51	.06	1.00	1.00	1.00

DRF 36: Operating the Vehicle in Erratic, Reckless, Careless or Negligent Manner

Table 9 includes the odds ratios for engaging in erratic, reckless, careless, or negligent operation of a motor vehicle (ERCN operation). After controlling for age, sex, alcohol consumption, other drugs, and previous driver history, testing positive for THC increased the odds of ERCN operation by 29% (OR = 1.29; 95% CI: 1.19, 1.41, $p < .001$). The linear term for BAC was also statistically significant (OR= 1.08; 95% CI: 1.07, 1.08, $p < .001$).

In addition, the quadratic term for alcohol was significant reflecting a non-linear relationship between alcohol and the odds of ERCN operation of a motor vehicle. Specifically, the odds of ERCN operation increased with BAC but leveled off at the highest BAC values.

Table 9

Coefficients and odds ratios with 95% CI for predicting DRF 36: Operating the Vehicle in Other Erratic, Reckless, Careless or Negligent Manner

Variable, referent	*B*	S.E.	Wald	Significance (*p*-value)	Odds ratio	95% CI (Lower)	95%CI (Upper)
THC +	0.257	0.043	35.82	< .001	1.29	1.19	1.41
BAC, 0.01 g/100 mL	0.074	0.003	528.23	< .001	1.08	1.07	1.08
BAC^2	-0.001	0.000	166.42	< .001	1.00	1.00	1.00
THC x BAC	-0.005	0.008	0.41	.52	0.99	0.98	1.01
THC x BAC^2	0.000	0.000	0.33	.57	1.00	1.00	1.00

DRF 44: Driving Too Fast for Conditions or in Excess of Posted Speed Limit

Speeding is a driver action often associated with impaired driving. The odds ratios for driving too fast for conditions, or in excess of the posted speed limit (i.e., speeding), are presented in Table 10. After controlling for age, sex, alcohol consumption, other drugs, and previous driver history, testing positive for THC increased the odds of speeding by 23% (OR = 1.23; 95% CI: 1.17, 1.29, $p < .001$).

Alcohol significantly increased the odds of speeding with a 10% increase in odds for each increase of 0.01 BAC, relative to drivers who tested negative for alcohol and THC (OR= 1.10; 95% CI: 1.10, 1.10, $p < .001$). The significant BAC-squared term indicates that the effect of BAC levels off at the highest values.

Table 10

Coefficients and odds ratios with 95% CI for predicting DRF 44: Driving Too Fast for Conditions or in Excess of Posted Speed Limit

Variable, referent	*B*	S.E.	Wald	Significance (*p*-value)	Odds ratio	95% CI (Lower)	95%CI (Upper)

THC +	0.207	0.024	73.92	< .001	1.23	1.17	1.29
BAC, 0.01 g/100 mL	0.096	0.002	2828.03	< .001	1.10	1.10	1.10
BAC^2	-0.002	0.000	1095.45	< .001	1.00	1.00	1.00
THC x BAC	-0.006	0.004	2.08	.15	0.99	0.99	1.00
THC x BAC^2	0.000	0.000	0.87	.35	1.00	1.00	1.00

DRF 45: Driving Less than Posted Maximum

The influence of THC and alcohol on predicting the odds of driving under the speed limit are presented in Table 11. The effect of THC was not significant (OR = 0.92; 95% CI: 0.37, 2.28, $p = .85$). The width of the confidence interval reflects a small number of cases in this analysis. Considering the data source, it is highly unlikely that driving under the speed limit would be identified as a contributing factor in fatal car crashes, regardless of the presence or absence of any substances. Thus, this result should be interpreted with caution.

Similarly, alcohol did not significantly increase the odds of driving under the speed limit. These analyses were constrained by similar factors as above with only 35 cases in the alcohol condition and five in the alcohol and THC condition. The analyses for driving under the speed limit were significantly under-powered to detect any meaningful effects of cannabis or alcohol.

Table 11

Coefficients and odds ratios with 95% CI for predicting DRF 45: Driving Less than Posted Maximum

Variable, referent	*B*	S.E.	Wald	Significance (*p*-value)	Odds ratio	95% CI (Lower)	95%CI (Upper)
THC +	-0.088	0.465	0.04	.85	0.92	0.37	2.28
BAC, 0.01 g/100 mL	0.027	0.046	0.36	.55	1.03	0.94	1.12
BAC^2	-0.002	0.002	0.94	.33	1.00	1.00	1.00
THC x BAC	0.041	0.123	0.11	.74	1.04	0.82	1.33
THC x BAC^2	-0.002	0.006	0.12	.73	1.00	0.99	1.01

Odds Ratios for Individual UDAs at Different Levels of BAC in the Presence/Absence of THC

To further understand the individual and combined effects of THC and alcohol on different driver actions, Table 12 reports on the odds ratios for all individual UDAs at different levels of BAC ranging from 0.01 to 0.30 when THC is present and absent.

Table 12

Odds Ratio of a Particular DRF by BAC level and THC Presence

				THC Absent				THC Present			
				Odds Ratio	95% Lower CI	95% Upper CI	Sig. (*p*)	Odds Ratio	95% Lower CI	95% Upper CI	Sig.
DRF	Following Improperly (26)	BAC	.01	0.97	0.96	0.98	< .001	0.88	0.72	1.07	.20
			.05	0.87	0.82	0.92	< .001	0.83	0.67	1.04	.11
			.08	0.81	0.74	0.88	< .001	0.80	0.61	1.04	.10
			.10	0.78	0.70	0.86	< .001	0.78	0.58	1.04	.09
			.15	0.71	0.62	0.81	< .001	0.72	0.52	0.99	.04
			.20	0.67	0.57	0.79	< .001	0.66	0.47	0.92	.02
			.25	0.65	0.53	0.79	< .001	0.60	0.39	0.92	.02
			.30	0.65	0.51	0.82	< .001	0.55	0.28	1.06	.07
	Improper or Erratic Lane Changing (27)	BAC	.01	1.01	1.00	1.02	.08	1.14	0.99	1.31	0.07
			.05	1.05	1.00	1.10	.07	1.24	1.08	1.42	< .001
			.08	1.07	1.00	1.15	.06	1.31	1.13	1.52	< .001
			.10	1.09	1.00	1.18	.06	1.36	1.16	1.59	< .001
			.15	1.11	1.00	1.24	.05	1.46	1.22	1.75	< .001
			.20	1.13	1.00	1.28	.05	1.56	1.28	1.89	< .001
			.25	1.14	0.99	1.32	.06	1.63	1.30	2.05	< .001
			.30	1.14	0.97	1.35	.12	1.69	1.24	2.30	< .001

Improper Lane Usage (28)	BAC	.01	1.05	1.04	1.05	< .001	1.13	1.08	1.19	< .001
		.05	1.24	1.22	1.25	< .001	1.21	1.16	1.26	< .001
		.08	1.39	1.36	1.41	< .001	1.27	1.21	1.33	< .001
		.10	1.48	1.45	1.52	< .001	1.31	1.24	1.37	< .001
		.15	1.72	1.67	1.77	< .001	1.41	1.33	1.49	< .001
		.20	1.93	1.86	1.99	< .001	1.51	1.42	1.61	< .001
		.25	2.09	2.01	2.17	< .001	1.61	1.50	1.74	< .001
		.30	2.19	2.10	2.29	< .001	1.72	1.56	1.89	< .001
Illegal Driving off Roadway (e.g., road shoulder; 29)	BAC	.01	1.06	1.04	1.08	< .001	1.34	1.00	1.79	.05
		.05	1.33	1.22	1.45	< .001	1.54	1.20	1.98	< .001
		.08	1.54	1.36	1.74	< .001	1.71	1.35	2.17	< .001
		.10	1.68	1.45	1.94	< .001	1.83	1.44	2.34	< .001
		.15	2.01	1.67	2.42	< .001	2.16	1.65	2.84	< .001
		.20	2.30	1.86	2.83	< .001	2.54	1.86	3.47	< .001
		.25	2.49	1.97	3.14	< .001	2.97	2.06	4.27	< .001
		.30	2.57	1.95	3.38	< .001	3.45	2.24	5.31	< .001
Operating the Vehicle in Erratic/ Reckless Manner (36)	BAC	.01	1.07	1.06	1.07	< .001	1.37	1.27	1.48	< .001
		.05	1.35	1.32	1.39	< .001	1.70	1.58	1.83	< .001
		.08	1.58	1.53	1.64	< .001	1.94	1.79	2.10	< .001
		.10	1.73	1.66	1.80	< .001	2.09	1.92	2.28	< .001
		.15	2.09	1.98	2.20	< .001	2.40	2.19	2.63	< .001
		.20	2.37	2.24	2.52	< .001	2.58	2.35	2.84	< .001
		.25	2.55	2.38	2.72	< .001	2.60	2.31	2.92	< .001
		.30	2.58	2.38	2.79	< .001	2.44	2.05	2.92	< .001
Driving too Fast for	BAC	.01	1.10	1.09	1.10	< .001	1.34	1.28	1.40	< .001
		.05	1.54	1.52	1.56	< .001	1.84	1.77	1.92	< .001

Conditions (44)		.08	1.91	1.88	1.95	< .001	2.26	2.16	2.36	< .001
		.10	2.17	2.12	2.23	< .001	2.55	2.43	2.67	< .001
		.15	2.82	2.74	2.91	< .001	3.26	3.09	3.44	< .001
		.20	3.36	3.25	3.48	< .001	3.87	3.66	4.09	< .001
		.25	3.68	3.55	3.82	< .001	4.24	3.97	4.53	< .001
		.30	3.70	3.54	3.87	< .001	4.31	3.91	4.74	< .001
Driving Less Than Posted Maximum (45)	BAC	.01	1.02	0.94	1.11	.60	0.97	0.42	2.23	.95
		.05	1.08	0.77	1.52	.66	1.15	0.46	2.89	.76
		.08	1.09	0.67	1.77	.73	1.22	0.41	3.66	.72
		.10	1.08	0.62	1.88	.79	1.22	0.38	3.97	.74
		.15	1.00	0.51	1.96	1.00	1.09	0.32	3.68	.89
		.20	0.86	0.41	1.82	.70	0.82	0.22	3.10	.77
		.25	0.69	0.28	1.67	.41	0.52	0.06	4.37	.55
		.30	0.51	0.15	1.67	.26	0.28	0.01	11.21	.50

Phase 2 Part 1: Focus Groups

Phase two pertains to the development and administration of a new survey to assess Canadians' beliefs and behavior related to cannabis use and driving. Focus groups were conducted as a first step to strengthen the preliminary survey developed based on the research objectives and identified gaps in existing national cannabis surveys.

Participants

Focus group participants were recruited nationally but the final sample was comprised of individuals currently residing in Ontario, Alberta, and British Columbia. Participant demographics were reviewed after the completion of the first two focus groups (N=11). At that point, the age range of participants was only 20-37 with a predominantly Caucasian sample. To increase the diversity in participant demographics, a final focus group was conducted, which was marginally successful in meeting the goal of a more diverse sample. After three focus groups, the final sample included 16 participants ranging in age from 20-55 (M = 32.93, SD = 9.69). A summary of the focus group participant characteristics can be found in Table 13.

Table 13

Focus Group Participant Characteristics

Characteristic	Category	*n* (% of sample)
Age	19-24	2 (12.5)
	25-34	10 (62.5)
	35-49	2 (12.5)
	50+	2 (12.5)
Gender	Female	11 (68.75)
	Male	5 (31.25)
Ethnicity (self-report)	Caucasian	13 (81.25)
	Indigenous	1 (6.25)
	Mixed ethnicity	1 (6.25)
Geographical location	Ontario	11 (68.75)
	British Columbia	3 (18.75)
	Alberta	2 (12.5)

Qualitative Analysis of the Focus Group Content

Focus group data were analysed using a deductive approach as per Bingham and Witkowscky (2022) and are summarized below in Table 14. The table describes the nodes that comprise the final coding structure obtained using NVIVO (Version 1.6.2). For each node, the definition is provided along with the number of times each node was referenced (i.e., coded) within the three focus group transcripts. The focus group was intended to provide researchers with a baseline on cannabis users' perspectives, while considering whether any additional questions or response options should be added to the online survey in phase two. Although the preliminary survey was developed prior to the focus groups, the focus groups were conducted to strengthen the survey by soliciting additional ideas and responses to key research questions.

Table 14

Final Coding Structure for Focus Group Analysis

Parent/Child Node	Definition	Number of References
Does cannabis use affect driving?		
Yes	Cannabis use affects driving ability	8
No	Cannabis use does not affect driving ability	0
It depends	Whether or not cannabis use affects driving ability depends on various factors	5
Factors that influence the effect of cannabis on driving	References to specific factors that may influence the effect of cannabis use on driving ability	52
Negative effects of cannabis	Negative effects of cannabis use	36
THC	THC specifically mentioned in relation to negative effects of cannabis	3
CBD	CBD specifically mentioned in relation to negative effects of cannabis	0
Positive effects of cannabis	Positive effects of cannabis use	21
THC	THC specifically mentioned in relation to positive effects of cannabis	0
CBD	CBD specifically mentioned in relation to positive effects of cannabis	4
Specific driver actions	Specific driver actions that participants feel may be affected by cannabis use	17
DUIC	References to driving under the influence of cannabis (e.g., engaging in, detection methods)	18
Yes- Know legal limit	Participants knew the THC blood concentration that corresponds to a criminal charge for DUIC	1
No- Don't know legal limit	Participants did not know the THC blood concentration that corresponds to a criminal charge for DUIC	14
Assessing impairment	References to how individuals evaluate impairment from cannabis within themselves	40
Decision making process	Factors that individuals consider when making decisions relating to cannabis and safe driving	41
Self versus other	References to differences in the decision-making process if you are a driver versus passenger	35

Time to peak effects		
Edible cannabis	Time it takes for edible forms of cannabis to reach peak levels in the blood (i.e., maximum effect)	23
Smoked cannabis	Time it takes for smoked cannabis to reach peak levels in the blood (i.e., maximum effect)	21
Sources of information	References to where participants seek out information on cannabis and safety	29
Tools		
Would use	References indicating that participants would use tools to aid in evaluating cannabis impairment and making safe driving decisions	20
Would not use	References indicating that participants would not use tools to aid in evaluating cannabis impairment and making safe driving decisions	2
Types of tools	Types of tools that people would use to help them evaluate impairment/make driving decisions	27
Factors that influence use	Factors that would influence the likelihood of using tools for evaluating impairment	44

Key Insights from Focus Group Analyses

How Cannabis Use Affects Driving

All participants who responded to this question reported that cannabis use does affect driving, or it can, depending on certain factors. No participants explicitly stated that cannabis use does not affect driving ability. When asked what factors influence the effect of cannabis on driving ability, participants identified factors including: cannabis characteristics (dose/potency, quantity smoked, THC/CBD, mode of administration), user characteristics (tolerance, age, experience, stomach contents, metabolism, familiarity with the area), and time elapsed since cannabis use. Tolerance, cannabis dose or potency, and cannabis form (i.e., edible or smoked) were the most frequently mentioned factors that affect the relationship between cannabis use and driving ability.

Negative Effects of Cannabis

At several points in the focus group discussion, participants described ways that cannabis use can negatively affect driving ability. Responses included negative effects on neurocognitive processes (reaction time, alertness, attention, perception) and negative changes in mood or affect (increased anxiety, decreased confidence in driving ability). No participants attributed negative effects to CBD, but THC was identified as being detrimental to driving ability, especially for users who are younger and less experienced with driving and/or cannabis use.

Positive Effects of Cannabis

Although less frequently mentioned than negative effects of cannabis on driving, focus group participants reported on several ways they felt cannabis use can have a positive effect on driving ability. Participants indicated that using cannabis can make them feel more relaxed or less anxious, more focused, and more cautious while driving after using cannabis. Two participants specifically mentioned increased attention to driving laws and rules of the road. Lastly, two participants noted that cannabis use (especially CBD) may assist with pain or other medical conditions (e.g., fibromyalgia) which can translate into improved driving performance.

