Canadian Drug Policy Coalition

Coalition canadienne des politiques sur les drogues

CANNABIS USE AND DRIVING: Evidence Review

Canadian Drug Policy Coalition (CDPC)
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EXECUTIVE SUMMARY

Cannabis is widely used in Canadian society (used by ~12% of Canadians in 2011) for both medical and recreational purposes. Recently, the federal government announced its intention to legalize cannabis, with the implementation of new laws expected in early 2018. The federal government's stated intention of the new laws is to mitigate potential risks of cannabis use. A potential risk that is of great concern is driving after using cannabis. Public education pertaining to the use of cannabis and driving must be based upon current research knowledge if it is to be effective and relevant.

To this end, we have undertaken a scoping review of available research evidence in order to:

1. Synthesize current research regarding risks associated with cannabis use in the context of driving;
2. Identify research that points to effective strategies for mitigation of this risk.[1]

This review focused on eight areas of research relating to cannabis use and driving. The main conclusions are presented below:

1. Prevalence of cannabis use and driving after use

Determining the prevalence of driving after cannabis use (DACU) in the Canadian population is not straightforward: two research designs, roadside tests and population surveys, have been used to answer this question each with its own strengths and weaknesses.

Summary and Conclusions

- Roadside testing indicates that only 4-6% of drivers drove within two hours of cannabis use in the past year.
- Population surveys found 20% of cannabis users self-report having driven within 2 hours after cannabis use.
- Two groups of cannabis users stand out as important targets for messaging:
    - 5% of cannabis users who report driving after cannabis use many times;
    - A higher proportion of male high school students report driving 1 hour of cannabis use.

2. Risks related to driving after cannabis use

This review considered two primary risks associated with driving after cannabis use: risk of motor vehicle accidents (MVA) and risks of legal penalties.

Summary and Conclusions

- The increased risk for cannabis-related motor vehicle collision currently found in the population is roughly 20-30%, with an MVA odds ratio (OR) of approximately 1.22.
- Studies that controlled for alcohol use, found the MVA OR for DACU is 1.18; those controlling for demographic factors and alcohol found no increased risk (OR=1).

[1] Another document provides recommendations for public communications strategies likely to be most effective and relevant in mitigating risks.

- These cannabis-related MVA OR estimates are lower than, but comparable to MVA ORs for blood alcohol concentration below .5 g/L, which is considered the acceptable BAC level in many jurisdictions.
- An increase of cannabis use involved in fatal car crashes has been seen in Washington State after the implementation of legalization regulations; however the presence of cannabis cannot be said to indicate impairment, nor be the main contributor to the crash risks.
- Overall, the rates of fatal crashes have declined in states with medical cannabis laws.
- The rate of cannabis-related driving offences in Canada remains low in comparison to the rate of driving offences associated with alcohol.

3. Effects of cannabis use on driving ability

Experimental studies have examined the relationship between cannabis use and cognitive or psychomotor function, however driving simulator studies and on-road studies provide direct insight regarding driving ability. Factors impacting the effects of cannabis use on driving ability, including dose-response relationship, tolerance, mode of use and use with other substances, were also considered.

Summary and Conclusions

- Cannabis use has been shown to have short-term negative impacts on reaction time, motor coordination, divided attention, short-term memory and decision-making under time-pressured and informationally-complex conditions.
- Cannabis use has a short-term negative impact upon driving performance as measured by driving simulation techniques, manifested primarily in difficulty with maintaining lateral road position within one's lane.
- The negative impact of cannabis use upon driving performance is dose-related, increasing with increased dosage of cannabis.
- Regular users of cannabis are more likely to be tolerant to the impairment effects of cannabis.
- Unlike alcohol use, cannabis use does not predispose to aggressive or violent behavior, which can affect driving ability.
- Use of cannabis and alcohol in combination creates an additive risk of impairment and serious motor vehicle accident, but at low doses of alcohol (<.05) may not increase risk of low severity crashes; alcohol whether alone or in combination with other drugs is the largest contributor to crash risk.

4. Factors associated with driving after cannabis use

Several interrelated demographic, personality and lifestyle factors have been shown to be associated with the decision to drive after using cannabis, and while not suggesting a causal link, can shed light on who engages in this behaviour and under what circumstances this behaviour is most likely to occur. These include: demographic characteristics, cannabis use with other substances, frequency of use and dependence, driving patterns and attitudes towards risk, physical discomfort and motivation for driving.

Summary and Conclusions

- Younger age and male gender have been shown to increase likelihood of DACU.
- Willingness to drive within one hour after cannabis use is associated with reckless driving.
- Cannabis-only users may be less prone to risky driving behaviours than users of other drugs, particularly in relation to seatbelt use.
- Use of cannabis with other substances, particularly alcohol, is associated with increased likelihood driving after substance use.

- Frequency of use has been found to increases the likelihood of DACU, and to be associated with risky driving behaviour, though this may mitigate impairment through tolerance.
- Higher levels of cannabis intoxication may reduce the likelihood of driving due to physical discomfort, particularly if the purpose for driving is considered unimportant.

5. Perceived risk of driving after cannabis use

Perceptions of the level of risk associated with driving after cannabis use includes the risk of impairment, the risk of being involved in an accident, and the risk of legal repercussions. These perceptions may impact the likelihood that an individual would drive after using cannabis. Perceptions of drivers in general and of cannabis users are important to address since drivers who currently do not use cannabis may one day begin using cannabis. It is also important to consider passengers' perceptions.

Summary and Conclusions

- Most cannabis users consider their driving to be only slightly impaired by cannabis use, and some believe it may be improved by cannabis use.
- Cannabis users have a perception that tolerance levels and experience enable them to control their driving behavior despite intoxication.
- More than 50% of cannabis users believe that DACU does not increase the risk of accidents.
- These perceptions are related to engaging in DACU, thus they may be a result of experience as well as support the behaviour.
- There is a low level of acceptance of driving within an hour after using cannabis.
- Most cannabis users perceive a low level of legal risk and have a low level of knowledge about the laws; perception of accidents is a more important contributor to DACU than perception of legal risk.
- Legalization provides a good opportunity to shift the concern with illegality of the substance itself to the illegality and risks of DACU.

6. Detection of cannabis-related impaired driving

Identification of drug-related impairment, through observational impairment testing and biological testing including blood and oral fluid testing, is intended to provide a critical tool for identifying dangerous drivers before accidents happen or imposing penalties for the consequences of accidents caused by impaired drivers. These tests are also meant to act as a deterrence to engaging in driving after use of drugs, and have implications for the medical use of cannabis.

Summary and Conclusions

- Observational impairment tests fail to meet minimal standards for sensitivity or specificity.
- Blood concentration of cannabis has been reliably linked to impaired driving capacity, allowing physiological measurement to be used as a proxy for functional impairment; a threshold level of a THC concentration of *7-10 ng/mL in serum* in blood appears to indicate driving impairment, however it is difficult to interpret so as to generate a precise comparison to the per se level set for alcohol.
- Research has shown that oral fluid concentrations of THC cannot be extrapolated to blood concentrations so that it is not possible to set a *per se* level for oral fluid that would indicate likely impairment due to cannabis use.
- Medical cannabis medications, like other prescription medications, can use label warnings and advice from a medical professional to educate the patient about the medicine's effect on their driving ability.

7. Risk mitigation

Cannabis users employ different approaches to mitigate potential risks of DACU. Some use behavioural strategies including: choosing alternate transportation options, waiting a period of time before driving, employing compensatory driving tactics, and substituting alcohol with cannabis. Cultural practices also play a role, such as the development of responsible use norms, de-stigmatization, and the normalization of preventive measures.

Summary and Conclusions

- While most impairment occurs in the first 2 hours after cannabis use and is cleared in 3-4 hours, other factors must be taken into consideration when establishing recommended waiting times for driving after cannabis use, such as dosage, potency and mode of administration.
- Experience with and tolerance to cannabis, and techniques like driving slower and taking less risks may mitigate level of impairment if tasks required are not too complex.
- The practice of substituting alcohol and other drugs for cannabis may reduce the likelihood of driving after using these substances; Different legal frameworks for cannabis and alcohol impact whether there is a substitution effect or complementary effects.
- The cannabis culture, developed in the context of prohibition, has created norms that encourage responsible use, with the aim of reducing stigma and differentiating itself from alcohol culture, and is a trusted source of information about potential risks.
- Legalization of cannabis provides opportunities for prevention of harms through acknowledging the norms that distinguish between responsible and irresponsible use; with the removal of the threat of criminalization, users can shift their focus from the risks of illegality to potential risks of driving while impaired by cannabis.

8. Public health education

This section reviews public health messages related to cannabis use, their effectiveness in promoting behaviour change, and their credibility.

Summary and Conclusions

- Public health education efforts have historically focused on harms of cannabis use and strongly discouraged cannabis use.
- Mass media campaigns for cannabis use are often ineffective due to a reliance on fear-based messaging or portrayal of scenarios that are highly unrealistic or derogatory, eliciting mockery from the intended audience.
- Maintaining a clear and consistent message that is relatable to cannabis users' personal experience and those of their peers improves the credibility of messaging.
- Non-judgmental, factual, and concise messages are more effective at promoting cannabis use-related behaviour changes, including change in DACU.

CANNABIS USE AND DRIVING: EVIDENCE REVIEW

1. Introduction

a. Background

Cannabis is widely used in Canadian society (used by ~12% of Canadians in 2011) for both medical and recreational purposes. Recently, the federal government announced its intention to legalize cannabis, with the implementation of new laws expected to be in early 2018. The federal government's stated intention is to do this in a way that mitigates potential risks. A potential risk that is of great concern is driving after using cannabis. Although this is a behaviour that has been occurring already, the new legal climate brings with it an opportunity, and responsibility, for open dialogue and public education about this issue. This will be undertaken by government as well as organizations that address road safety and suppliers of cannabis. Public education pertaining to the use of cannabis and driving must be based upon current research knowledge in order for it to be effective and relevant.

To this end, we have undertaken a scoping review of available research evidence in order to:

1. Synthesize current research regarding risks associated with cannabis use in the context of driving;
2. Identify research that points to effective strategies for mitigation of this risk; and
3. Make recommendations for public communication strategies likely to be most effective and relevant in mitigating the risks.

b. Methods

A scoping review was carried out focusing on research concerning cannabis and driving. A literature search was conducted on the keywords “cannabis”, “marijuana”, “driving”, and “testing”. The reference lists of key papers were also searched for relevant references. Gray literature such as organizational reports or fact sheets were included in the search. Input from experts in this field was also sought. Knowledge derived from this review was summarized in terms of key issues regarding risks associated with cannabis use in the context of driving, and recommendations made for a knowledge translation strategy.

c. Terminology

Terminology used to describe the nature and consequences of the effects of cannabis use upon driving capacity varies throughout the research literature in this area and at times blurs important distinctions. It is important to distinguish among: 1. *Presence of cannabis*, meaning that a certain amount of cannabis is present in a driver, usually referring to a situation where this presence has been detected through biological testing. 2. *Impairment of driving ability by cannabis*, meaning that cannabis use has had a serious impact upon an individual's ability to drive safely. 3. *Driving under the influence of cannabis (DUIC),* which is commonly used in literature, meaning that a driver has used cannabis within a short time period before driving, and as a result impairment is implied. 4. *Driving After Cannabis Use (DACU),* a term we have coined, meaning that an individual has driven within several hours of using cannabis. We will often use the DACU term descriptively to avoid making unfounded assumptions about whether an individual is influenced or impaired by recent cannabis use.

d. Interpretation of findings

i. Causality vs. association

In considering the evidence, it is critical to remain aware of the distinction between a demonstrated causal relationship (e.g., between controlled administration of cannabis and subsequent deficits on cognitive testing) and mere association (e.g., a correlation between presence of cannabis and involvement in motor vehicle accidents). Two variables may show a statistically significant association because they are causally related or because they are both related to a third (confounding) variable that influences both of them (e.g. a correlation between frequent cannabis use and high-risk driving behavior, both influenced by a stimulation-seeking personality style).