Specific Driver Actions

When asked how cannabis use may positively or negatively affect specific driver actions, participants predominantly described negative effects including distracted driving, delayed reaction time which may increase crash risk or delay responding (e.g., failing to proceed at a green light), overcorrecting lane position leading to swerving, and perceptual errors (e.g., mistaking a stop sign for a red light). Two participants felt that cannabis use is associated with a reduction in speed and decreased swerving due to increased focus on maintaining lane position. The assertion that cannabis use decreases swerving is inaccurate based on research.

DUIC

Although opinions on DUIC were not directly solicited from participants, this topic naturally came up throughout the discussions. Participants were skeptical of the current assessment protocols for DUIC and shared stories of individuals being charged for having cannabis in their system, despite not being “high” or “impaired” at the time. In addition, there were concerns about having one standard legal limit for DUIC that does not consider tolerance, previous experience with cannabis, or use for medicinal purposes.

Two participants felt that, even as experienced cannabis users, they could not determine how different doses of products translate to blood THC concentration, making it impossible to evaluate the risk of being charged with DUIC. One participant noted that there is not a clear benchmark for promoting safe driving with cannabis use, like there is with alcohol (i.e., one drink per hour).

Two stories are worth including in this discussion. One participant shared an instance where their partner was charged with DUIC after having a seizure while driving, despite no evidence of cannabis impairment and several witnesses of the seizure causing the crash. The individual did have a medical prescription to use cannabis to help manage epilepsy.

Although THC was detected in the blood, no additional tests were conducted to determine if the driver was impaired at the time of the crash. Another participant noted that a friend was charged with DUIC at 8 times the legal limit (40 ng THC/mL of blood). However, after doing some research, the participant learned that THC blood concentrations can be as high as 100-200 ng THC/mL after smoking cannabis so they wondered how high a chronic cannabis users blood THC concentration would be at baseline, even hours after using cannabis.

The group members expressed concern about the validity of the current blood THC level that is being used to indicate impairment and of the assessment protocols used in DUIC investigations. In addition, a lack of information on how doses of specific products translate to biological indicators makes it difficult for individuals to make informed decisions related to safe driving. Participants in the focus groups were passionate about discussing DUIC and the legal implications of newly proposed thresholds.

Awareness of the legal limit for DUIC

When specifically asked if they knew the blood THC concentration at which you can be charged with DUIC, only one person had the correct answer, and it was inferred from the standardized maximum dose sold at legal dispensaries in Canada. Although they did not know the actual number for blood THC concentration, it was suggested that one 5-10 mg edible would put you "at the limit". One participant has a rough idea ("*5 nana something"*) but was unsure how to interpret it. Thirteen other regular cannabis users had no idea what the legal limit for DUIC was and even when the facilitator shared the answer, there was confusion as to what this number meant in terms of cannabis dose or quantity.

Assessing Impairment

A focus of this research is how individuals evaluate impairment within themselves when making decisions about their own ability to drive safely. To make the question more approachable, we asked focus group participants "If you decided that you were too high to drive, how would you know?". Responses fell into several categories including consideration of physical characteristics (flush cheeks, red eyes), cognitive state (mental clarity, speech, alertness, psychomotor skills, feeling detached, anxious), cannabis factors (type, potency, time elapsed), use of other substances (alcohol and other drugs) and experience with cannabis (tolerance, confidence in making these self-evaluations).

Interestingly, respondents had difficulty articulating exactly how they assess impairment within the self, as evidenced in statements such as "*I know myself*" or "*You get that gut feeling, that this isn't how I usually am. I'm not myself… I shouldn't drive*". Responses suggest that this process is a subjective evaluation in which people compare their internal state to their baseline, with little appreciation for the specific factors being considered.

Decision-Making Process

In addition to the components of subjectively evaluating impairment described above, participants were asked about other factors that may be considered when making decisions about driving after cannabis use. Responses included driving distance, familiarity with the route/location (e.g., driving in a rural area versus the highway, or a foreign country), who else is in the car (e.g., no one versus children), risk of getting pulled over or in an accident, opinions of others (e.g., expressing discomfort or disapproval).

When asked about riding as a passenger with a driver who had used cannabis, many of the same factors were mentioned as relevant to the decision. However, there were some unique considerations including how well you know or trust the driver, their experience with cannabis and driving (younger drivers are less experienced in both domains), and behavioral indicators (acting strange, rambunctious, distractible).

Time To Reach Peak Effects

Many focus group participants mentioned that the amount of time elapsed since cannabis use would be an important factor to consider when making decisions relating to driving. Research has highlighted the vast differences in pharmacokinetic profiles of different cannabis forms (i.e., smoked versus edible products) so knowledge of these differences was assessed within the focus groups.

For edible cannabis products, the blood THC concentration peaks within 60-120 minutes. Fourteen participants answered the question assessing this knowledge. The responses were as follows (response frequency in parentheses): 45 minutes (1), 1 hour (5), 1-1.5 hours (3), 1-2 hours (2), 2 hours (2) and 3-4 hours (1). Participants accurately noted that it may depend on factors such as an individual's metabolism and stomach contents.

For smoked cannabis, blood THC concentration peaks within 10 minutes. Thirteen participants answered this question. The responses were as follows (response frequency in parentheses): immediately (1), 5-15 minutes (7), 30 minutes (1), 30-60 minutes (2), and two participants reported that they were unsure.

Sources of Information

When asked where they seek out information relating to cannabis and safety, participants listed several sources of information including Google and Google Scholar, government websites, cannabis product or dispensary websites, social media, and friends or family. Three individuals specifically mentioned consulting peer-reviewed research. Several participants reported researching laws related to cannabis use and driving on government websites. Four people reported relying on information obtained from peers or experienced cannabis users.

Tools to Assess Impairment and Aid in Decision-Making

Participants were asked if they would use tools to help assess impairment and/or make decisions related to their ability to drive safely after using cannabis. Two participants indicated that they would not, due to hesitancy about the validity of these tools. Eight participants indicated that they would use a tool to aid in these processes. Specific tools that were proposed by participants included saliva testing (6 references), smartphone applications (3 references), blood analysis similar to finger prick for checking insulin (2 references), a driving simulation (1 reference), a retina scanner (1 reference), and other non-specific tests of cognitive ability (e.g., reaction time) although no modalities such as an application were mentioned (2 references).

Several factors were mentioned that would influence the use of such tools. Most of these concerns centralized around validity (i.e., the ability to make accurate evaluations or predictions about driving ability). For example, participants wondered how an application would take into consideration tolerance or previous experience with cannabis if only user characteristics (e.g., age, weight gender) and cannabis usage (e.g., amount of cannabis consumed, type) were entered into the application. Similarly, if you entered a certain quantity of dried cannabis, this may not consider other characteristics of the cannabis that may influence the level of impairment such as strain or potency.

Additional factors that were mentioned included the time to complete the assessment and obtain results, the cost, degree of invasiveness, ability for discretion (e.g., an application can be used privately whereas a fluid sample may be more easily noticed by others), access, and availability of the assessment tools (e.g., sold at dispensaries, pharmacies, big box stores).

There were interesting discussions about the possibility that cannabis users may use an application to justify the decision to drive within themselves. For example, a cannabis user may enter incorrect information into the application to reassure themselves or others that they can drive. The potential for misuse was a point that had not been considered by the research team, demonstrating the value of this focus group component in soliciting information and opinions on these important issues.

As a result of the focus group, new questions and response options were added to the preliminary survey. Items that were added after the focus group analyses have been highlighted in the final online survey content in Appendix D.

Phase 2: Part 2: Online Survey Results

Participants

In total, there were 98 questions in the online survey. Participants were only included if they completed 70% of more of the survey. Several participants (n =157) initiated the survey but either discontinued immediately or before completing the key questionnaires. In reviewing the survey composition, 70% was selected as an appropriate cut point because the questionnaires included beyond this point were only used in supplementary analyses. Most non-completers discontinued after the first page of the survey. Demographic information was only available for roughly 50% of non-completers so no analyses were completed to assess for differences in completers versus non-completers. Completers finished the survey in an average time of 33 minutes.

The final sample was comprised of 416 participants, ranging in age from 19-66 (*M*= 32.70, *SD*= 8.95). Most of the sample was Caucasian (86%), male (60%), with a post-secondary education (63%). Detailed demographic information for online survey completers (i.e., 70% or more completed) can be found in Table 15. Approximately half of participants (49%, n=196) reported using cannabis for medicinal purposes. Only 46% (n=90) of these participants reported having a prescription for cannabis.

Given the nature of this investigation, the sampling strategy (i.e., convenience) did not intend to solicit a sample that was representative of the Canadian population. Comparisons will be drawn between our sample and the sample obtained in the CCS where relevant.

Table 15

Online Survey Participant Characteristics

Characteristic	Frequency (%), $N = 416$
Gender	
Male	251 (60.3)
Female	153 (36.8)
Non-Binary	4 (1.0)
Prefer not to disclose	2 (0.5)
Missing/Did not report	6 (1.5)
Ethnicity	
Caucasian (e.g., Canadian/European)	357 (85.8)
Arab (e.g., Armenian, Egyptian, Iranian, Lebanese)	14 (3.4)
Black (e.g., African, Haitian, Jamaican, Somali)	14 (3.4)
Indigenous (e.g., Inuit/First Nations/Metis)	19 (4.6)
Latino (e.g., Latin American, Hispanic descent)	11 (2.6)
Asian (e.g., Chinese, Pilipino, Japanese, Korean)	13 (3.1)
Biracial	3 (0.7)
Other	7 (1.7)
Level of Education	
Less than high school	7 (1.7)
High school diploma	90 (21.6)
College diploma/certificate	135 (32.5)
University undergraduate degree	126 (30.3)
University graduate degree	47 (11.3)
Missing/Did not report	11 (2.6)

Results of Cannabis and Driving Survey

Cannabis Use Behaviour

Survey participants were asked to report on a variety of cannabis use behaviours. When asked about frequency of use, most reported using cannabis daily (47%), followed by 2-5 times per week (22%), once per week (11%), 2-3 times per month (11%), once per month (6%) and lastly, less than once per month (3%). Participants were asked how long they have been smoking cannabis at this rate and the responses were variable, suggesting that the survey sample was comprised of new and chronic cannabis users. Responses included less than one year (10%), 1-2 years (27%), 3-5 years (28%), 5-10 years (14%) and more than 10 years (21%).

Roughly half of participants reported using cannabis for medicinal purposes (49%) and 44% of those indicated that they had a prescription for cannabis. Of those who did report using cannabis for medicinal purposes (n= 229), 40% indicated that THC was the preferred cannabinoid, with 19% preferring CBD, and 38% reporting that THC and CBD were equally beneficial for their medicinal needs. A small percentage (2%) reported that they were unsure about their preferred cannabinoid for medicinal cannabis use.

Participants were asked about the preferred cannabis products (i.e., form) and the frequency of use for each type of cannabis product that is available. Overall, 47% of cannabis users reported that dried cannabis (i.e., bud, flower) was their preferred product, followed by edibles (27%), vaporizer pens (12%), oil (6%), extracts/concentrates (6%) and hash (2%). Differences based on gender were considered. Our results mirror the CCS. A higher percentage of males reported preferring dried cannabis (44.8%), extracts/concentrates (8.4%), and oil (6.8%) compared to females (43.8%, 2.6%, and 5.9% respectively). A higher percentage of females (34.6%) reported that edibles were their preferred cannabis product, compared to 28% of males. Similar to the CCS, males and females equally preferred vaporizer pens (10%).

Dried cannabis was identified as the preferred cannabis product but was also most frequently used with 33% percent of participants reporting daily use and another 19% reporting usage 2-5 times per week. Vaporizer pens were the second most frequently used product with 27% using this method multiple times per week. Even though edibles were the second most popular type of product, participants use edibles relatively infrequently, with less than once per month being the most common response (25%). However, 21% of participants use edible products multiple times per week. The reported frequency of use for each type of cannabis product can be found in Table 16 below.

Table 16

Frequency and percent of use reported for different cannabis products in the online survey

	Daily	2-5 times per week	Once per week	2-3 times per month	Once per month	Less than once per month	Never
Dried cannabis	154 (33%)	88 (19%)	42 (9%)	66 (14%)	42 (9%)	52 (11%)	23 (5%)
Edible products	35 (7%)	66 (14%)	73 (16%)	91 (20%)	68 (15%)	116 (25%)	14 (3%)
Oil (oral use)	19 (4%)	33 (7%)	49 (11%)	59 (13%)	44 (10%)	111 (25%)	138 (30%)
Vaporizer pens	56 (12%)	66 (15%)	45 (10%)	74 (16%)	60 (13%)	70 (15%)	88 (19%)
Other concentrates	27 (6%)	46 (10%)	42 (9%)	63 (14%)	56 (12%)	76 (17%)	146 (32%)
Hash	15 (3%)	18 (4%)	48 (11%)	79 (17%)	48 (10%)	112 (25%)	134 (30%)

Participants reported considering the THC and CBD levels when purchasing cannabis products. When asked to indicate the cannabinoids used, participants were instructed to select all that apply. The most used products, in terms of cannabinoid content, are THC dominant (62%), THC only (43%), equal parts of THC/CBD (37%), and CBD dominant (23%) and CBD only (21%). For those using THC-dominant products, 75% of cannabis users reported smoking between 0.5-2 grams of dried cannabis per day, with approximately 25% of participants reporting 0.5 grams or less, 0.51-1.00 grams and 1-2 grams. For edible products the most frequently reported dosage was 10 mg (20%), followed by 5 mg (17%) and greater than 50 grams (13%). For participants that reported using CBD-dominant products, 23% of cannabis users reported smoking 0.5 gram of CBD-dominant dried cannabis on an average day of use, and for edible CBD products, the most common dose was 10 mg (20%).

Prior to asking more in-depth questions about cannabis use and driving, participants were asked to report on their level of knowledge about different cannabis products and how this relates to driving. Overall, most participants reported that they are knowledgeable about the effects of smoked cannabis (81%) and edible cannabis products (77%). Similarly, participants reported being knowledgeable about the effects of smoked and edible forms of cannabis on driving performance (78% and 73%, respectively).

Driving History and Habits

Using an adapted set of questions from the Centre for Research on Safe Driving, the driving history and habits of participants were assessed. For the number of kilometres driven per week, responses in order of frequency were: 21-50km (38%), over 100km (26%), 51-100 (22%) and 0-20 km (14%). On a local street where the speed limit is 50 km/hr, most participants reported driving 46-55 km/hr (46%), followed by 36-45 km/hr (22%) and 56-65 km/hr (22%). On major highways where the posted speed limit is 90km/hr, most participants reported driving 96-105 km/hr (36%), followed by 86-95 km/hr (25%) and 106-115 km/hr (21%).

The average number of lifetime, at-fault collisions (involving a person, car, or fixed object as a driver), was 1.13 (range 0-12, *SD* = 1.78). Nearly 40% reported that they have never had a collision, but for those that had, most indicated that their last at-fault collision was 2-3 years ago (12%), followed by less than one year ago (11%). Similarly, the average number of lifetime collisions where the driver was not at-fault was 1.29 (range 0-12, *SD* = 1.68). Most participants reported that they have never had a not-at-fault collision (31%), but for those that had, their most recent collision was 1-2 years ago (15%), followed by 2-3 years ago (13%).

Participants were not asked to report on driving charges or infractions for the purpose of this investigation.

Knowledge, Beliefs and Behaviour Related to Impaired Driving

Most respondents (60%) indicated that their beliefs about cannabis and driving did not change following the legalization of cannabis in October 2018. For the 33% that did report a change in beliefs, 60% reported that they are more cautious about driving after using cannabis use due to new laws about cannabis and driving. On the other hand, 40% reported that they have become more lenient when it comes to driving after using cannabis since legalization.