Where an important confounding variable is known to exist, in particular use of alcohol concurrently with cannabis prior to driving, we will draw attention to whether the evidence was analyzed so as to statistically control for this confounding variable. It is important to note, that many studies do not control for the presence of alcohol, nor make this clear when reporting findings about cannabis use and driving.

ii. Reasons for cannabis use

There may be important differences among individuals who are using cannabis recreationally or medicinally. Each of these types of cannabis use may be associated with a unique profile of risk factors, user characteristics and relevant messaging. However, we found very little research evidence bearing on this distinction, likely reflecting the rapidly evolving context of cannabis use in Canadian society, with researchers scrambling to catch up to social change so as to generate the evidence base needed to guide social policy and individual practice.

2. Prevalence of cannabis use and driving after use

a. Prevalence of cannabis use

According to data from the 2012 Canadian Community Health Survey (CCHS), 12% of Canadians reported using cannabis in the last year.[1] In 2018, an estimated 4.6 million individuals aged 15 and over will use cannabis at least once, according to projections by the Parliamentary Budget Officer. By 2021, this level could rise to 5.2 million.[2]

However, trends in use differ according to age group, with Canadians between the ages of 18-24 having the highest prevalence of reported use. There is also variation in use between the provinces, with Nova Scotia, British Colombia, and Newfoundland and Labrador having the highest reported prevalence of reported use after age standardization. The table below highlights patterns of reported cannabis use by age group and by province.

	Prevalence of Last Year Cannabis Use (2012) (%)
Age Group	
15-17	17.0
18-24	30.6
25-44	14.4
45-64	5.9
65 and over	0.6
Province (Age Standardized)	
Newfoundland and Labrador	12.2
Prince Edward Island	10.8
Nova Scotia	15.7
New Brunswick	11.6
Quebec	11.9
Ontario	12.0
Manitoba	11.1
Saskatchewan	9.9
Alberta	11.1
British Columbia	14.3

Adapted from Statistics Canada. Data from the 2012 CCHS.
Excludes Canadian territories and individuals <15 years of age.

The number of Canadians registered with Health Canada for medical use of cannabis has been growing, with 75,166 clients registered at the end of June 2016 compared to 23,930 registered at the end of June 2015.[3]

[1] Statistics Canada. Health Reports, Vol. 26, no. 4, pp. 10-15, April 2015. Statistics Canada, Catalogue no. 82-003-X Prevalence and correlates of marijuana use in Canada, 2012. Health Matters.
[2] Wodrich, N. PBO Blog. Office of the Parliamentary Budget Officer. November 1, 2016. http://www.pbo-dpb.gc.ca/en/blog/news/Legalized_Cannabis
[3] Health Canada. Drugs and Health Products – Market Data. Updated October 21, 2016. http://www.hc-sc.gc.ca/dhp-mps/marihuana/info/market-marche-eng.php

b. Prevalence of driving after cannabis use

The prevalence of individuals driving after cannabis use affects the perceived priority of the problem: if this rarely happens, the question might be moot; but if it happens frequently, the question of the relationship between cannabis use and driving becomes more relevant. Determining the prevalence of driving after cannabis use in the Canadian population is not straightforward: two research designs have been used to answer this question, each with its own strengths and weaknesses.

i. Roadside tests

This type of study surveys drivers selected by the roadside, randomly sampled to represent the general driving population. Prevalence rates are likely to vary across geographic regions, gender, time of day, etc., and these factors are often included in study design. This approach frequently encounters the methodological problem of significant refusal rates, which raises difficulty in the interpretation of results.

One such study was carried out by a group of California researchers.[4] They obtained oral fluid samples from almost 1000 individuals driving at night on the weekend across six California jurisdictions. They found that 8.5% of these drivers tested positive for THC, with a surprising degree of variability between jurisdictions (from 4.3% to 18.3%). This highlights the need to obtain locally relevant data. A more recent study in California specifically examined the question of whether there has been an increase in prevalence of driving after cannabis use since it was decriminalized in that state, using the same roadside survey accompanied by oral fluid testing.[5] These researchers compared survey findings prior to decriminalization (in 2010) with those after (in 2012): they found no change in the prevalence of THC positive drivers.

The studies of most relevance to establishing prevalence of driving after cannabis use (DACU) in Canada are the roadside surveys conducted in British Columbia in 2008 and 2010. The 2008 survey, in which drivers were randomly selected across three cities and several time periods, used oral fluid testing to determine the presence of THC.[6] The study was affected by a fairly high number of drivers refusing to complete the oral fluid testing (20% refusal rate). The study found 4.6% of drivers to have a detectable level of THC. The 2010 B.C. Roadside Survey used a similar methodology. The refusal rate for the oral fluid testing in this study (30%) was notably higher than in the 2008 survey, raising concern over the validity of findings. With this caveat in mind, the study reported a higher rate of THC-positive drivers than in the 2008 survey: 5.8%.[7] This finding suggests an increase in the number of individuals driving after using cannabis.

ii. Population surveys

This type of survey asks about substance use and driving to establish correlations between these self-reported behaviors. Some methodological problems associated with this study design are that individuals may not be honest about their propensity for using substances before driving.