To assess for potential differences in knowledge about driving under the influence of cannabis and alcohol, participants were asked about the legal limits at which one can be charged with impaired driving. Surprisingly, only 39% of participants reported knowing the blood alcohol concentration (BAC) at which they can be charged with driving under the influence of alcohol. When asked to report the specific BAC, the most common answer was correct at 0.08 (n=69, 45% of respondents). Other common responses included 0.05 (n=25) and 0.80 (n=13). Cannabis users demonstrated appropriate knowledge in terms of how many alcoholic drinks they can safely to consume to remain under the legal limit for impaired driving; one drink per hour was the most common response (n=85, 56%).

Importantly, only 7% of cannabis users reported knowing the THC blood concentration at which they can be charged with driving under the influence of cannabis (DUIC). When asked to the report on the specific THC blood concentration, a mere 1% (n=4) responded with the correct answer, 5ng of THC/mL of blood. Although only 27 participants attempted to answer this question, responses were highly variable, and most participants did not even know the correct metrics of the legal limit for driving under the influence of cannabis. Given that most cannabis users were unfamiliar with the legal limit for DUIC, it follows that most respondents did not know how the quantity of cannabis that would put them “over the legal limit”; 95% of cannabis users did not answer this question.

An important component to making informed decisions about cannabis and driving is understanding the effects of cannabis, including the differences between cannabis products. Cannabis users were asked how many minutes it takes for smoked cannabis, and edible cannabis products to reach peak levels in the blood (i.e., maximum effect). For smoked cannabis, responses ranged from 1 minute to 3 hours, with 10 minutes (n=55, 15%) being the most common response. The second and third most common responses were 5 minutes (n=54, 15%) and 30 minutes (n=40, 11%) respectively. The correct answer is 5-10 minutes. Including all responses within 10 minutes, 38% of cannabis users (n=136) who responded were correct, and most responses (n= 261, 73%) were within a reasonable range (0-30 minutes). Fourteen percent (n=60) did not provide a response to this question and an additional 7% of respondents wrote “I don’t know” or “unsure”.

For edible cannabis, responses ranged from 1 minute to 8 hours, and 60 minutes was the most common response (n=47, 13%). The second and third most common responses were 90 minutes (n=34, 10%) and 120 minutes (n=28, 8%), respectively. The correct answer is 1-2 hours. Several participants provided a range in their response. Including all participants with responses in the range of 1-2 hours, 40% (n=142) of cannabis users who responded were correct about the time required for edible cannabis to reach peak levels in the blood. Fifteen percent (n=62) did not provide a response to this question and an additional 6% of respondents wrote “I don’t know” or “unsure”.

In terms of the perceived risk level for driving under the influence of cannabis relative to alcohol, 52% of participants felt that driving under the influence of alcohol was more dangerous, 14% felt that driving under the influence of cannabis was more dangerous, 23% felt that the risk level was equal, and the remaining 11% were unsure about the relative risk.

To assess the prevalence of impaired driving, participants were asked to report on these behaviours while being reminded of their anonymity to encourage honest responding. Many cannabis users (77%) reported drinking alcohol in the past year. For those who did report drinking alcohol, frequency was assessed. Responses included: daily (6%) 2-3 times per week (28%), once per week (23%), once every 2-3 weeks (13%), once per month (10%) and less than once per month (20%). On a typical night of drinking, the average number of drinks consumed was two (one drink = one beer, 5oz. wine, 1oz. liquor).

Most participants (n=194, 65%) denied that they have driven while over the legal blood alcohol limit. Males were more likely (39%) than females (29%) to report driving while over the legal limit, to the best of their knowledge. It should be noted that only 71% of survey completers answered this question. For those who reported engaging in this behaviour (n=91), 47% indicated that they do this at least once per month.

Participants were asked if they have driven after using cannabis even though they felt “high” in the past 30 days and fortunately, 95% of people answered this question. Among respondents, 47% admitted to driving a motor vehicle even though they felt “high”. A greater percentage of males endorsed this behaviour (52%) compared to 38% of females.

With respect to a combination of alcohol and cannabis, 39% of participants (n=116) reported driving within 3 hours of using both substances. Males were more likely to report driving under the combined influence of cannabis and alcohol than females (45% compared to 32%, respectively). To assess the frequency of this behaviour, participants were asked how often in the past year they used cannabis and drove while *under* the legal limit for alcohol (to the best of their knowledge) and the most common response was once or twice (38%). Participants were also asked to report how often in the past year they have driven after using cannabis and consuming a *moderate to large amount of alcohol* (i.e., over the legal limit) and the most common response was once or twice (32%) but 24% reporting doing this once or twice per month. These results should consider the fact that only 39% reporting knowing the legal limit.

Influence of different types of products on driving ability

Participants were asked to rate their level of agreement with several statements on a five-point scale ranging from strongly disagree to strongly agree. Most cannabis users who completed the survey believe that cannabis does affect driving performance with 54% reporting that they agree/strongly agree with this statement, 23% indicated that their neither agree or disagree, and the remaining 23% disagreed or strongly disagreed that cannabis affects driving performance.

For smoked cannabis, 47% believe that it impairs their ability to drive safely, while 25% believe that smoking cannabis causes them to drive more safely. For edible cannabis products, 52% believe that consuming edible products impairs their ability to drive safely, while 18% believe that consuming edibles causes them to drive more safely. These results are consistent with the fact that most respondents agreed that different types of cannabis have different effects on the ability to drive safely. As an explicit comparison of the perceived differential effects, most cannabis users felt that edible cannabis would lead to more driving impairment than smoked cannabis (41%), whereas only 25% reported that smoked cannabis would lead to more driving impairment. For both statements, approximately 30% of participants responded "neither agree nor disagree", which may reflect uncertainty or a desire for more information.

With respect to the two main cannabinoids (i.e., THC and CBD), 57% of participants believe that THC and CBD have different effects on driving ability. Forty-two percent of participants believe that THC impairs driving performance, whereas only 24% felt that CBD impairs driving performance. Consistent responses were noted in the relative comparison where 40% participants believe that they would drive more safely after using CBD-based cannabis products than THC. Only 15% believed that would drive more safely on THC than CBD.

Influence of Cannabis on Specific Driver Actions

The next set of questions provided participants with a list of driver actions. Participants were asked if they believe that cannabis use makes them more or less likely to engage in this action, if cannabis has no effect, or if they were unsure. The results for each driver action are reported in Table 17 as percentages of the total responses.

Table 17

Perception of the influence of cannabis on specific driver actions (N=425)

Driver Action	More likely (%)	Less likely (%)	No effect (%)	Unsure (%)
Speeding	18.2	55.4	20.8	5.7
Driving too slow	43.6	26.9	22.9	6.6
Being distracted while driving	40.9	31.1	22.1	5.9
Getting lost	37.1	24.4	31.2	7.3
Driving too close to another vehicle	23.9	40.1	28.9	7.0
Swerving into the wrong lane	25.1	32.9	34.3	7.7
Driving on the shoulder	25.8	31.7	34.7	7.7
Colliding with an object (e.g., vehicle, animal)	29.5	26.0	37.7	6.8
Drinking and driving	17.4	33.4	37.2	12.0
Failing to follow road signs	31.8	30.7	29.5	8.0
Going through red light/stop sign	31.2	30.8	32.4	5.6
Wearing a seat belt	25.5	24.8	43.9	5.9
Being alert	32.5	36.6	22.6	8.3

Time Required to Drive Safely

To assess cannabis users' knowledge about the time required to drive safely following cannabis use, participants were asked to rate their level of agreement with a series of statements, using the same five-point scale ranging from strongly disagree to strongly agree. As an example, the first statement was "*I would drive immediately after smoking cannabis"*. Additional time periods included within one hour, two hours, three hours, or four hours. The same statements were repeated for edible forms of cannabis. In addition to asking about the amount of time people would wait before driving, the same questions were asked about accepting a ride as a passenger with a driver who had use cannabis. Results are summarized in Table 18.

Table 18

Assessing perceptions of time required to drive safely following cannabis use

	Strongly Disagree (%)	Disagree (%)	Neither agree nor disagree (%)	Agree (%)	Strongly Agree (%)
I would drive immediately after smoking cannabis	28.2	24.7	16.7	22.1	8.2
I would accept a ride with someone who just smoked cannabis	19.3	21.9	23.1	30.1	5.6
I would drive within one hour of smoking cannabis	20.0	21.9	21.2	25.6	11.3
I would accept a ride from someone who smoked cannabis one hour ago	14.8	22.1	20.0	34.8	8.2
I would drive within two hours of smoking cannabis	13.4	18.6	19.3	33.3	15.3
I would accept a ride from someone who smoked cannabis two hours ago	12.0	16.5	23.8	36.6	11.1
I would drive within three hours of smoking cannabis	11.6	14.2	18.6	35.6	20.0
I would accept a ride from someone who smoked cannabis three hours ago	9.4	15.7	21.4	39.2	14.3
I would drive within four hours of smoking cannabis	6.3	11.0	17.6	41.1	23.9
I would accept a ride from someone who smoked cannabis four hours ago	5.9	12.9	22.1	41.6	17.4

I would drive immediately after eating an edible.	22.2	21.5	22.5	25.5	8.2
I would accept a ride from someone just consumed an edible product	20.3	20.3	25.7	27.4	6.4
I would drive within one hour of eating an edible.	27.2	27.7	21.4	20.0	3.8
I would accept a ride from someone who consumed an edible product one hour ago	24.9	24.0	26.4	20.2	4.5
I would drive within two hours of eating an edible.	28.6	21.8	24.6	20.4	4.5
I would accept a ride from someone who consumed an edible product two hours ago	25.1	25.5	26.2	18.0	5.2
I would drive within three hours of eating an edible.	24.4	22.7	22.2	24.8	5.9
I would accept a ride from someone who consumed an edible product three hours ago	21.4	23.3	26.1	23.8	5.4
I would drive within four hours of eating an edible.	17.1	18.3	27.9	29.6	7.0
I would accept a ride from someone who consumed an edible product four hours ago	16.9	19.0	26.1	31.1	6.9

Participant responses reflected a tendency to wait longer before driving after consuming edible cannabis products than smoking cannabis. Most participants indicated that they would not drive immediately after smoking cannabis (52%) or within one hour (42%). However, a significant proportion of participants indicated that they would drive immediately after smoking cannabis (30%) or within one hour (36%). This is the time frame in which THC reaches peak levels in the blood when inhaled. Most respondents reported that they would drive within two (49%), three (56%), or four hours (65%) of smoking cannabis. The proportion of respondents indicating that they would drive increased as the time frame increased.

For edible cannabis, most participants indicated that they would not drive immediately after consuming an edible cannabis product (44%) or within one (55%), two (50%) or three hours (47%). At four hours, a slight majority reported that they would drive (37%), while 35% reported that they would not and 28% were unsure. When consumed orally, blood THC concentration peaks in the blood within 1-2 hours and 25% of cannabis users in this survey reported that they would drive in this time frame.

Cannabis users' responses reflected a tendency to be more lenient in terms of time required to drive safely when they were riding as passengers. Interestingly, participants were more likely to respond "neither agree nor disagree" when the statements were involving decisions to ride as a passenger, suggesting more indifference in these decisions.

Evaluating Impairment from Cannabis

To our knowledge there is no research on the process that individuals engage in when evaluating impairment from cannabis as it relates to driving decisions. Most cannabis users (70%) reported feeling confident in their ability to self-evaluate impairment following cannabis use. Similarly, 68% indicated that they trust the decisions they make about their ability to drive safely after cannabis use. For comparative purposes, we asked the same questions about alcohol and determined that participants were slightly more confident in their ability to evaluate their impairment and make driving decisions for cannabis. With alcohol, 61% of participants were confident about their ability to self-evaluate impairment and 60% trust the decisions they make about their ability to drive safely after consuming alcohol.

Driving under the influence of cannabis is a prevalent behaviour among cannabis users. Nearly half of participants (47%) reported driving even though they "felt high" within the past 30 days. Based on previously reported results, the high prevalence of this behaviour is likely explained by the fact that a significant proportion of cannabis users do not believe that "being high" is associated with driving impairment.

To better understand the individualized process of evaluating impairment as it relates to driving, participants were asked to imagine that they felt "too high" to drive and report on how they arrived at this decision. This was an open-ended question due to the lack of previous research on this subject. Given the exploratory nature, no response options were provided to avoid influencing participants' subjective decision-making process. Table 19 summarizes the factors that cannabis users identified in self-evaluations of cannabis-attributable impairment. After qualitative analysis, responses were organized into five categories of factors considered in evaluating impairment. These categories were labelled as cognitive, physical, emotional, cannabis and driving. In Table 19, the individual responses are listed in order of frequency (i.e., number of references) within the five overarching response categories.

Table 19

Factors considered when self-evaluating impairment from cannabis

Factor	Description	Number of References
Cognitive		
Fatigue	Feeling tired, drowsy, falling asleep	44
Concentration	Difficulties with concentration, focus, attention	35
Clarity	Brain fog, confusion, disoriented, unaware, groggy	32
Psychomotor coordination	Impaired motor skills, balance, speech, clumsy	24
Reaction time	Delayed reaction time, reflexes	14
Perception	Skewed perception (depth, time, visual)	11
Slow thought	Slow processing, delayed cognition	11
Memory	Short term memory loss, forgetting	8
Poor judgement	Distorted thoughts, errors in decision-making	5

Physical		
Eyes	Eyes red, heavy, tired, blurry	21
Sensations	"Body high", feeling tingly or numb, airy, heavy limbs	16
Dizziness	Feeling dizzy, lightheaded	10
Nausea	Feeling nauseous, sick, unwell	3
Dry mouth	Dry mouth	2
Hunger	Increased hunger, cravings	2
Elevated heart rate	Elevated heart rate	1
Emotional		
Anxiety	Feeling anxious, paranoid, not confident to drive	18
Euphoria	Euphoric, excessive laughing/smiling, giddy	11
Negative state	Stress, mental decline, hallucinations, altered state	7
Cannabis		
Quantity consumed	Amount of cannabis used	14
Time elapsed	Amount of time passed since cannabis use	14
Type of cannabis	Method of consumption, potency, strain, cannabinoid	7
Tolerance	Consideration of tolerance or experience	3
Other substances	Consumption of other substances (i.e., alcohol)	1
Driving		
Distance	How far the driving distance is	5
Situation	Urgency of the drive, importance, emergency	3
Time of day	Day or nighttime driving (comfort and risk)	1

Cognitive factors were most frequently reported by participants. Specifically, fatigue, cognitive clarity, concentration, and psychomotor coordination were the most common responses listed by participants attempting to articulate the subjective process of evaluating impairment from cannabis. Physical indicators were also important considerations, especially the appearance/ feeling of eyes, and changes in bodily sensations. For emotional states, cannabis users reported that indicators of impairment include feeling anxious or paranoid, but also euphoria as reflected in a sense of giddiness or excessive laughing and smiling. Cannabis characteristics were frequently considered in evaluating impairment. The quantity of cannabis used, time passed since usage, and type of cannabis were the most frequently reported cannabis factors. Although less frequent, cannabis users considered situational factors in driving situations such as driving distance, time of day, and the importance of the drive (i.e., an emergency situation).

Interestingly, several participants wrote responses suggesting that the process of evaluating impairment is difficult to articulate as evident in responses such as "*you just know*" or "*it's a feeling*". This mirrors response patterns from the focus groups.

Following the open-ended exploration into the subjective process of evaluating impairment as it relates to driving ability, participants were provided with a scenario to help gain further insight into this process. Participants were asked to imagine that they were high from using cannabis at a party when a friend asks for a ride home. Based on previous research and focus group results, participants were provided with a list of 11 factors and asked to indicate which factors they would consider when deciding whether they should drive the friend home. In Table 20, the factors are reported in order of frequency selected. The percentage of respondents who indicated that this factor would be considered in their decision-making process is included.