The most relevant population survey is the Canadian Alcohol and Drug Use Monitoring Survey, conducted by Health Canada in 2012.[8] The survey asked relevant respondents (who had used cannabis in the past

[4] Johnson MB, Kelley-Baker T, Voas RB, Lacey JH. The prevalence of cannabis-involved driving in California. Drug and alcohol dependence. 2012 Jun 1;123(1):105-9.
[5] Pollini RA, Romano E, Johnson MB, Lacey JH. The impact of marijuana decriminalization on California drivers. Drug and alcohol dependence. 2015 May 1;150:135-40.
[6] Beirness DJ, Beasley EE. A roadside survey of alcohol and drug use among drivers in British Columbia. Traffic injury prevention. 2010 Jun 14;11(3):215-21.
[7] Beirness, D.J., & Beasley, E.E. (2011). Alcohol and drug use among drivers: British Columbia Roadside Survey 2010. Ottawa, ON: Canadian Centre on Substance Abuse.
[8] Health Canada (2013). *Canadian Alcohol and Drug Use Monitoring Survey (CADUMS)*. Ottawa, ON: Health Canada.

year and were drivers) how often they had in the previous 12 months driven a motor vehicle within two hours of using cannabis.[9] The results are shown below:

Frequency of driving within 2 hrs of using cannabis	Cannabis-Using Drivers (N=808)
Never	79%
1-10	13.6%
11-20	1.2%
21 and over	4.9%

Approximately 20% of cannabis-using drivers in this sample have (in the past year) driven at least once within 2 hours of using cannabis. It is worth noting that the large majority of those who have used cannabis in the past year have chosen not to drive within two hours of using, and intriguing to find a subgroup of cannabis users (about 5%) who have driven shortly after using on many occasions in the past year.

Another survey of particular interest was carried out with Ontario high school students in 2001.[10] The finding most relevant in the current context was that 19.7% of the students reported that they had driven a car within an hour after using cannabis; there was a gender difference, with 24.5% of males reporting this behavior versus 13.7% of females.

Summary and Conclusions

Prevalence data for driving after cannabis use, based on roadside testing, are generally reassuring, indicating that only 4-6% of all drivers were found to have driven within two hours of using cannabis in the previous year. In population surveys about 20% of cannabis users report driving within this two-hour window. However, two groups of cannabis users stand out: (a) the 5% of cannabis users who report having driven after using cannabis many times in the previous year; and (b) the higher proportion of male high school students than female students who report driving within one hour after using cannabis. These two groups might be important targets for messaging.

[9] Health Canada (2013). *Canadian Alcohol and Drug Use Monitoring Survey 2012: Microdata User Guide*. Ottawa, ON: Health Canada. Page 159, table dr9.

[10] Adlaf EM, Mann RE, Paglia A. Drinking, cannabis use and driving among Ontario students. Canadian Medical Association Journal. 2003 Mar 4;168(5):565-6.

3. Risks related to driving after cannabis use

a. Risk of motor vehicle accident

Motor vehicle accident (MVA) risk associated with cannabis use has been examined in epidemiological studies, including general population surveys and case control designs. The statistic used to express increased risk (in this case, associated with driving after cannabis use) is the odds ratio (OR). An OR of 1 would mean that there is no increased risk for driving after cannabis use versus driving without having used cannabis. An odds ratio of 4 would mean that the risk of an accident is 4 times higher when driving after cannabis use; etc.

General population surveys rely on self-reported DACU. A 2016 review of international literature on countermeasures that address DUIC, reported that general population surveys have found that drivers who report driving after using cannabis report increased MVA involvement, even after controlling for alcohol use.[11] One study found those who reported driving after cannabis use had an increased risk of collision involvement (OR = 1.84) compared to those who never drove after using cannabis.[12]

Case control studies involve comparing the rate of cannabis-presence (usually THC detected by blood testing) among drivers who have been involved in motor vehicle crashes to the rate for drivers who have not been involved in motor vehicle crashes. Three notable meta-analytic reviews of case-control studies have been conducted in the past 5 years. Asbridge et al. (2012) reviewed case-control studies that measured recent cannabis use in drivers by analysis of THC in whole blood or self-report, and controlled for alcohol with 'no alcohol' subsamples.[13] They found that MVA-involved drivers were almost twice as likely to have THC in their blood as those not in MVAs, yielding an OR of **1.92**. This review included culpability studies, however, did not adjust culpability estimates for increased risk of accidents. A similar meta-analytic review of observational case-controlled studies by Li et al. (2012) concluded that an OR of **2.66** would accurately characterize the effect of cannabis use upon crash risk.[14] However, Li et al. included surveys amongst the studies reviewed, and many of the studies included did not control for concurrent alcohol use. This generates ambiguity regarding the MVA risk associated with cannabis use *only*.

A recent review by Rogeberg and Elvik (2016) carried out the most sophisticated analysis to date of the available literature, including studies covered by these previous reviews and newer studies, with critical consideration of methodological issues.[15] This analysis concluded that the most defensible OR for cannabis-related motor vehicle collision is **1.22** (1.11- 1.36) or roughly 20-30%. Their analysis indicates that the MVA OR determined specifically from studies that have controlled for alcohol is **1.18** (1.07 - 1.3). One of the studies included in the review was a large case-controlled observational study conducted by the United States National Highway Traffic Safety Administration in 2015, which did *not* find an increased rate of overall motor vehicle accidents in drivers who had used cannabis when controlling for alcohol use and demographic factors (adjusted odds ratio = **1.00**).[16] It should be noted that this study did not focus on fatal or serious injury crashes, but rather provides information on overall crash risk. Rogeberg and

[11] Watson TM, Mann RE. International approaches to driving under the influence of cannabis: A review of evidence on impact. Drug and Alcohol Dependence. 2016 Dec 1;169:148-55.
[12] Mann RE, Stoduto G, Ialomiteanu A, Asbridge M, Smart RG, Wickens CM. Self-reported collision risk associated with cannabis use and driving after cannabis use among Ontario adults. Traffic injury prevention. 2010 Mar 31;11(2):115-22.
[13] Asbridge M, Hayden JA, Cartwright JL. Acute cannabis consumption and motor vehicle collision risk: systematic review of observational studies and meta-analysis. BMJ. 2012 Feb 9;344:e536.
[14] Li MC, Brady JE, DiMaggio CJ, Lusardi AR, Tzong KY, Li G. Marijuana use and motor vehicle crashes. Epidemiologic Reviews. 2012 Jan 1;34(1):65-72.
[15] Rogeberg O, Elvik R. The effects of cannabis intoxication on motor vehicle collision revisited and revised. Addiction. 2016 Aug 1;111(8):1348-59.
[16] Compton RP, Berning A. Drug and alcohol crash risk. 2015 Feb. (Traffic Safety Facts Research Note. DOT HS 812 117). Washington, DC: National Highway Traffic Safety Administration.

Elvik found that the MVA OR determined from studies that did not control for alcohol is **1.69** (1.15 - 2.28). The difference between the OR estimates clearly shows that concurrent alcohol use contributes substantially to MVA risk. The authors conclude that acute cannabis intoxication is associated with a statistically significant increase in motor vehicle crash risk that is of low to medium magnitude.

Some studies assess culpability, which involves determining among drivers who have experienced a motor vehicle crash, the rate of cannabis-present drivers among those judged to be culpable for a motor vehicle crash versus those judged not to be culpable for the crash. Culpability studies help to answer the question of whether driving under the influence of cannabis raises the risk of being responsible for a motor vehicle crash. A 2004 review of culpability studies by Ramaekers et al. found that drivers with measurable THC in their blood, particularly at higher doses, were 3-7 times more likely to be responsible for the crash compared to drivers that had not used drugs or alcohol."[17] This finding was based on one study that reported a significant effect of cannabis on crash culpability (OR = 2.70 and OR = 6.6).[18] However this study was subject to methodological problems that challenge the credibility of the findings, since 'cases' and 'controls' were not selected from the same driver population, as well as not adjusting for culpability under non-impaired conditions. Two other large scale culpability studies reported non-significant ORs for the effects of cannabis on the risk of being culpable for a crash.[19, 20]

Other studies have looked at the association of cannabis laws with traffic fatality rates. A recent report put out by the American Automobile Association (AAA) Foundation for Traffic Safety found that a doubling in fatal crashes involving the use of cannabis occurred about 9 months after new legislation came in to effect in Washington State.[21] The timing of the changes suggests to the authors that they may not be related to the legislation. The authors also highlight several challenges to research in this area, noting that simply detecting THC in blood doesn't necessarily indicate impairment, and that the presence of alcohol or other drugs may have in some cases contributed more to crash risk. The AAA expanded on this point in a related report, and recognized that with the long metabolism of THC and individual variability in THC metabolism, measuring THC in the blood at a certain point in time gives little insight into individual impairment.[22]

A 2017 study looking at the association of cannabis laws with traffic fatality rates between 1985 and 2014, found that States that legalized medical marijuana experienced a reduction in traffic fatalities in those aged 25-44.[23] The authors suggest that this may be related to a reduction in the use of alcohol. It was also found that such laws are associated with a reduction in opioid-related fatal crashes among 21-40 year olds.[24]

It is important to maintain perspective on the motor vehicle crash risk associated with cannabis by placing it in the context of crash risk associated with other substances. Case control studies show that driving after the use of cannabis does not increases the risk of crashing as much as driving with a BAC of

[17] Ramaekers JG, Berghaus G, van Laar M, Drummer OH. Dose related risk of motor vehicle crashes after cannabis use. Drug and alcohol dependence. 2004 Feb 7;73(2):109-19. P. 109.

[18] Drummer, O. H., Gerostamoulos, D., Batziris, H., Chu, M., Caplehorn, J. R. M., Robertson, M. D., & Swann, P. (2004). The involvement of drugs in drivers of motor vehicles killed in Australian road traffic crashes. *Accident Analysis and Prevention, 36*, 239-248.

[19] Longo, M. C., Hunter, C. E., Lokan, R. J., White, J. M., & White, M. A. (2000). The prevalence of alcohol, cannabinoids, benzodiazepines and stimulants amongst injured drivers and their role in driver culpability. Part II: The relationship between drug prevalence and drug concentration, and driver culpability. *Accident Analysis and Prevention, 32*, 623-632.

[20] Poulsen, H., Moar, R. & Pirie, R. (2014). The culpability of drivers killed in New Zealand road crashes and their use of alcohol and other drugs. *Accident Analysis and Prevention, 67*, 119-128.

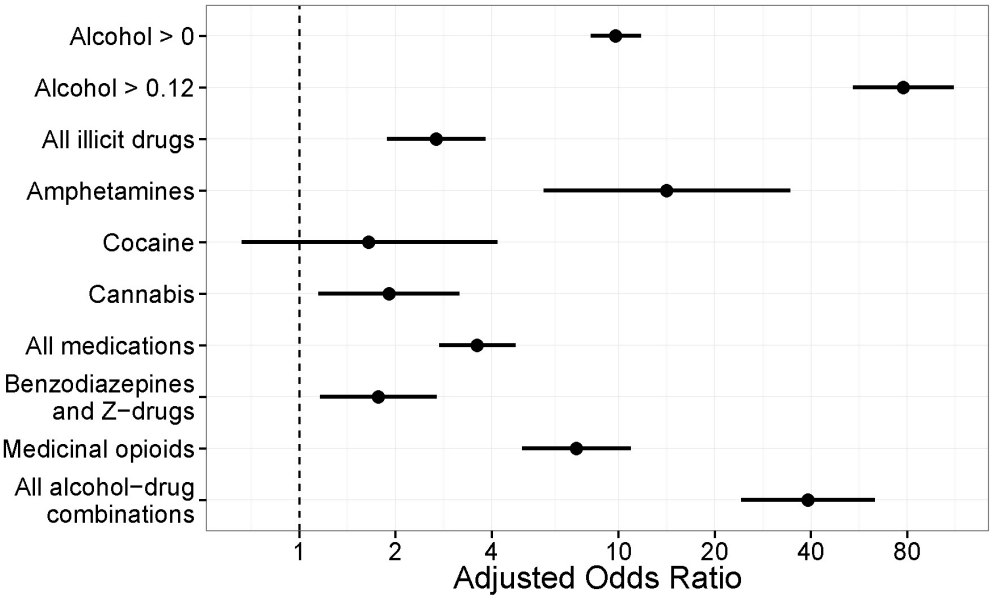
[21] Tefft B.C., Arnold L.S., & Grabowski, J. G. Prevalence of Marijuana Involvement in Fatal Crashes: Washington. 2010-2014. Washington (DC): AAA Foundation for Traffic Safety; 2016 May.