Table 20

Factors considered in driving decisions following cannabis use

Factor	Frequency (%), *n* = 398*
Evaluation of impairment (i.e., do I feel too high to drive?)	250 (62.8%)
Time elapsed since cannabis use	189 (47.5%)
Availability of alternate transportation	178 (44.7%)
Quantity of cannabis used	177 (44.5%)
Beliefs about how cannabis affects driving	165 (41.5%)
Driving distance	163 (41.0%)
Likelihood of getting caught by law enforcement	157 (39.4%)
Appearance (e.g., red eyes, heavy eyes, smell)	155 (38.9%)
Consequences of getting caught	125 (31.4%)
Opinions of others	91 (22.9%)
Who else is in the car	90 (22.6%)
Other	18 (4.5%)

*Participants were instructed to select all that apply

Participants were provided an opportunity to select "other" as an option and fill in their own response. Eighteen participants provided additional factors for consideration, and these included: other substances consumed (e.g., alcohol), how busy the driving area is, time of day, type of cannabis used, weather, and perceived tolerance.

After asking cannabis users to identify *all* factors that they would consider in this decision, we asked them to indicate which factor out the eleven listed is the *most important*, followed by the second and third most important factor in the decision. The most common response for the "most important" factor was evaluation of impairment (35%), followed by availability of alternate transportation (8.5%), likelihood of getting caught (8.5%) and beliefs about how cannabis use affects driving (8.5%). The most common response for the second most important factor was time passed since I used cannabis (15%) and for the third, consequences of getting caught (13%). For the second and third factor, the responses were variable and distributed evenly among the response options.

Sources of Information and Consideration of Tools

One objective of this research was to explore the sources of information that Canadian cannabis users rely on and trust. In addition, we were interested in whether cannabis users were willing to use tools to assist in evaluating impairment and making informed decisions about cannabis use and driving.

Most respondents (70%) indicated that they have researched safety information on cannabis and 68% reported looking up information specifically related to cannabis and driving. When asked about the information they were seeking, the most common responses were how law enforcement can detect driving under the influence of cannabis (55%), laws about impaired driving (53%), how cannabis affects driving (52%), and penalties for impaired driving (49%).

Participants were asked about the sources of information they trust when it comes to information relating to responsible cannabis use. Government websites (e.g., Government of Canada or Ontario, Public Health) were listed most frequently (64%), followed by experienced cannabis users (36%), family doctor (34%) and social media (32%).

Despite identifying trusted sources of information relating to cannabis use, 59% of participants reported that they would like more information about how to make safe decisions about cannabis use and driving. If a tool was available to aid in assessing impairment levels and making informed decisions about driving ability, 78% of respondents reported that they would use it. When asked about the tool that they would be most likely to use, 45% selected a smart phone application, 30% chose an oral screening tool and 20% selected a brief online questionnaire or screening tool. Participants were given the opportunity to choose "other" tools that could be used (5%) and additional responses included AI voice recognition (speech patterns) and instant blood test. Five participants indicated that their own judgement or self-evaluations are the tool that they trust and rely on the most.

Factors that would influence the likelihood of tool utilization included the accuracy of the tool (56%), cost (51%), ability to use discreetly (46%) access/availability of the tool (46%) and time to use or process results (35%).

Influence of Risk Taking on Impaired Driving Behaviour

In our survey, total scores on the DOSPERT (n=383) ranged from 30-210 (*M*= 108.36, *SD* = 25.77). The range, mean, and standard deviation for each subscale are reported in Table 21.

Table 21

Descriptive statistics for DOSPERT subscale scores

Risk-taking Subscale	Range	Mean	Standard Deviation
Ethical	6-42	17.78	7.90

Financial	6-42	19.63	7.84
Health and Safety	6-42	21.22	6.63
Social	6-42	28.13	6.59
Recreational	6-42	22.14	7.67

A series of logistic regression models were constructed to investigate the relationship between age, gender, general risk-taking, the five different domains of risk-taking, and self-reported driving under the influence of cannabis and/or alcohol. There were three questions that assessed driving under the influence. The first asked participants to indicate if they have driven even though they felt "high" in the past 30 days. The second question asked participants if they have ever driven while over the blood alcohol limit (to the best of their knowledge). The third asked participants if they have ever driven after drinking alcohol and within three hours of using cannabis. All three questions had dichotomous response options (i.e., yes or no).

Correlation matrices were created to check for collinearity. For the five domains of risk-taking, correlations ranged from $r = -.05$ (social and financial) to .68 (ethical and health/safety). Based on this analysis, the five domains can be entered into a model together because the correlations do not meet the threshold for collinearity (Dormann et al., 2013).

To assess the association with risk taking and impaired driving behaviour, total score on the DOSPERT was used as an explanatory variable. Four of the five domains had correlations with the total DOSPERT scores exceeding .75. To address collinearity, separate models were constructed for general risk-taking (i.e., total DOSPERT scores), and the five domains of risk-taking. There were three separate impaired driving outcome variables (i.e., dependent variables). Thus, a total of six logistic regression models were used total to address the risk-taking hypothesis.

Model 1: Age, gender, general risk-taking, and DUIC.

Age and gender were not associated with self-reported DUIC. General risk-taking behaviour was associated with greater odds of DUIC (OR= 1.02; 95% CI: 1.01, 1.03, $p < .001$). Holding all other variables constant, the odds of DUIC increased by 2% for every one-unit increase in total DOSPERT scores. According to the Cox & Snell R-square and the Nagelkerke R-square, the entire model accounts for 8-11% of the variance in driving under the influence of cannabis. The model correctly classifies 66% of cases.

Model 2: Age, gender, five risk-taking domains, and DUIC.

Age and gender were not associated with self-reported DUIC. The only domain of risk-taking behavior that changed the odds of DUIC was ethical risk-taking (OR= 1.07; 95% CI: 1.02, 1.12, $p = .007$). Holding all other variables constant, the odds of DUIC increased by 7% for every one-unit increase on the ethical risk-taking subscale of the DOSPERT. It is worth noting that the health and safety risk taking domain was approaching significance (OR = 1.05; 95% CI: 1.00, 1.11, $p = .075$). Social, recreational, and financial risk-taking behaviour were not associated with self-reported DUIC. According to the Cox & Snell R-square and the Nagelkerke R-square, the entire model accounts for 11-15% of the variance in driving under the influence of cannabis. The model correctly classifies 66% of cases.

Model 3: Age, gender, general risk-taking, and DUI (Alcohol).

Age and gender were not associated with self-reported driving while over the legal limit for alcohol (DUI). General risk-taking behaviour was associated with the odds of DUI (OR= 1.02; 95% CI: 1.01, 1.03, $p = .005$). Holding all other variables constant, the odds of DUI increased by 2% for every one-unit increase in total DOSPERT scores. According to the Cox &

Snell R-square and the Nagelkerke R-square, the entire model accounts for 4-5% of the variance in driving under the influence of cannabis. The model correctly classifies 69% of cases.

Model 4: Age, gender, five risk-taking domains and DUI (Alcohol).

Age and gender were not associated with self-reported driving while over the legal limit for alcohol (DUI). The only domain of risk-taking behavior associated with DUI was health and safety (OR= 1.09; 95% CI: 1.02, 1.16, p = .007). Holding all other variables constant, the odds of DUI increased by 9% for every one-unit increase on the health and safety risk-taking subscale of the DOSPERT. According to the Cox & Snell R-square and the Nagelkerke R-square, the entire model accounts for 9-12% of the variance in driving under the influence of cannabis. The model correctly classifies 68% of cases.

Model 5: Age, gender, general risk-taking and DUIC + Alcohol.

Age, gender, and general risk-taking behaviour were not significantly associated with self-reported driving while under the combined influence of alcohol and cannabis.

Model 6: Age, gender, five risk-taking domains and DUIC + Alcohol.

Age and gender were not associated with self-reported driving under the combined influence of alcohol and cannabis. The only domain of risk-taking behavior associated with DUI was health and safety (OR= 1.09; 95% CI: 1.03, 1.16, p = .005). Holding all other variables constant, the odds of driving under the combined influence of alcohol and cannabis increased by 9% for every one-unit increase on the health and safety risk-taking subscale of the DOSPERT. According to the Cox & Snell R-square and the Nagelkerke R-square, the entire model accounts for 6-8% of the variance in driving under the influence of cannabis. The model correctly classifies 64% of cases.

Discussion

Using a variety of data sources and methodological approaches, this research has made valuable contributions to the knowledge base for cannabis and driving. In attempting to investigate the risks associated with cannabis use and driving, most research relies on driving simulations or highly controlled experimental conditions. Although the legalization of cannabis has eased restrictions on research, on-road investigations typically involve low doses of THC and experimental studies may not reflect naturalistic behaviour.

This research project utilized both secondary data and a primary study, including focus groups and a survey, to address two main objectives. The objectives were to investigate the association between cannabis use and the risk of committing unsafe driver actions in the context of fatal crashes. In addition, this phase of the research sought to identify specific driver actions that are associated with cannabis-related fatalities. The second phase focused on addressing gaps in the literature and existing national surveys by further assessing knowledge about the effects of smoked and orally consumed cannabis products and how this relates to the process of evaluating impairment and making decisions about safe driving ability. This research can help to inform public health initiatives by promoting responsible cannabis use and reducing rates of DUIC.

The first phase of this project utilized data from fatal crashes to quantify the risk associated with cannabis use. Forty unsafe driver actions (UDAs) were used a proxy measure for crash responsibility. If any of these UDAs were coded by trained analysts, crash responsibility was inferred. After analysing the data from over 242,000 crashes that met the inclusion criteria, we concluded that drivers who tested positive for THC had 29% greater odds of making an unsafe driver action (i.e., be responsible) for a fatal crash, relative to drivers who tested negative for THC and alcohol. Thus, hypothesis one was confirmed.

This phase of our research replicated analyses completed by Dubois and colleagues (2015), adding 11 years of data, or nearly 100,000 cases. Over time, testing for drugs, including THC, increased. Thus, relative to the analysis by Dubois (2015), our study saw a 300% increase in the number of drivers that were included in the THC analyses (9449 cases). In the previous publication, THC was associated with a 17% increase of committing an UDA (Dubois et al., 2015). The increased odds obtained in our analysis (i.e., 29%) may be attributable to increased screening.

The influence of alcohol was also considered in the FARS analyses. For each increase of 0.01 in BAC, the odds of committing an UDA increased by 9%. Although slightly lower than hypothesized (OR= 1.10), these results are consistent with Dubois at al. (2015), which reported an 11% increase for each 0.01 change in BAC. Our analysis found that at a BAC of 0.05, there was a 56% increase in odds of committing a UDA. Comparing the odds ratios for THC and alcohol, the data indicate that when a driver has consumed approximately two alcoholic beverages (i.e., BAC of 0.05), the odds of committing unsafe driver actions increase more than for a driver who tested positive for THC. It is important to note that these analyses did not consider variation in blood THC concentration, it was coded dichotomously. Based on the FARS analysis, the odds ratio for THC-positive drivers corresponds to the odds ratio of a driver with a BAC of 0.03.

Using 28 years of data, our research sought to identify specific driver actions that have been implicated in fatal crashes when the driver tested positive for THC or alcohol. The presence of THC in a driver's blood significantly increased the odds of engaging in three unsafe driver actions including failure to keep in proper lane, speeding, and operating a vehicle in an erratic, reckless, careless, or negligent manner. Thus, hypothesis two was partially supported.

Failure to keep in proper lane (i.e., swerving) is operationally defined as standard deviation of lane position (SDLP) in research. This study provided support for SDLP as a sensitive indicator of cannabis impairment, as determined in prior simulator studies, on-road investigations, and meta-analyses (Arkell et al., 2019, 2020; Hartman & Huestis, 2013; Lenné et al., 2010; McCartney at al., 2021; Ronen et al., 2008; Sexton, Tunbridge, Brook-Carter, & Wright, 2000; Simmons et al., 2022). The presence of THC increased the odds of failing to keep in proper lane by 11% which was comparable to the odds for a BAC of 0.02.

Speeding was the second driver action that was significantly associated with cannabis use in the FARS analyses. Interestingly, most previous research that detected an effect of cannabis use on driving speed concluded that cannabis use led to a reduction in speed (Anderson et al., 2010; Hartman & Huestis, 2013; McCartney at al., 2021; Simmons et al, 2022). In our study, cannabis use did not increase the odds of driving less than the posted maximum, but this analysis was limited by the small number of cases due to the nature of the dataset. However, there was a strong association with cannabis use and speeding, in the context of fatal crashes.

Further consideration of the nature of the dataset helps to contextualize these results. The FARS database only includes fatal crashes, and driver actions that contributed to the crash are subsequently coded from various sources (e.g., police reports). Thus, it is more likely that cannabis use would be associated with speeding, than driving slowly, in the context of fatal car crashes. For these reasons, there were less than ten cases in the THC-only condition analysis for driving less than the posted maximum which may have limited the ability to detect an effect. A different relationship may be observed in every day driving scenarios, under experimental conditions, or where crashes did not result in fatalities.

The third driver action that was found to be associated with cannabis use in fatal crashes was operating the vehicle in erratic, reckless, careless, or negligent manner (ERCN). THC increased the odds of this driver action by 29%; this increase in the odds is comparable to a BAC of 0.035. Since ERCN driving corresponds to driving offences, as opposed to specific behaviour, it is more difficult to draw parallels to research findings. However, this driver action was chosen for individual analysis because it encompasses driver actions and cognitive effects that have been associated with cannabis impairment in the literature such as delayed reaction time, divided attention, and critical tracking (Bondallez et al., 2016; Hartman & Heustis, 2013; McCartney et al., 2021). Therefore, this study provides support the notion that the neurocognitive effects of THC increase the likelihood of dangerous motor vehicle operation and fatalities.

Previous research suggested that cannabis use may influence improper following, operationally defined in research as headway distance, or as measured using car following tasks (Ramaekers et al., 2004; Robbe, 1998; Ramaekers, Robbe & O'Hanlon, 2000). In our research, the presence of THC in drivers' blood was not associated with increased odds of improper following in the context of fatal crashes, when compared to sober drivers. This is consistent with the recent meta-analysis by Simmons and colleagues (2022) which failed to find an effect of THC on headway distance or variability. In our research, there was an effect of THC on improper following when combined with large quantities of alcohol (BAC between 0.15 and 0.25). Research has considered the effect of cannabis on headway distance or variability (i.e., the ability to maintain a consistent distance from the vehicle in front of you) .This is not inherently the same as the driver infraction of improper following coded in FARS, which infers that the driver follows too closely. The specific driver actions selected for individual analysis were chosen based on previous research, but in interpreting the results, consideration of these subtle conceptual differences became important.

Alcohol significantly increased the odds of committing several unsafe driver actions including improper or erratic lane change, failure to keep in proper lane, driving off the road, operating the vehicle in an erratic, reckless careless or negligent manner, and speeding. For all driver actions listed above, except improper or erratic lane change, the quadratic term for BAC was significant meaning that the data had a curvilinear fit. This indicates that the effect of alcohol increases up to a certain point, before levelling off at high BACs. Once individuals are significantly impaired by alcohol, the odds do not increase at the same rate due to attenuation.

In the analyses of individual driver actions, interactions between cannabis and alcohol were considered. For failure to keep in proper lane and speeding, the interaction between THC and BAC was significant. For failure to keep in proper lane, a closer analysis of the odds ratios for different BACs when THC was present suggests that THC has an additive effect at low levels of BAC (increases the odds ratio), but at higher BACs (0.05 and above), the odds ratios decrease when THC is present, compared to when its absent. This was an unanticipated result but should not be interpreted as THC *reducing* the odds of swerving when the driver is under the influence of alcohol and cannabis. At the individual level, the presence of either substance increased the odds of engaging in this unsafe driver action and should be considered risk factors for swerving.