[22] Banta-Green, C. & Williams, J. Overview of Major Issues Regarding the Impacts of Alcohol and Marijuana on Driving. Washington (DC): AAA Foundation for Traffic Safety; 2016 March.

[23] Santaella-Tenorio J, Mauro CM, Wall MM, Kim JH, Cerdá M, Keyes KM, Hasin DS, Galea S, Martins SS. US Traffic Fatalities, 1985–2014, and Their Relationship to Medical Marijuana Laws. American journal of public health. 2017 Feb(0):e1-7.

[24] Kim JH, Santaella-Tenorio J, Mauro C, Wrobel J, Cerdà M, Keyes KM, Hasin D, Martins SS, Li G. State medical marijuana laws and the prevalence of opioids detected among fatally injured drivers. American Journal of Public Health. 2016 Nov;106(11):2032-7.

0.05; a blood alcohol concentration (BAC) between 0.5 g/L- 0.8 g/L (i.e. .05% and .08% BAC, which are the limits over which administrative and criminal sanctions, respectively, can be laid in many jurisdictions in Canada) yields a motor vehicle crash OR between 2 and 4; a BAC of around .3 g/L yields MVA ORs comparable to those found currently in the population for cannabis.[25-28] The presence of benzodiazepine medication yields a motor vehicle crash OR of about 1.7.[29] The chart below displays odds ratios for severe injury resulting from a MVA related to different substances; although assigning an OR to cannabis somewhat higher than found in Rogeberg and Elvik's analysis, it provides an illustration of risks related to different substances.[30]



b. Risk of legal penalties

The individual choosing to drive after using cannabis is subject to a degree of risk that this behavior will be identified by law enforcement personnel and subject to legal penalties. The penalties imposed by the Canadian government for offenses related to impaired driving are based on Section 253 of the Criminal Code of Canada and clearly summarized by Mothers Against Drunk Driving (MADD).[31] The summary shows that Driving While Impaired (first offence) is associated with a minimum penalty of $1000 fine and a 1-year driving prohibition, with a maximum penalty of the $2000 fine, 18-month sentence and a three-year driving prohibition. Meanwhile, a second Driving While Impaired offence is associated with a

[25] Movig KL, Mathijssen MP, Nagel PH, Van Egmond T, De Gier JJ, Leufkens HG, Egberts AC. Psychoactive substance use and the risk of motor vehicle accidents. Accident Analysis & Prevention. 2004 Jul 31;36(4):631-6.
[26] Hels T, Lyckegaard A, Simonsen KW, Steentoft A, Bernhoft IM. Risk of severe driver injury by driving with psychoactive substances. Accident Analysis & Prevention. 2013 Oct 31;59:346-56.
[27] Gjerde H, Bogstrand ST, Lillsunde P. Commentary: why is the odds ratio for involvement in serious road traffic accident among drunk drivers in Norway and Finland higher than in other countries?. Traffic injury prevention. 2014 Jan 1;15(1):1-5.
[28] Compton RP, Berning A. Drug and alcohol crash risk. 2015 Feb. (Traffic Safety Facts Research Note. DOT HS 812 117). Washington, DC: National Highway Traffic Safety Administration.
[29] Dassanayake T, Michie P, Carter G, Jones A. Effects of benzodiazepines, antidepressants and opioids on driving. Drug safety. 2011 eb 1;34(2):125-56.
[30] Brubacher J. Drug-impaired driving. 2016. Presentation at Vancouver Coastal Health Authority: Graph adapted from: Hels T, Lyckegaard A, Simonsen KW, Steentoft A, Bernhoft IM. Risk of severe driver injury by driving with psychoactive substances. Accident Analysis & Prevention. 2013 Oct 31;59:346-56.
[31] Mothers Against Drunk Driving. Impaired Driving Laws. http://madd.ca/pages/impaired-driving/stopping-impaired-driving/impaired-driving-laws/ Accessed October 24, 2016.

minimum penalty of a 30-day sentence and a 2-year driving prohibition and a maximum penalty of a $2000 fine, 18-month sentence and 5-year driving prohibition. Also, "many provinces authorize the police to impose an immediate short-term suspension (usually 24 hours) for driving after drug use or poor performance on the SFST".[32] The SFST (Standardized Field Sobriety Test) is discussed elsewhere in this research review, where we highlight its striking degree of unreliability and doubtful validity in identifying cannabis related impairment. It is worth noting the serious consequences that may ensue from performing poorly on this questionable test. Furthermore, the federal government has built a second test, the Drug Recognition Evaluation test, into legislation:

> Though driving while impaired by drugs has been an offence since 1925, police had little means of enforcing the provision. In 2008, the Government of Canada passed an amendment that gave police authority, in specific circumstances, to demand that impaired driving suspects participate in a drug recognition evaluation (DRE). Officers are specially trained and certified to conduct a DRE to determine if the driver is impaired by drugs and, if so, what type of drug. The DRE involves two major components and consists of a series of steps to help the officer determine if drugs are involved. If the officer concludes that a suspect is impaired by drugs, he or she is then authorized to demand a blood, urine or saliva sample from the suspects.[33]

Given the lack of reliability and validity for both the SFST and DRE (see Section 7), there is a risk of being penalized after erroneous identification as impaired by cannabis use.

A Canadian government report examined the incidence of drug impaired driving offences according to police data, for 2015.[34] This report found that "almost all police-reported impaired driving incidents continued to involve alcohol in 2014 (96%), while a small proportion (4%) involved drugs" [note that the analysis does not specify which of these offences were for cannabis vs. other drugs]. The rate of drug impaired driving violations varied across the provinces, with some increasing, some decreasing and others staying the same. Overall it increased 10% between 2014 and 2015, but remained very low (7.8 per 100,000 population) compared to alcohol impaired driving violations (193 per 100,000 population). The authors of this report noted that measuring drug impairment is more difficult than measuring alcohol impairment, contributing to the low rate of drug driving violations, and that the likelihood of driving offences being reported by police is affected by changes in legislation, enforcement priorities and practices across jurisdiction, and social attitudes. We were not able to find research indicating the likelihood that an individual who had used cannabis before driving might be stopped by police on suspicion of impairment.

There are certain aspects of the encounter between drivers who may have used cannabis and law enforcement personnel worth noting. A police officer is empowered to pull over a driver if there is, according to the officer's discretion, a pattern of driving that raises concern over impairment ('probable cause'). An example of this would be a driver who was traveling too slowly or otherwise erratically. The smell of marijuana in the car may foster the impression on the part of police that the person might be impaired, which creates the risk of *confirmation bias*: that is, the officer may be biased to interpret results of the SFST in a manner that fits a pre-existing belief that the person must be impaired.[35]

Apart from understanding the nature of potential legal consequences of DACU and the quality of impairment determination related to cannabis use, it is also worth considering the evidence as to the effectiveness of legal deterrence in reducing the risk of cannabis-impaired driving. A recent systematic

[32] Beirness DJ, Porath-Waller AJ. Clearing the Smoke on Cannabis. http://www.ccsa.ca/Resource%20Library/CCSA-Cannabis-Use-and-Driving-Report-2015-en.pdf Accessed October 24, 2016. P. 3.
[33] MADD. Enforcement. http://madd.ca/pages/impaired-driving/stopping-impaired-driving/enforcement/ Accessed October 24, 2016.
[34] Allen M. Police-reported crime statistics in Canada, 2015. Juristat: Canadian Centre for Justice Statistics. 2016 Jul 20:1.
[35] Kane G. The methodological quality of three foundational law enforcement drug influence evaluation validation studies. Journal of negative results in biomedicine. 2013 Nov 4;12(1):1.

review of the impact of various strategies designed to deter DACU found that it was not possible to derive a firm conclusion as to the effectiveness of these strategies.[36]

Summary and Conclusions

From the best data available, it appears that there is an approximately 20%-30% increased risk for cannabis-related motor vehicle collision (OR = 1.22) A confounding factor in many studies is the use of alcohol in combination with cannabis. Based on the available evidence, the MVA OR for DACU from studies that control for alcohol use is roughly 1.18, and those controlling for demographic factors and alcohol found no increased risk in overall crash risk (OR=1). These are low but meaningful increased risk estimates, comparable to the MVA risk associated with blood alcohol concentrations below the accepted level of .5 g/L. An increase of cannabis use involved in fatal car crashes has been seen in Washington State after the implementation of legalization regulations, however the presence of cannabis cannot be said to indicate impairment, nor be the main contributor to the crash risks. Overall, the rates of fatal crashes have declined in states with medical cannabis laws. There are significant legal risks for individuals deemed to be driving while impaired by cannabis: suspension of driving privilege, fines and even imprisonment. The legal risk situation is complicated by widespread reliance upon impairment tests of dubious validity (see Section 6). The rate of cannabis-related driving offences in Canada remains low in comparison to the rate of driving offences associated with alcohol. The effectiveness of legal deterrence of DACU has not been determined.

[36] Watson, Tara Marie, and Robert E. Mann. "International approaches to driving under the influence of cannabis: A review of evidence on impact." *Drug and Alcohol Dependence* 169 (2016): 148-155.

4. Effects of cannabis use on driving ability

a. Cognitive function and motor coordination

A number of experimental studies have examined the relationship between cannabis use and cognitive or psychomotor functions.[37-42] These changes in cognitive and psychomotor functions may have an effect on driving ability. The overall thrust of the findings is that moderately high levels of cannabis use (which is variably defined across studies, but in general is considered to be doses between 40-300µg/kg[43]) have a significant negative impact upon several cognitive functions related to driving:

- increased reaction time;
- reduced motor coordination, although this effect is relatively mild and short-lived after use;
- reduced short-term memory;
- temporal distortion
- poor divided attention
- poor decision-making in rapidly-changing situations

However, experimental studies that measure these cognitive and psychomotor functions do not always provide direct insight regarding driving ability. For this, the best studies to consider are driving simulator studies and on-road studies.

Driving simulator studies test the effect of cannabis use on related cognitive and psychomotor deficits on driving performance in a controlled environment. A driving simulator is designed to recreate the conditions of driving and require the same set of skills as does driving (motor coordination, reaction time, attention, decision-making, etc.). One of the most advanced simulators is located at the University of Iowa and is described as follows:

> The National Advanced Driving Simulator was developed from 1996 through 2001 by the National Highway Traffic Safety Administration (NHTSA) to conduct human factors research on driver behavior. The simulator consists of a dome with a vehicle cab inside. The vehicle is attached to a motorized turntable that allows the dome to rotate and simulate different driving conditions. 64 feet of longitudinal and lateral travel and 330 degrees of rotation are used to give motion cues to the driver inside. Different makes and models of car cabs can be utilized. The simulation runs using a software package called Real Time Recursive Dynamics (RTRD), as well as NADSdyna submodules for specific vehicle specs.[44]

Studies using sophisticated driving simulators of this kind have found that moderate-dosage cannabis use (resulting in blood concentrations greater 8.2µg/L) impairs an index known as Standard Deviation