For speeding, there is a clear additive effect when THC and alcohol are combined. The combined effects are most pronounced at up to a BAC of 0.20 where the effect levels off and weakens. The combination of alcohol and THC significantly increases the odds of speeding. At the legal limit (BAC of 0.08), the odds of speeding contributing to a fatal crash increased by 91% for drivers who tested negative for THC. When THC was detected at the same BAC (0.08), the odds of speeding increased by 126%. At a BAC of 0.15 (i.e., double the legal limit), the odds of speeding contributing to a fatal crash increased by 182% for THC was absent, and 226% when THC was detected. Therefore, the combination of these two substances interact to increase dangerous driving behaviour which can lead to fatal outcomes.

The FARS analyses made a valuable contribution to the cannabis and driving literature by replicating the analyses by Dubois et al. (2015) and adding 11 years of new data. In addition to considering the effect of cannabis on *any* unsafe driver action as an inference of crash responsibility, this research expanded on previous FARS analyses to include novel contributions. In our research, unsafe driver actions were analysed at the individual level to identify driver actions implicated in fatal crashes when the driver was under the influence of cannabis. In addition to identifying three unsafe driver actions implicated in fatal crashes where the driver was DUIC, the influence of alcohol and the combination of alcohol and THC were considered. By calculating odds ratios for different BACs in the presence or absence of THC, the effects of these substances could be compared across conditions and specific driver actions.

This research was unique in utilizing data from real world fatal crashes, relying less on simulated driving scenarios or highly controlled experimental conditions. These results should be interpreted with an appreciation for the context of data collection. The fact that only fatal crash data were included limits the ability to make conclusions about the effect of cannabis in everyday life or instances where there were no negative consequences. Thus, the results cannot be generalized to all driving scenarios. However, it does provide an empirically sound explication of the risks associated with cannabis use and driving in extreme cases (i.e., when an individual’s life was lost in a crash).

The online survey was developed with the goal of expanding on the existing national cannabis surveys, while addressing gaps and focusing solely on the beliefs of Canadian cannabis users. In addition to these adaptations, new content was developed to better understand how cannabis users assess impairment in themselves in the context of driving decisions. The decision-making process was further investigated to expand knowledge in this area. The willingness to use tools designed to assist with evaluating impairment and decision-making was explored through the survey. Results of this survey can help balance Canadians' right to use cannabis with the interests of public safety. More specifically, results can be used to identify targets for public health campaigns or inform tool development using opinions of the intended users.

Before results from our survey are compared with existing national surveys, differences between the two datasets must be considered. The Canadian Cannabis Survey (CCS) is administered to a representative sample of Canadians and in the most recent survey (2022), only 27% identified themselves as cannabis users. Our survey participants were *all* Canadian cannabis users who reported using cannabis more frequently than the CCS sample with 47% reporting daily use. In the CCS sample, only 18% of cannabis users reported daily use, with the majority (52%) indicating that they used cannabis three days per month or less. It is possible that regular cannabis users may have been more motivated to participate in our online survey about cannabis use and driving, due to increased investment in the research's purpose and objectives.

There were differences in the demographic profiles as well. In the CCS, 51% of respondents were male, and in our online survey 60% of respondents were male. In both the CCS and our survey, roughly 80% of respondents were aged 25 or older. Our sample ranged in age from 19-66 with an average age of 32.70 (SD = 8.95). Unfortunately, the CCS does not report descriptive statistics for age, and does not further explicate the age groups, making it difficult to compare the full age distribution of the two samples.

Although the CCS includes participants who were not cannabis users, this survey reports demographic information and results for cannabis users separately which allows for relevant comparisons. The racial composition of the CCS sample of cannabis users was more diverse than our sample, given the recruitment and sampling strategy. Interestingly, in the CCS sample of cannabis users, only 30% of respondents identified as Caucasian. In our survey, 85% of participants identified as Canadian/Caucasian. Our survey is more representative of Canada's population given that 70% of Canadians identified as "white" in the most recent census (Government of Canada, 2022b). This significant difference in ethnic composition between CCS cannabis users and our survey participants should be kept in mind when interpreting the results. It is possible that cultural considerations may influence the beliefs assessed in these comprehensive surveys.

In this survey, we were particularly interested in assessing Canadian cannabis users' knowledge about different products, with a focus on the differences between smoked cannabis and edible cannabis products. To be eligible for participation in the survey, individuals were required to have used cannabis at least five times in the past year, including both smoked and edible cannabis. Most participants exceeded this minimum threshold with 80% reporting that they use cannabis at least once per week. There was appropriate variation in the length of time individuals had been using cannabis. New users (i.e., less than one year experience) comprised roughly 10% of the sample, 27% reported using cannabis for one to two years, 28% for three to five years, 14% for five to ten years and 22% reported using cannabis for more than ten years. This distribution of experience is important to ensure the breadth of Canadian cannabis users are represented. Other than having a predominantly Caucasian sample, we are pleased with the variability in demographic characteristics and cannabis use behaviours captured through the online survey.

Smoking was the preferred method of consumption for 67% of cannabis users surveyed. Within this method of consumption, dried cannabis was the preferred product (47%), followed by vaporizer pens (12%), other extracts/concentrates (5.7%) and hash (2.3%). Edible cannabis products were the second most popular, selected by 27% of cannabis users as the preferred type. Although cannabis legalization has resulted in a rapid expansion of products that are available to Canadians, the data suggest that traditional modes of administration remain most popular.

Cannabis users reported using a variety of cannabis products but there were clear differences in frequency of use. Dried cannabis was used most frequently; 61% of participants reporting smoking cannabis at least once per week with 33% reporting daily use. Although edible products are popular with Canadians, results suggest these products are used less frequently with only 38% using edibles at least once per week and 8% reporting daily use. The most popular response option for frequency of edible use was less than once per month (25%). According to our results, this form of cannabis is not one that users rely on for daily use.

Survey respondents reported similar degrees of knowledge on the effects of the two types of cannabis products (smoked versus edible) and the effects of these products on driving. It was anticipated that cannabis users would report feeling more knowledgeable about the effects of smoked cannabis, and how this relates to driving performance but there were similar response patterns for the two main product types of interest. Approximately 80% of participants reported feeling knowledgeable about these four domains (i.e., effects of two products and on driving).

Our survey results identified gaps in knowledge about the time it takes for different cannabis products to reach peak levels in the blood. Using open-ended questions to assess true knowledge, only 38% of respondents provided the correct response for smoked cannabis (i.e., 5-10 minutes) and 40% provided the correct response for edible cannabis (i.e., 1-2 hours). For both questions, approximately 20% either failed to respond or explicitly stated that they were unsure. We anticipated that cannabis users would be more knowledgeable about the effect of smoked cannabis than edible forms; thus, it was surprising that there were comparable rates of accuracy for the two cannabis forms. However, if a more generous window was used to classify correct responses for smoked cannabis (i.e., 0-30 minutes), 73% of cannabis users who provided a response were correct. This is more aligned with the anticipated gap in knowledge between the two cannabis forms and provides support for hypothesis three.

In the 2022 CCS, 82% of respondents felt that cannabis use negatively affected driving and this number drops to 76% when only cannabis users were considered (Government of Canada, 2022a). In our survey, only 54% believed that cannabis use affected driving performance, whereas 23% believed that it did not and 23% neither agreed nor disagreed. Positive and negative effects were not specified in this question. Regardless, a significant proportion of regular cannabis users are indifferent, or unsure about whether cannabis use influences driving performance.

Interestingly, only 46% reported that smoking cannabis impairs their ability to drive safely which is 30% less than reported in the CCS. In addition, 25% of our sample felt smoking cannabis causes them to drive more safely. Assuming that this survey can be generalized to the Canadian population, that translates to 2.3 million Canadian cannabis users who believe that cannabis use makes them a safer driver. Addressing this misconception would be an appropriate target for public health campaigns, especially considering high base rate and preference for smoked cannabis.

This effect was present but less pronounced for edible cannabis products. Fifty-two percent of cannabis users reported that edible products impair their ability to drive safely, while 18% believe edibles make them a safer driver. These results are concerning especially given the longer duration of effects for edible cannabis products. Similar to above, 22% and 30% of responses were "neither agree nor disagree", reflecting a lack of certainty or strong opinions.

Prior to 2020, the CCS did not ask any questions about the perception of impairment from different cannabis products. Since these questions were introduced, a couple of the statistics stood out and served as inspiration for further study through this project. According to the 2022 CCS, 21% of cannabis users were not sure if products with lower levels of THC lead to greater impairment and 9% believed that it did. For edible cannabis products, 13% of cannabis users did not believe that it could take up to four hours to feel the full effects and another 13% were not sure. Finally, 8% of cannabis users incorrectly believed that the effects of smoked cannabis lasted longer than edible products and 25% weren't sure which type of product had longer lasting effects (Government of Canada 2022a). Therefore, over 3 million Canadian cannabis users are misinformed or unaware about the pharmacokinetic differences between smoked and edible cannabis products. This is problematic because it leads to inaccurate expectations about the duration of effects, and this information is required to make informed driving decisions.

The 2022 CCS reported that 23% of cannabis users have driven within two hours of smoking or vaporizing cannabis, and 14% reported driving within four hours of ingesting cannabis. In our survey, nearly half of cannabis users (49%) indicated that they would drive within two hours of using cannabis with 30% stating they would drive immediately after smoking, when the maximum effects are experienced. Thirty-seven percent reported that they would drive within four hours of eating an edible cannabis product and 25% stated they would drive within two hours, when effects are at their peak. Our survey produced much higher estimates of engaging DUIC than the CCS. It is possible that these differences are attributable to meaningful differences between the samples. For example, our survey was comprised of individuals who use cannabis more frequently, so it is possible that these individuals are more confident in their level of experience with driving after cannabis use or believe they have developed tolerance to the effects of cannabis. These results provide additional support for the notion that cannabis users hold permissive attitudes towards DUIC, and this effect may be even more pronounced when frequency of use is considered.

One unique contribution of the survey was asking participants to indicate if they believed cannabis use made them more or less likely to engage in specific behaviours relevant to driving. Other response options included “cannabis has no effect” and “unsure”. In terms of speed, 55% of participants believe that cannabis use makes them less likely to speed, while 18% feel that cannabis use increases the odds of speeding. On the other hand, 44% believed that cannabis use makes you more likely to drive too slowly, and 27% believed that it made this behaviour less likely. Previous research has produced mixed results on this subject (Anderson et a., 2010; Hartman & Huestis, 2013; Liguori, Gatto, & Jarrett, 2002; McCartney at al., 2021; Simmons et al., 2022).

In the FARS analyses, testing positive for THC significantly increased the odds of speeding, and no effect of THC was found on driving less than the posted maximum. Although these results are from two different datasets, it is worth noting the opinion of cannabis users does not necessarily align with the FARS data for the effect of THC on speed. As previously noted, the observed effects of THC in cases with catastrophic driving outcomes may be different than the effects of THC in driving circumstances where no fatalities occurred. Similarly, survey respondents may differ in important ways from drivers who are involved in fatal crashes. These considerations should be kept in mind when comparisons across study phases are discussed.

Driving impairment research has consistently identified SDLP, or failure to maintain lane position, as a sensitive indicator of cannabis impairment. This was confirmed in the FARS analyses where THC was significantly associated with increased odds of this driver action. However, only 25% of participants felt that drivers were more likely to swerve when under the influence of cannabis. 33% reported that cannabis use made this behaviour less likely and 34% believed cannabis had no effect. Given the strength of empirical support for the relationship between this driver action and cannabis use, increasing awareness of this risk factor may be an effective risk management strategy.

To summarize other driver actions, most participants reported that cannabis use makes drivers more likely to be distracted, become lost, or fail to follow road signs. Most participants felt that cannabis use decreased the odds of speeding, following too closely, and staying alert. Lastly, most participants believed there was no effect of cannabis on swerving, driving on the shoulder, going through a red/light, drinking and driving, wearing a seatbelt, and colliding with an object (e.g., vehicle or animal). It was surprising that 38% of cannabis users believed that cannabis had no effect on the likelihood of colliding with an object including another vehicle, especially considering that most (41%) agreed cannabis increases distracted driving behaviour.

Given that cannabis users are more likely to report impaired driving and tend to hold more permissive beliefs about DUIC (Government of Canada, 2022a; Statistics Canada, 2019), a better understanding of these decision-making processes can help to explain these differences.

Our survey identified the top five factors that were considered by participants when contemplating driving after using cannabis. The top five factors cannabis users reported considering include how impaired they felt, the time elapsed since cannabis use, availability of alternate transportation, quantity of cannabis used and personal beliefs about how cannabis use affects driving. These factors were hypothesized to be key considerations. In our survey, participants were allowed to select all factors that they would consider from a list of eleven factors selected based on previous research and the focus groups. The top five were selected by 42-63% of participants. The next set of questions asked about the most important factor in this decision, prompting the participant to only select one factor from the list. Evaluation of impairment was most frequently selected (35%), followed by availability of alternate transportation (8.5%), likelihood of getting caught (8.5%) and beliefs about how cannabis use affects driving (8.5%).

The CCS only asks about the main reason (i.e., one reason) that participants drove within two hours of smoking cannabis or four hours of ingesting it. Most reported that they did not feel impaired (84%), followed by the belief that they could drive carefully (19%), did not have far to drive (17%) or no alternate transportation was available (10%) (Government of Canada, 2022a).

The current survey and the CCS both highlighted that an evaluation of impairment is the most important factor that cannabis users consider when making decisions about driving. However, there has been no research into this process, assessing specifically how individuals evaluate impairment in themselves in the context of driving ability. Our survey was designed to address this gap in the literature through qualitative analysis, using an open-ended question. The factors that participants considered in the evaluation of impairment were organized into five domains: cognitive, physical, emotional, cannabis and driving. Hypothesis five predicted three of these five domains, indicating partial support for this exploratory analysis.

Cognitive factors were most frequently mentioned by participants. When participants were attempting to assess if they were too impaired to drive, individuals reported considering fatigue, the ability to concentrate, cognitive clarity, psychomotor coordination, reaction time and perception. It makes intuitive sense that cognitive factors are most prominent in the assessment given the importance of such factors (e.g., alertness, psychomotor coordination) in safe driving ability. Fortunately, many of the cognitive factors that individuals associate with cannabis impairment are consistent with well-documented neurocognitive effects of cannabis (McCartney et al., 2021; Ramaekers et al., 2021).

Individuals reported also relying on physical indicators of impairment including red or heavy eyes, feeling a “body buzz”, or dizziness. In addition to assess cognitive and physical characteristics within themselves, participants reported considering cannabis factors such as the amount of cannabis used, time elapsed since cannabis use, and type of cannabis.

Overall, the self-evaluation of impairment appears to be an automatic and subjective process that individuals may struggle to articulate or explain. Previous research has struggled to correlate behavioural and physical characteristics with driving impairment so future research should attempt to clarify these associations (Bosker et al., 2012; Downey et al., 2012; Papafotiou et al., 2005) Our study was the first known investigation into clarifying the process of self-evaluating impairment as it relates to driving.

As a next step, research should attempt to validate if these subjective indicators of impairment are associated with driving performance deficits. Research should focus on under-studied variables that were frequently mentioned by participants in the survey such as skewed perception (e.g., time, depth), appearance of eyes, and emotional states such as euphoria. The interaction between cannabis use, emotional states and driving performance, is an interesting area of research that has not received much attention. For example, anxiety or paranoia would likely impair driving performance due to the physiological effects of these emotional states. A euphoric state, often associated with cannabis use, may cause individuals dismiss the risks of DUIC or overestimate their ability to drive safely.

In the most recent CCS, 84% of people who admitted to DUIC reported that they drove because they did not feel impaired (Government of Canada, 2022a). However, research has clearly demonstrated that THC does negatively affect driving performance, although there is less consensus on how the risk for impairment should be quantified and enforced. In addition to likely underestimating impairment, a study involving people charged with impaired driving indicated that there are biases in risk perception including comparative optimism bias; this bias causes individuals to believe that they are less likely than others to be involved in a collision than other individuals (Wickens et al., 2019). Therefore, assistive tools that can identify impairment may be an effective means of overcoming these biases and highlighting the risks of driving after using cannabis.

Our survey data reveals that most Canadian cannabis users (78%) would use tools to assess impairment and inform safe driving decisions. However, the development of a valid tool would rely on the availability of empirical research that links measurable behaviour to cannabis-attributable driving impairment. Participants indicated that validity of the tool was the most important factor that would influence the likelihood of tool utilization. Although most participants (46%) reported a preference for smart phone applications, this type of tool would rely more on tasks that are sensitive to cognitive and behavioural indicators of cannabis impairment. This approach should defer to previous research on established indicators of impairment and the development of an existing drug screening application, DRUID (Arkell et al., 2021; Richman & May, 2019; Ramaekers et al., 2021; Spindle et al., 2021). These results provide support for hypothesis eight, predicting that smart phone applications would be preferred with an emphasis on validity and cost-effectiveness.

A proportion of participants (32%) expressed a preference for tools that rely on bodily fluids such as saliva or blood to inform decisions about the ability to drive safely. Although this is the current standard used by law enforcement, research has cast doubt on one universal blood THC concentration ("per se limits") as a valid indicator of driving impairment (Arkell et al., 2021; Spindle et al., 2021). There is not a clear relationship between self-administered dose and blood THC concentration (Spindle et al., 2021). In addition, blood THC concentration may not reliably predict impairment because cannabis users differ in important ways (e.g., metabolism, experience with cannabis, baseline driving ability, and tolerance). Despite these considerations, screening tools that measure THC levels in blood or saliva would be most valuable in assessing risk of being charged with DUIC due to alignment with law enforcement procedures. However, this benefit may be offset by increased cost and thus, decreased accessibility.

DUIC was discussed earlier in the context of assessing beliefs about the time required to drive safely for different cannabis products. In addition to beliefs and assessing anticipated actions (i.e., I *would* drive immediately after smoking cannabis), our survey assessed self-reported impaired driving behaviour using three questions. Individuals were asked if they have driven "high" in the past 30 days, driven over the legal limit for alcohol or under the combined influence of alcohol and cannabis.

A greater proportion of participants reported driving under the influence of cannabis (47%) than alcohol (35%). For driving under the combined influence of cannabis and alcohol, 39% reported engaging in this behaviour. For all conditions, males reported higher rates of driving under the influence, which is consistent with previous research (Emery et al., 2008; Government of Canada, 2019, 2022; Health Canada, 2014; Perreault, 2019).

In order to better understand associations with impaired driving behaviour, regressions models were constructed. Contrary to above, age and gender were not significantly associated with impaired driving outcomes in our models including risk-taking. General risk taking propensity, as measured using the total DOSPERT score, was significantly associated with self-reported driving under the influence of cannabis and alcohol individually. Curiously, general risk-taking was not associated with driving under the combined influence of cannabis and alcohol.

For the five domains of risk-taking (i.e. DOSPERT subscales), ethical risk-taking was significantly associated DUIC, whereas health and safety risk-taking was significantly associated with driving under the influence of alcohol alone, and the combination of both substances. Therefore, hypothesis nine was partially supported by these analyses.

Limitations of the Current Research

Strengths of this research have been emphasized throughout the discussion. However, no project is without limitations. As previously noted, the relationships detected through FARS analyses only pertain to fatal crashes. Therefore, the ability to detect effects of cannabis was limited by outcome severity. Cannabis use may negatively affect driving performance in ways that don’t necessarily result in catastrophic outcomes or criminal charges. However, this dataset did not allow for those relationships to be investigated. Similarly, our FARS dataset included data from over 1.1 million fatal crashes but only 242,924 cases were included for analysis because the research objectives required drivers to be blood tested for alcohol and THC. If the driver was responsible for a crash but fatally injured, screening for the presence of drugs or alcohol would be futile since criminal charges would likely not be pursued.

The driver responsibility factors (i.e., unsafe driver actions) that were used as dependent variables in this study are coded by trained analysts after the crash, using data from various sources but mainly police reports. Thus, depending on the circumstances, it is possible that not *all* unsafe driver actions were coded if one or two specific actions were deemed to cause the fatal crash. This coding bias may have limited the ability to detect relationships between cannabis use and specific driver actions if they were "under-coded" by the trained FARS analysts based on circumstances of the crash.

Another limitation pertains to coding for THC exposure. This variable was coded dichotomously and not continuously, which restricted our ability to assess for differences based on the specific THC blood concentration. Presumably, this would be an important consideration in quantifying risk for engaging in unsafe driver actions. In addition, since the variable was coded based on the detection of THC (i.e., yes/no), a positive test could indicate the presence of THC, or possibly even THC metabolites.

In the FARS analyses, we controlled for several variables that were associated increased odds of committing unsafe driver actions based on previous research (Dubois et al., 2015). It is possible that over-controlling may have limited the ability for significant effects to be detected. Although required to detect pure effects, controlling for the presence of other substances, medications, or driver history may have extracted shared variance that was relevant.

Phase two of this research is not without limitations. In the online survey, there were several questions that could have been added to bolster our analyses. For example, it was an oversight not to ask participants about regional location to assess for regional differences as depicted in the CCS. Recruitment strategies for our project specifically targeted cannabis users in various provinces, but it would have been valuable to quantify the regional distribution of the final participant pool.

Additional limitations relate to ways that the survey development could be improved. For stronger comparisons between our data and the CCS, wording of the questions could have been more consistent. Especially for assessing DUIC behaviour, the survey should have included the exact question used in the CCS (i.e., In the past 12 months, have you driven a motor vehicle within two hours of smoking/vaporizing cannabis or within four hours of ingesting cannabis?).

In addition, several questions required participants to indicate their level of agreement with statements on a five-point scale ranging from strongly agree to strongly disagree. Across questions, a significant number of participants (between 10-30%) chose the option “neither agree nor disagree”. For this proportion of participants, opinions were not successfully solicited. With this response option, it is hard to determine whether participants were uncertain, did not have strong opinions either way, or it is possible that their response depended on information not specified in the question.

Although comparisons were made across datasets (i.e., FARS and online survey data) for exploratory purposes, the reader is reminded that the FARS analyses were based on secondary data from the United States, whereas the survey data represents current views of Canadian cannabis users. No statistical comparisons between data sets were made, but where parallels were drawn, this limitation must be kept in mind.

Implications of Research

For Cannabis Users

The legalization of cannabis in Canada represented a victory for cannabis users after years of advocacy for this movement. Now that Canadians have the right to use cannabis without fear of repercussion, it is important to balance that right with responsible use, including making safe and informed decisions about driving.

To support this goal, cannabis users should familiarize themselves with current research about how cannabis use affects driving performance, and the risks associated with this behaviour. Our research can advance that goal while helping cannabis users identify gaps or inaccuracies within their own current belief systems. Not all false beliefs are the result of negligence, it is possible that false information is shared among peers or through communities where cannabis users network (e.g., Reddit). Our survey indicated that 36% of cannabis users rely on other experienced users for information, and 30% consult family or friends. It is possible that these channels contribute to the spread of misinformation. To protect themselves, cannabis users should rely on credible sources of information that are based on empirical research, rather than personal experience.

As examples, 20-25% of cannabis users believe smoking or using edibles makes them a safer driver. Less than 10% knew the blood THC limit at which they can be charged with DUIC. In addition, many cannabis users were not aware of the fact that cannabis use can increase the likelihood of engaging in unsafe driver actions, such as swerving, which have been implicated in fatal car crashes, as demonstrated in the FARS analyses. These are a few examples of areas where cannabis users could benefit from dissemination of information that encourages them to evaluate, and potentially reconsider, their current beliefs about cannabis and driving.

An additional implication of this research for cannabis users relates to their participation in research. By participating in research such as this, cannabis users are contributing to the solution by informing appropriate targets for public health campaigns. Participants reported a willingness and desire for tools to assist in evaluating cannabis impairment, so engaging with research ensures that their needs and views are represented and shared with stakeholders.

For Public Health and Policy-Makers

There are several implications of this research for government agencies, public health organizations, and policy-makers. The first pertains to clarifying the risks associated with driving after using cannabis. The FARS analyses quantified the risk associated with cannabis use in the context of fatal crashes, using a massive dataset based on real-world data. In our study, cannabis use increased the odds of committing an unsafe driver action by 29%. It is likely that this is an under-estimate of the risk associated with cannabis use in the context of every-day driving, given the severity of the outcome used to assess this relationship.

This project has identified several targets for public health education to address misconceptions that may lead to dangerous decisions (e.g., driving while impaired due to the belief that cannabis does not influence driving ability). In addition to identifying specific beliefs as targets, this research identified different groups who are more likely to engage in DUIC (e.g., males, cannabis users) and those who are most at risk for holding inaccurate beliefs. With this information, knowledge dissemination and marketing initiatives can intentionally prioritize these groups to maximize return on the investment in public health.

The specific driver actions that are implicated in cannabis-attributable fatalities (e.g., swerving) can be considered by law enforcement in screening and detection procedures as potential indicators of DUIC.

In addition, the legalization of cannabis has resulted in a surge of research involving cannabis, including several new studies on driving. Policy-makers and legal stakeholders are continuing to review recent research and meta-analyses to ensure that the legal threshold for classifying impairment (i.e., blood THC concentration) is valid. There is growing evidence to suggest that the current per se limit does not reliably predict driving impairment (Arkell et al., 2021; Ramaekers et al., 2021). This issue is further complicated by the fact that a standard dose of THC does not result in a consistent blood THC concentration across individuals (Spindle et al., 2021). The policies and legislation are developed to assume effects on the average Canadian which, by definition, encompasses new cannabis users and those with more experience. Policy makers will continue to evaluate emerging literature to ensure that the standards for impairment and safety that are acceptable to the average cannabis user. Thus, it is possible that the proposed limits may not predict driving impairment, especially in regular, long-term cannabis users.

Whether or not the current limits for enforcing driving under the influence of cannabis are adjusted, an essential next step is educating cannabis users about these legal thresholds and how these relate to doses of different products. Only 1% of survey respondents knew the legal limit at which they could be charged with DUIC. If cannabis users are not even aware of this limit, it follows that they cannot limit usage to ensure they remain under it. There is no recommended benchmark, as there is with alcohol (i.e., one drink per hour), that cannabis users can abide by to encourage responsible cannabis use in the context of driving decisions. Defining a standard THC unit may be part of this solution (Canadian Centre of Substance Use and Addiction, 2023). In a recent panel discussion, 5 mg of THC was proposed as a standard unit (Canadian Centre of Substance Use and Addiction, 2023). Implementing this standard would increase clarity for consumers and can help to inform dosing standards for safe driving.

Conclusion

This research has made valuable contributions to the knowledge base of cannabis and driving by replicating, and expanding on, existing research from different sources. A large data set from the United States was used to quantify the increased odds of being responsible for a fatal crash when a driver is under the influence of cannabis. As a novel contribution, driver actions were analyzed at the individual level to identify specific driver actions that have been implicated in fatal crashes when the driver tested positive for THC or alcohol.

A new survey was developed to assess Canadians' knowledge, belief and behaviour about different cannabis products and driving. The new survey expanded on information captured through existing national surveys, while adding new questions based on identified caps and focus group discussions. Novel contributions included describing the process of how individuals self-evaluate impairment from cannabis in the context of driving, and how this information is used in combination with other factors to make driving decisions.

Taken together, these results have implications for several groups of stakeholders including cannabis users, law enforcement, government agencies, and policy makers. Recommendations and suggestions for future research have been emphasized throughout. It is our hope that this research can adds to the knowledge base on cannabis use and driving risk, while identifying areas where Canadians may be misinformed or require more information to make responsible decisions. Legalization signaled a major shift in our country's relationship with cannabis. It is imperative that the policy changes that accompany this shift are based on valid research to ensure a fair balance between Canadians' right to use cannabis and the objectives identified in *the Cannabis Act* to protect public health and safety.

Appendix A

Focus Group Recruitment Materials

Lakehead UNIVERSITY

CENTRE FOR RESEARCH ON CRSD SAFE DRIVING

Cannabis and Driving:
Focus Group Participants Needed

We are looking for cannabis users to participate in an online focus group discussion related to cannabis use and decision-making related to safe driving. All focus groups are completed over Zoom. You can remain anonymous by leaving the camera off. Groups run 1-2 hours in length

Eligibility

- ✓ Minimum age of 19
- ✓ Drives at least weekly (valid license)
- ✓ Access to the internet and Zoom
- ✓ In the past 12 months:
  - ✓ Have used cannabis 5 or more times
  - ✓ Have smoked cannabis
  - ✓ Have used edible cannabis products

Receive an entry into a draw for **1 of 3 $100 Amazon gift cards!**

For more information, please email Steph at: drivingstudy.psych@lakeheadu.ca

Cannabis & Driving Study: *Email Steph: drivingstudy.psych@lakeheadu.ca*

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Social Media Ad for Focus Group Recruitment

Appendix B

Script for the Part 2 Focus Group Discussions

Introduction

(Facilitator introduces self and affiliations)

First off, we would like to thank you all for participating in this focus group today. This is the first phase of a research project that is investigating Canadians' beliefs and perceptions relating to cannabis use and driving. The information collected from these focus groups will be used to inform further development of an online survey which will be used in phase two of the research. Your input is valuable and appreciated, and we want you to know that all information will be coded anonymously to protect your identity. Your name will never be linked to your responses and all information will be securely protected. Your participation in this research is completely voluntary, and you are free to withdraw your consent to participate at any time by simply leaving the Zoom call. We will be recording the session in order to create a transcription of the group, but please feel free to leave your cameras off or change your display name if it makes you feel more comfortable. Your openness and honesty are critical to the success of this focus group, so we encourage you to share your experiences and opinions openly and honestly. Taking that into consideration, we also rely on the respect of confidentiality from other group members. We ask that you please keep the content of our discussions today private, so everyone feels comfortable to share openly.

Does anyone have any questions?

If you remain on the call, you are indicating your consent to participate in this phase of our research.

Research Questions

1. In your own words, can you tell me how you think cannabis use affects the ability to drive safely?

2. Which specific driving behaviours do you think are most affected by cannabis?

3. Imagine you are high from using cannabis at a party and the host of the party tells everyone is it time to go home. You are considering driving yourself home. What factors would influence your decision?

4. Let's assume you decided that you felt "too high" to drive. How would you know?

5. Imagine you at a party and your friends want to go to another location. Your best friend offers to drive but you know they have been using cannabis. What factors would influence your decision about getting in the car as a passenger?

6. Let’s assume you decided that you friend was “too high” to drive. How would you know?

7. Would there be any differences in the decision-making process if it was you or your friend driving?

8. Do you know the legal limit for your THC blood concentration? At which THC blood concentration can you be charged with DUIC?

9. Do you know roughly how much smoked cannabis puts you “over the limit”?

10. Do you know what dosage of edibles puts you “over the limit”?

11. If there was a tool available to help you self-assess for cannabis impairment as it relates to driving ability, would you use it?

12. What kind of self-assessment tool would you be most likely to use to evaluate your ability to drive safely after using cannabis?

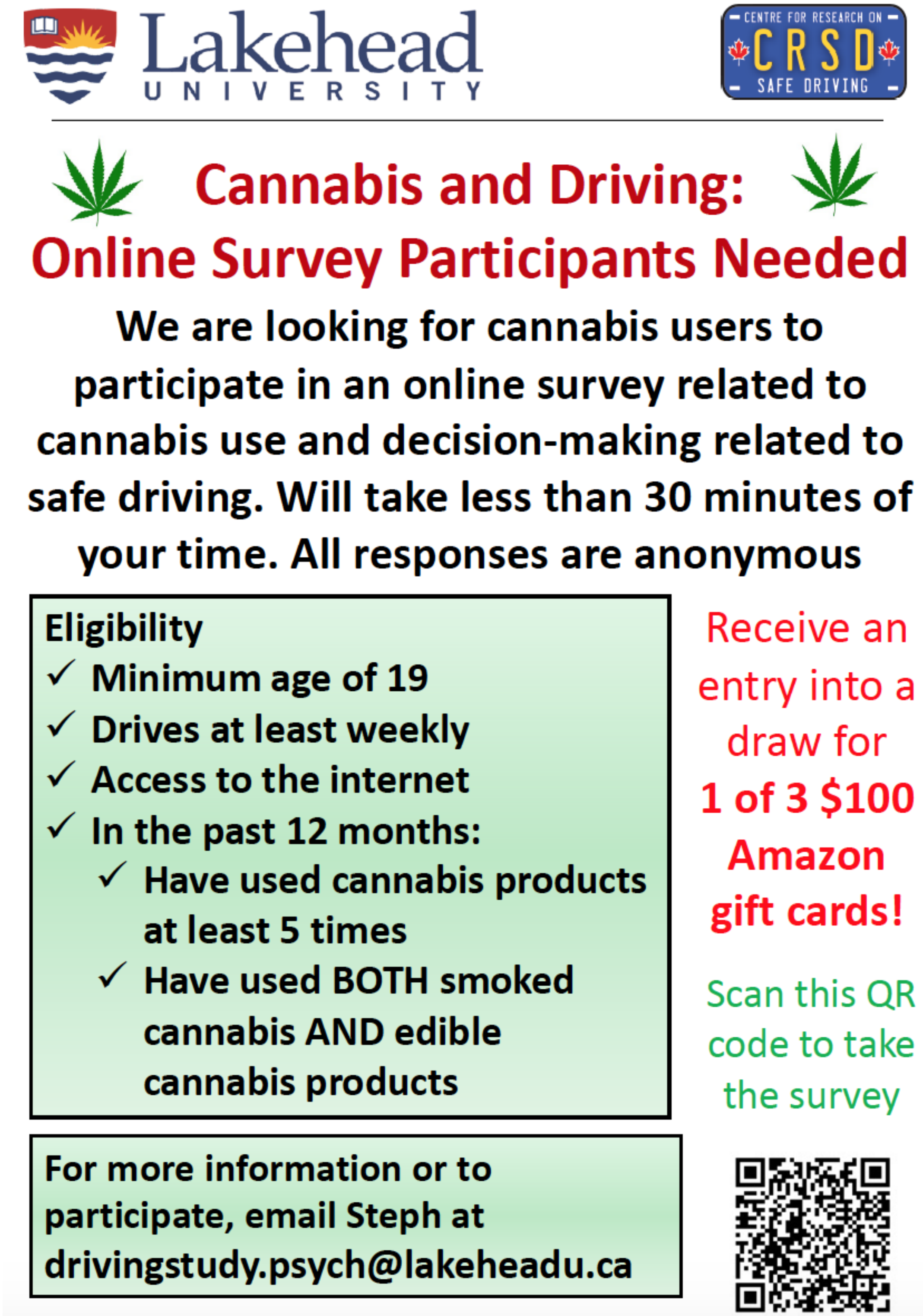
13. What factors would affect your likelihood of using a self-assessment tool to evaluate cannabis-attributable impairment?

14. Where do you currently seek out information relating to cannabis and driving safety?

15. Where and from whom would you like information about cannabis and driving?

Appendix C

Online Survey Recruitment Flyers and Social Media Advertisements



Social Media Ad for Online Survey Recruitment

Appendix D

Online Survey Content: Cannabis and Driving in Canada

Yellow highlight = questions or response options added from focus group analyses

Eligibility

Are you currently residing in Canada? Yes/No
Are you at least 19 years of age? Yes/No
Do you drive at least weekly? Yes/No
Have you used cannabis at least 5 times in the past year? Yes/No
Have you smoked cannabis at least once in the past year? Yes/No
Have you used edible products at least once in the past year? Yes/No

If any of these are answered no, redirect to disqualification page that reads:

Thank you for your interest in participating in this online survey related to cannabis use and driving. Unfortunately, based on the responses provided, you are not eligible to participate. However, we greatly appreciate your willingness and consideration.

Demographic Information

Please indicate your gender
Male
Female
Non-Binary
Prefer Not to Disclose

Please indicate your age _________

Please indicate your ethnicity:
Caucasian (e.g., Canadian/European)
Arab/West Asian (e.g., Armenian, Egyptian, Iranian, Lebanese, Moroccan)
Black (e.g., African, Haitian, Jamaican, Somali)
Indigenous (e.g., Inuit/First Nations/Métis)
Latino (e.g., Latin American, Hispanic descent)
Asian (e.g., Chinese, Pilipino, Japanese, Korean, South East Asian)
Biracial
Other

What is the highest level of education you have completed?
Less than high school
High school diploma
College diploma/certificate
University undergraduate degree
University graduate degree

Cannabis Use Behaviour

Pinned at the top (definition): Cannabis use is defined as the use of cannabis products in any form (e.g., flower, edibles, hashish, concentrates or vaporizers)

How frequently do you use cannabis?
Daily
2-5 times per week
Once per week
2-3 times per month
Once per month
Less than once per month

How long have you been using cannabis at this rate?
Less than one year
1-2 years
3-5 years
5-10 years
More than 10 years

Do you use cannabis for medicinal purposes?
Yes
No

If yes, do you have a prescription for cannabis?
Yes
No

Please indicate whether you agree or disagree with the following statements.
Strongly Disagree Disagree Neither Agree nor Disagree Agree Strongly Agree

I am knowledgeable about the effects of smoked cannabis
I am knowledgeable about the effects of edible cannabis.
I am knowledgeable about the effects of smoked cannabis on driving performance.
I am knowledgeable about the effects of edible cannabis on driving performance.
I am confident in my beliefs about smoked cannabis and driving.
I am confident in my beliefs about edible cannabis and driving.

Please indicate if you use the following cannabis products and how often (grid):
Rows:
Dried cannabis (i.e. buds, flower)
Edibles (e.g., gummy candy, chocolate, infused beverages)
Oil (oral use)
Vaporizer pens
Extracts/concentrates (e.g., dabs)
Hash

Columns:
Daily
2-5 times per week
Once per week
2-3 times per month
Once per month
Less than once per month
Never

Of all the cannabis products you use, what is your preferred type?
Dried cannabis (i.e. bud, flower, leaf)
Edibles (e.g., gummy candy, chocolate, infused beverages)
Oil (oral use)
Vaporizer pens
Extracts/concentrates (e.g., dabs)
Hash
Other: _____________

Do you consider THC and CBD levels when purchasing cannabis products?
Yes
No

Check off all of the following cannabis products you typically use:
THC-only
THC dominant
CBD-only
CBD dominant
Equal parts of THC and CBD

If you smoke cannabis that is THC dominant, how much do you smoke on an average day?
0.5 grams or less
0.51 grams – 1 gram
1.01 – 2.00 grams
2.01 - 3.0 grams
3.01 – 4.0 grams
More than 4.0 grams
Not applicable. I do not smoke THC-dominant cannabis.

If you smoke cannabis that is CBD dominant, how much do you smoke on an average day ?
0.5 grams or less
0.51 grams – 1 gram
1.01 – 2.00 grams
2.01 - 3.0 grams
3.01 – 4.0 grams
More than 4.0 grams
Not applicable. I do not smoke CBD-dominant cannabis.

If you use edibles (e.g., gummies, chocolate, beverages), what is your average dose of THC?
5mg
10mg
15 mg
20 mg
25 mg
30 mg
35 mg
40 mg
45 mg
50 mg
Greater than 50 mg
Not Applicable. I do not use edibles.

If you use edibles (e.g., gummies, chocolate, beverages), what is your average dose of CBD?
5mg
10mg
15 mg
20 mg
25 mg
30 mg
35 mg
40 mg
45 mg
50 mg
Greater than 50 mg
Not Applicable. I do not use edibles.

If you use cannabis for medicinal purposes, please indicate the cannabinoid you prefer:
THC
CBD
I prefer them both equally.
I do not use cannabis for medicinal purposes

Cannabis and Driving

Please indicate whether you agree or disagree with the following statements.
Strongly Disagree Disagree Neither Agree nor Disagree Agree Strongly Agree

Cannabis use does not affect driving performance.
Smoking cannabis causes me to drive more safely.
Smoking cannabis impairs my ability to drive safely.
Consuming edibles causes me to drive more safely.
Consuming edibles impair my ability to drive safely.
Different types of cannabis have different effects on my ability to drive safely (e.g., smoking vs. edibles)

My driving ability would be more impaired if I smoked cannabis than if I ate an edible cannabis product.
My driving ability would be more impaired if I used edibles than if I smoked cannabis.

Below you will see a list of driver actions. Indicate if you believe driving under the influence of cannabis makes you MORE likely to engage in this action, LESS likely, or if you believe cannabis has no effect.

Columns: More likely, Less likely, No effect, Not sure
Rows:
Speeding
Driving too slow
Distracted driving
Getting lost
Driving too close to another vehicle
Swerving into the other lane
Driving on the shoulder
Collide with an object (e.g., vehicle, animal)
Drinking and driving
Failure to follow road signs
Go through a red light/stop sign
Wearing a seat belt
Alertness

Please indicate whether you agree or disagree with the following statements.
Strongly Disagree Disagree Neither Agree nor Disagree Agree Strongly Agree

Different cannabinoids have different effects on my ability to drive safely (THC vs. CBD)
THC causes me to drive more safely.
THC impairs my ability to drive safely.
CBD causes me to drive more safely.
CBD impairs my ability to drive safely.
I drive more safely on THC than CBD.
I drive more safely on CBD than THC.

Please indicate whether you agree or disagree with the following statements.
Strongly Disagree Disagree Neither Agree nor Disagree Agree Strongly Agree

I would drive immediately after smoking cannabis.
I would drive within one hour of smoking cannabis.
I would drive within two hours of smoking cannabis.
I would drive within three hours of smoking cannabis.
I would drive within four hours of smoking cannabis.

I would drive immediately after eating an edible.
I would drive within one hour of eating an edible.
I would drive within two hours of eating an edible.
I would drive within three hours of eating an edible.
I would drive within four hours of eating an edible.

I would accept a ride with someone who just smoked cannabis.
I would accept a ride with someone who smoked cannabis one hour ago.
I would accept a ride with someone who smoked cannabis two hours ago.
I would accept a ride with someone who smoked cannabis three hours ago.
I would accept a ride with someone who smoked cannabis four hours ago.

I would accept a ride with someone who just consumed an edible cannabis product.
I would accept a ride with someone who consumed an edible cannabis product one hour ago.
I would accept a ride with someone who consumed an edible cannabis product two hours ago.
I would accept a ride with someone who consumed an edible cannabis product three hours ago.
I would accept a ride with someone who consumed an edible cannabis product four hours ago.

Have your beliefs around driving after cannabis use changed since the legalization of cannabis in October 2018?
Yes
No
Not sure

Please indicate whether you agree or disagree with the following statements.
Strongly Disagree Disagree Neither Agree nor Disagree Agree Strongly Agree

I have become more lenient when it comes to driving after using cannabis (e.g., because it is legal now)
I have become more cautious when it comes to driving after using cannabis (e.g., due to new laws around cannabis use and driving)

How do you interpret the risk level of driving under the influence of cannabis, relative to alcohol?
Driving under the influence of cannabis is <u>more dangerous</u> than driving under the influence of alcohol.
Driving under the influence of cannabis is <u>less dangerous</u> than driving under the influence of alcohol.
Driving under the influence of cannabis involves equal risk to driving under the influence of alcohol.
I am not sure about the relative risk levels.

Do you know the blood alcohol concentration (BAC) at which you can be charged with driving under the influence of alcohol?
Yes
No

What is the blood alcohol concentration (BAC) at which you can be charged with driving under the influence of alcohol? ________

To stay "under the limit", approximately how many alcoholic drinks can you have per hour? ______

Do you know the blood concentration of THC at which you can be charged with driving under the influence of cannabis?

Yes

No

What is the THC blood concentration (ng/mL) at which you can be charged with impaired driving? (No Googling!) _______________

To stay "under the limit", approximately how many grams of cannabis can you consume per hour? ______

How many minutes does it take for smoked cannabis to reach peak levels in the blood (maximum effect)? ____________

How many minutes does it take for edible forms of cannabis to reach peak levels in the blood (maximum effect)? ____________

Evaluating Impairment from Cannabis

This next set of questions pertains to the decision-making process you engage in when deciding whether or not you can/should drive following cannabis use.

Imagine you are high from using cannabis at a party and a friend asks you for a ride home. What factors would influence your decision? Please check off all factors that you may take into consideration when evaluating whether or not you should drive your friend home.

Evaluation of impairment (i.e., do I feel "too high" to drive?)
Appearance (e.g., red eyes, heavy eyes, smell)
Driving distance
The opinions of others at the party
Availability of alternate transportation
Likelihood of getting caught by law enforcement
My beliefs about how cannabis use affects driving
The quantity of cannabis I used
Time passed since I last used cannabis
Consequences if I do get caught by police (e.g., job, charges, disappointment of others)
Who else is in the car
Other _______________

From the list above, please indicate the 3 factors that would be most important in your decision to drive/not drive your friend home from the past. Using the drop down list, please indicate the factor that would be *most important.*

Using the drop down list, please indicate the factor that would be the *second most important.*

Using the drop down list, please indicate the factor that would be the *third most important.*

Evaluation of impairment (i.e., do I feel too high to drive?)
Appearance (e.g., red eyes, heavy eyes, smell)
Driving distance
The opinions of others at the party
Availability of alternate transportation
Likelihood of getting caught by law enforcement
My beliefs about how cannabis use affects driving
How much cannabis I used
Time elapsed since I last used cannabis
Consequences if I do get caught by police (e.g., job, charges, disappointment of others)
Who else is in the car

In the past 30 days, have you driven even though you felt "high" at the time?
Yes
No

If you felt "too high" to drive, how would you know? In other words, how do you know you are too impaired from cannabis to drive? Please list ALL factors that help you arrive at this decision. (Open ended) ______________________

Rate your agreement with the following statements:
Strongly Disagree Disagree Neither Agree nor Disagree Agree Strongly Agree

I am confident in my ability to self-evaluate impairment following cannabis use.
I trust the decisions I make about my ability to drive safely while on cannabis.
I trust my ability to evaluate the impairment of others who have used cannabis.
I trust the decisions I make about others' ability to drive safely after they have used cannabis.
I would feel comfortable telling a friend I think they are too impaired to drive following cannabis use.
I am confident in my ability to self-evaluate impairment following alcohol use.
I trust the decisions I make about my ability to drive safely after drinking alcohol.
I trust my ability to evaluate the impairment of others who have drank alcohol.
I trust the decisions I make about the ability of others to drive safely after they have consumed alcohol.
I would feel comfortable telling friends I think they are too impaired to drive after they have consumed alcohol

Sources of Information

Have you ever looked up information relating to cannabis use and safety?
Yes
No

Have you ever looked up information relating to cannabis use and driving?
Yes
No

If yes, what information were you searching for? (Check all that apply)
How cannabis affects driving
Laws about impaired driving
Penalties for impaired driving
How law enforcement can detect driving under the influence of cannabis
Time required to drive safely
Other: ___________

If you wanted accurate information related to responsible cannabis use, what sources would you trust? (check all that apply)
Government websites (e.g. Government of Canada/Ontario, Public Health)
Commercials (e.g. TV, radio)
Social media (e.g. Facebook, Instagram)
Family Doctor
Friends
Family members
Experienced cannabis users
Other websites: Please specify ____________

Would you like more information about how to determine if you are too impaired to drive from cannabis?
Yes
No
Not sure

If a tool was available to help you assess your impairment level and make informed safe driving decisions, would you use it?
Yes
No

What kind of tool would you be most likely to use to evaluate impairment and make informed decisions about safe driving? (Check only one)
Brief online questionnaire/screen
Smart phone app
Oral screening tool

What factors would affect your likelihood of using a tool to help you make safe decisions relating to cannabis use and driving?
Accuracy of the tool
Cost
Ability to use discreetly
Access/availability
Time to complete
Other: ___________

Driving History/Habits Questionnaire (Adapted from Centre of Research on Safe Driving)

Approximately how many kilometres do you drive per week?
0-20 km
21-50 km
51-100 km
Over 100 km

As a driver, how many collisions (involving a person, car, or fixed object) have you been involved in where you were at fault? (*Do not include cases where you were a passenger*)

____

As a driver, how many collisions (involving a person, car, or fixed object) have you been involved in where you were not at fault? (*Do not include cases where you were a passenger*)

____

How long ago was your last at fault collision involving a person, car, or fixed object?
Less than 1 year
1-2 years
2-3 years
3-4 years
4-5 years
5-10 years
More than 10 years
Never had an accident

How long ago was your last not at fault collision involving a person, car, or fixed object?
Less than 1 year
1-2 years
2-3 years
3-4 years
4-5 years
5-10 years
More than 10 years
Never had an accident

What speed do you typically drive on local streets (with a posted speed limit of 50 km/hr)?

35 km/hr or less
36-45 km/hr
46-55 km/hr
56-65 km/hr
66 km/hr or more

What speed do you typically drive on major highways (with a posted speed limit of 90 km)?

85 km/hr or less
86-95 km/hr
96-105 km/hr
106-115 km/hr
116 km/hr or more

Domain-Specific Risk-Taking (Adult) Scale — RT scale

For each of the following statements, please indicate the likelihood that you would engage in the described activity or behavior if you were to find yourself in that situation. Provide a rating from *Extremely Unlikely* to *Extremely Likely*, using the following scale:

1- Extremely unlikely
2- Moderately unlikely
3- Somewhat unlikely
4- Not sure
5- Somewhat likely
6- Moderately likely
7- Extremely likely

1. Admitting that your tastes are different from those of a friend. (S)
2. Going camping in the wilderness. (R)
3. Betting a day's income at the horse races. (F)
4. Investing 10% of your annual income in a moderate growth mutual fund. (F)
5. Drinking heavily at a social function. (H/S)
6. Taking some questionable deductions on your income tax return. (E)
7. Disagreeing with an authority figure on a major issue. (S)
8. Betting a day's income at a high-stake poker game. (F)
9. Having an affair with a married man/woman. (E)
10. Passing off somebody else's work as your own. (E)
11. Going down a ski run that is beyond your ability. (R)
12. Investing 5% of your annual income in a very speculative stock. (F)
13. Going whitewater rafting at high water in the spring. (R)
14. Betting a day's income on the outcome of a sporting event (F)
15. Engaging in unprotected sex. (H/S)
16. Revealing a friend's secret to someone else. (E)
17. Driving a car without wearing a seat belt. (H/S)

18. Investing 10% of your annual income in a new business venture. (F)
19. Taking a skydiving class. (R)
20. Riding a motorcycle without a helmet. (H/S)
21. Choosing a career that you truly enjoy over a more prestigious one. (S)
22. Speaking your mind about an unpopular issue in a meeting at work. (S)
23. Sunbathing without sunscreen. (H/S)
24. Bungee jumping off a tall bridge. (R)
25. Piloting a small plane. (R)
26. Walking home alone at night in an unsafe area of town. (H/S)
27. Moving to a city far away from your extended family. (S)
28. Starting a new career in your mid-thirties. (S)
29. Leaving your young children alone at home while running an errand. (E)
30. Not returning a wallet you found that contains $200. (E)

Note. E = Ethical, F = Financial, H/S = Health/Safety, R = Recreational, and S = Social.

<u>Driving and Substance Use</u>

Alcohol Use History
In the past year, did you drink alcohol?
Yes
No (if no, following questions skipped)

In the past year, on average, how often did you drink alcohol?

Daily
2-3 times per week
Once per week
Once every 2-3 weeks
Once per month
Less than once per month

On average, when you drink, how many drinks do you have? (one drink is defined as 12 ounces of beer, 5 ounces of wine, or one standard cocktail [1.5 ounces of 80-proof liquor])?

_______ drinks

Have you ever driven when, to the best of your knowledge, you were <u>over</u> the legal blood alcohol limit?
Yes
No

In the past year, approximately how often have you driven while <u>over</u> the legal blood alcohol limit (to the best of your knowledge) ?

Daily
2-3 times per week
Once per week

Once every 2-3 weeks
Once per month
Less than once per month
Never

Driving Under the Influence of Alcohol and Cannabis

Have you ever driven after drinking *any* amount of alcohol and within 3 hours of using cannabis?

Yes
No

In the past year, how often have you driven after using cannabis and drinking a *small* amount of alcohol (i.e., to the best of your knowledge, you remained under the legal blood alcohol limit)?

Daily
2-3 times per week
Once per week
Once every 2-3 weeks
Once per month
Less than once per month
Never

In the past year, how often have you driven after using cannabis and drinking a *moderate or large* amount of alcohol (i.e., to the best of your knowledge, you were over the legal blood alcohol limit)?
Daily
2-3 times per week
Once per week
Once every 2-3 weeks
Once per month
Less than once per month
Never

Draw for Gift Card

As a thank you for participating, we are giving away THREE $100 Amazon gift cards.

If you would like to enter the draw, please click the link below to be re-directed to a new web page. Your email will be requested in a separate Google form that is stored separately from the survey data. Your email is ONLY for the draw will NOT be linked to any of your cannabis survey responses. All information provided in the cannabis survey is completely anonymous and confidential. If you do not wish to enter the draw, simply click the submit button below.

CLICK HERE TO ENTER THE DRAW FOR AMAZON GIFT CARDS

Participation Draw for Amazon Gift Card

On a Google Form (Separate link)

Please complete the following information for entry into the gift card draw. This survey is completely separate from the cannabis survey data. Your contact information will NOT be linked in any way to your cannabis survey responses. All information provided in that survey is completely confidential and anonymous. Thank you for your participation and have a great day.

Do you want to be entered into the draw for one of three $100 Amazon gift cards as compensation for your participation in this research?
Yes
No

Do you want to be sent a copy of the survey results once this project is complete?
Yes
No

If you answered yes to either of the above, please enter your email address below. This survey is completely separate from the survey data so your contact information will not be linked to your survey responses.

Thank you for your participation in this research.

Appendix E

Focus Group Letter of Information and Consent

Focus Groups Investigating Beliefs about Cannabis Use, Evaluating Impairment & Decision Making Related to Driving

Dear Potential Participant:

Thank you for your interest in our research study. We are inviting you to participate in a focus group discussion that will inform further development of an online survey for phase two in this research. In the focus groups, you will be asked to report on: beliefs relating to cannabis use and driving, the process of evaluating cannabis impairment in self and others and the decision-making process around driving following cannabis use. The purpose of this project is to better understand the current knowledge base relating to individual beliefs and decision-making process relating to cannabis use and driving. This information can help inform public health campaigns by identifying targets for intervention. This project is under the supervision of Dr. Michel Bédard in the Department of Health and Behavioural Sciences at Lakehead University. This project is being completed as part of a dissertation and the student researcher is Stephanie Campbell from the Department of Psychology at Lakehead University.

Taking part in this study is voluntary. Before you decide whether or not you would like to take part in this study, please read this letter carefully to understand what is involved. After you have read the letter, please ask any questions you may have.

WHAT INFORMATION WILL BE COLLECTED?

Researchers will ask you to report on demographic information (e.g. age, ethnicity, gender) and there will be a facilitated discussion with the group about cannabis use beliefs and behaviours as described above. Although open and honest discussions are an integral component of this research, you can report as much or as little information as you are comfortable with.

WHAT IS REQUESTED OF ME AS A PARTICIPANT?

You will be invited into a videoconference using the Zoom platform. There will be 8-10 focus group participants and one facilitator. The focus group will not take more than two hours of your time. You can choose to keep your video camera off if preferred to protect your anonymity.

WHAT ARE MY RIGHTS AS A PARTICIPANT?

- You have the right to withdraw from the focus group at any time without any penalty
- You do not have to answer any question that you don’t feel comfortable answering
- Your responses are confidential and anonymous
- Participation in this research will have no effect on your academic status if you are a student

WHAT ARE THE RISKS AND BENEFITS?

There is a negligible social risk that individuals may be identified as cannabis user. However, this risk will be significantly minimized through the opportunity to remain anonymous by leaving your camera off for the focus group which is conducted via videoconference. In addition, recruitment for the focus groups will be national so it is highly unlikely that you will know any other participants; however, it is possible so this risk must be considered. All participants will be encouraged to keep the information discussed confidential. However, the research team cannot guarantee focus group members will preserve the confidentiality of the discussion. Lastly, the information obtained in this focus group will be used to refine survey development. Therefore, the meeting will be recorded so that the research team can obtain a transcript of the interview content for further analysis.

There are no direct benefits of participating in this study, beyond receiving an entry into a draw for a $100 gift card. Following the focus group, a research team member will post a link in the chat where participants can enter contact information for the draw entry. Participants are free to use a fake email if desired to protect anonymity. We expect that this study will advance our understanding of Canadian cannabis users' knowledge base and how individuals make decisions as it relates to cannabis use and driving. This knowledge has the potential to benefit all road users by informing public health interventions.

HOW WILL MY CONFIDENTIALITY BE MAINTAINED?

All information collected in the focus groups will be transcribed anonymously. There will be no identifying information linked to your individual comments or responses. Any information you provide during the study will be securely stored at Lakehead University for a minimum of 5 years. Only the researchers involved with this study will have access to this information. Electronic records will be stored on password-protected computers.

QUESTIONS ABOUT THE STUDY/RESULTS

A summary of the research results will be available to those interested. If you decide at a later date that you wish to receive a summary of the results, please contact one of the researchers. Should you have any questions about this study or require further information, please do not hesitate to contact one of the researchers.

If you have any concerns regarding your rights as a research participant or wish to speak to someone other than a research team member about this research project, you are welcome to contact the Research Ethics and Administrator Officer, Office of Research Services, Lakehead University, by phone (807) 343-8283 or email at research@lakeheadu.ca.
Thank you for your interest and for considering participating in this project.

Stephanie Campbell, M.A.
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Centre for Research on Safe Driving
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Consent Form for Focus Group Participants

MY CONSENT:

By agreeing to participate in the focus group, I agree to the following:

- ✓ I have read and understand the information contained in the Information Letter
- ✓ I agree to participate
- ✓ I understand the risks and benefits to the study
- ✓ That I am a volunteer and can withdraw from the study at any time and may choose not to answer any question
- ✓ That the data will be securely stored at Lakehead University for a minimum period of 5 years following completion of the research project
- ✓ I understand that the research findings will be made available to me upon request
- ✓ I can choose to remain anonymous by leaving my camera off for the videoconference
- ✓ All of my questions have been answered
- ✓ **I understand that the focus group will be recorded in order to obtain a transcription of the content. This will only be viewed by the research team.**

By consenting to participate, I have not waived any rights to legal recourse in the event of research-related harm.

By joining and remaining on the Zoom call for the discussion, you are indicating your consent to participate. If you are interested after reading this letter of information, please email me back at drivingstudy.psych@lakeheadu.ca and I will forward you the date/time and the Zoom link for the focus group.

Online Survey Letter of Information and Consent

Online Survey Investigating Beliefs about Cannabis Use, Evaluating Impairment & Decision Making Related to Driving

Dear Potential Participant:

Thank you for your interest in our research study. We are inviting you to participate in an online survey related to cannabis use and safe driving. In the survey, you will be asked to report on: substance use behaviour (i.e. cannabis and alcohol), beliefs relating to cannabis use and driving, the process of evaluating cannabis impairment in self and others and the decision-making process around driving following cannabis use. The purpose of this project is to better understand the current knowledge base relating to individual beliefs and decision-making process relating to cannabis use and driving. This information can help inform public health campaigns by identifying targets for intervention. This project is under the supervision of Dr. Michel Bédard in the Department of Health and Behavioural Sciences at Lakehead University.

This project is being completed as part of a dissertation and the student researcher is Stephanie Campbell from the Department of Psychology at Lakehead University.
Taking part in this study is voluntary. Before you decide whether or not you would like to take part in this study, please read this letter carefully to understand what is involved.

WHAT INFORMATION WILL BE COLLECTED?

Researchers will ask you to report on demographic information (e.g. age, ethnicity, gender), cannabis and alcohol use patterns/experience, perceived effects of cannabis, beliefs relating to cannabis use and driving, how you determine if you are impaired from cannabis use, how you make decisions about cannabis use and the ability to drive safely, preferred sources for information relating to cannabis safety, and willingness to use tools (e.g. smart phone apps) to aid in the process of evaluating cannabis and making decisions regarding safe driving.

WHAT IS REQUESTED OF ME AS A PARTICIPANT?

You will be required to complete an anonymous survey online using a secure platform. The survey will take approximately 45 minutes to complete.

WHAT ARE MY RIGHTS AS A PARTICIPANT?

- You have the right to withdraw from the survey at any time prior to survey submission without any penalty
- You do not have to answer any question that you don't feel comfortable answering
- Your responses are confidential and anonymous
- Participation in this research will have no effect on your academic status if you are a student. The university has no way of knowing who participated in this study.

WHAT ARE THE RISKS AND BENEFITS?

There are no physical or psychological risks to participating in this study. Although you will be asked to report on risky behaviour (i.e. impaired driving), the responses are all anonymous so you will not be identifiable. The success of this project hinges on accurate reporting so we respectfully request that you provide honest responses.

There are no direct benefits of participating in this study, beyond receiving an entry into a draw for a $100 gift card. Following completion of the survey, you will be re-directed to a new online page to enter your contact information for entry into the draw. Your survey responses will not be connected to their contact information in any way so anonymity is protected.

We expect that this study will advance our understanding of Canadian cannabis users' knowledge base and how individuals make decisions as it relates to cannabis use and driving. This knowledge has the potential to benefit all road users by informing public health interventions.

HOW WILL MY CONFIDENTIALITY BE MAINTAINED?

All survey responses will be collected anonymously. Any information you provide during the study will be securely stored at Lakehead University for a minimum of 5 years. Only the researchers involved with this study will have access to this information. Electronic records will be stored on password-protected computers.

QUESTIONS ABOUT THE STUDY/RESULTS

A summary of the research results will be available to those interested. If you decide at a later date that you wish to receive a summary of the results, please contact one of the researchers. Should you have any questions about this study or require further information, please do not hesitate to contact one of the researchers.

If you have any concerns regarding your rights as a research participant or wish to speak to someone other than a research team member about this research project, you are welcome to contact the Research Ethics and Administrator Officer, Office of Research Services, Lakehead University, by phone (807) 343-8283 or email at research@lakeheadu.ca.

Thank you for your interest and for considering participating in this project.

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Consent Form for Online Survey Participants

MY CONSENT:

I agree to the following:

- ✓ I have read and understand the information contained in the Information Letter
- ✓ I agree to participate
- ✓ I understand the risks and benefits to the study
- ✓ That I am a volunteer and can withdraw from the study at any time prior to the survey submission and may choose not to answer any question
- ✓ That the data will be securely stored at Lakehead University for a minimum period of 5 years following completion of the research project
- ✓ I understand that the research findings will be made available to me upon request
- ✓ I will remain anonymous
- ✓ All of my questions have been answered

By consenting to participate, I have not waived any rights to legal recourse in the event of research-related harm.

I have read and agree to the above information and by completing and submitting this survey, agree to participate.

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