[37] Ashton CH. Adverse effects of cannabis and cannabinoids. British Journal of anaesthesia. 1999 Oct 1;83(4):637-49.
[38] Armentano P. Cannabis and psychomotor performance: A rational review of the evidence and implications for public policy. Drug testing and analysis. 2013 Jan 1;5(1):52-6.
[39] Crean RD, Crane NA, Mason BJ. An evidence based review of acute and long-term effects of cannabis use on executive cognitive functions. Journal of addiction medicine. 2011 Mar 1;5(1):1.
[40] Ramaekers JG, Moeller MR, van Ruitenbeek P, Theunissen EL, Schneider E, Kauert G. Cognition and motor control as a function of Δ 9-THC concentration in serum and oral fluid: limits of impairment. Drug and alcohol dependence. 2006 Nov 8;85(2):114-22.
[41] Ramaekers JG, Kauert G, Theunissen EL, Toennes SW, Moeller MR. Neurocognitive performance during acute THC intoxication in heavy and occasional cannabis users. Journal of psychopharmacology. 2008 Aug 21.
[42] Riedel G, Davies SN. Cannabinoid function in learning, memory and plasticity. In Cannabinoids 2005 (pp. 445-477). Springer Berlin Heidelberg.
[43] Ramaekers JG, Berghaus G, van Laar M, Drummer OH. Dose related risk of motor vehicle crashes after cannabis use. Drug and alcohol dependence. 2004 Feb 7;73(2):109-19.
[44] Wikipedia. National Advanced Driving Simulator. https://en.wikipedia.org/wiki/National_Advanced_Driving_Simulator

Lateral Position (SDLP), that is, having difficulty maintaining lateral road position within one's lane.[45] Cannabis use does not appear to produce other impairments of driving performance seen with alcohol use such as inappropriate acceleration or lane departures.

While on-road studies may be considered the ideal test of how individuals behave in a natural environment, due to safety and feasibility constraints they are limited in number. We identified one on-road study which also used SDLP as a measure of driving performance.[46] This study found that taking an oral dose of cannabis increased impairment as measured by SDLP, and that this effect was larger in individuals who were self-reported occasional users of cannabis compared to frequent users.

Other cognitive functions that may relate to driving are aggression and violence. Cannabis use differs from alcohol use in that alcohol use is related to aggressive and violent behaviours which can affect driving ability. Cannabis use is not generally associated with aggression or violence, and may even decrease the likelihood of violence.[47] This is one pathway through which alcohol contributes to impaired driving which is not a factor with cannabis use.

b. Factors impacting effects of cannabis use on driving ability

i. Dose-response relationship

Effects of cannabis on cognition and motor coordination are mild at low doses and increase in magnitude at higher doses.[48] Raemakers et al. (2004) summarized the pattern of findings as follows: "Experimental studies have repeatedly shown that THC impairs cognition, psychomotor function and actual driving performance in a dose related manner."[49] This conclusion is based on a review of many studies, including epidemiological studies which show that the odds ratio for accident culpability increases with blood level of THC, and experimental studies showing that impairment as measured by SDLP gradually increases with increasing doses of THC.[50]

ii. Tolerance

One issue that complicates studying the relationship between dose and impairment is the differing effects of cannabis depending on the user's history of use. This phenomenon is known as *tolerance*. Current evidence indicates that in general, infrequent users are more likely to be negatively impacted by use than frequent users, who show a degree of resistance to the negative cognitive effects of cannabis.[51,52,53] This

[45] Hartman RL, Brown TL, Milavetz G, Spurgin A, Pierce RS, Gorelick DA, Gaffney G, Huestis MA. Cannabis effects on driving lateral control with and without alcohol. Drug and alcohol dependence. 2015 Sep 1;154:25-37.

[46] Bosker WM, Kuypers KP, Theunissen EL, Surinx A, Blankespoor RJ, Skopp G, Jeffery WK, Walls H, Leeuwen CJ, Ramaekers JG. Medicinal Δ9-tetrahydrocannabinol (dronabinol) impairs on-the-road driving performance of occasional and heavy cannabis users but is not detected in Standard Field Sobriety Tests. Addiction. 2012 Oct 1;107(10):1837-44.

[47] Marijuana Policy Project (MPP). Marijuana is safer than alcohol: it's time to treat it that way. 2016. https://www.mpp.org/marijuana-is-safer/

[48] Weinstein A, Brickner O, Lerman H, Greemland M, Bloch M, Lester H, Chisin R, Sarne Y, Mechoulam R, Bar-Hamburger R, Freedman N. A study investigating the acute dose—response effects of 13 mg and 17 mg Δ 9-tetrahydrocannabinol on cognitive—motor skills, subjective and autonomic measures in regular users of marijuana. Journal of psychopharmacology. 2008 Jun 1;22(4):441-51.

[49] Ramaekers JG, Berghaus G, van Laar M, Drummer OH. Dose related risk of motor vehicle crashes after cannabis use. Drug and alcohol dependence. 2004 Feb 7;73(2):109-19.

[50] Ramaekers JG, Berghaus G, van Laar M, Drummer OH. Dose related risk of motor vehicle crashes after cannabis use. Drug and alcohol dependence. 2004 Feb 7;73(2):109-19.

[51] Desrosiers NA, Ramaekers JG, Chauchard E, Gorelick DA, Huestis MA. Smoked cannabis' psychomotor and neurocognitive effects in occasional and frequent smokers. Journal of analytical toxicology. 2015 May 1;39(4):251-61.

[52] Ramaekers JG, Kauert G, Theunissen EL, Toennes SW, Moeller MR. Neurocognitive performance during acute THC intoxication in heavy and occasional cannabis users. Journal of psychopharmacology. 2008 Aug 21.

[53] Ramaekers JG, Theunissen EL, de Brouwer M, Toennes SW, Moeller MR, Kauert G. Tolerance and cross-tolerance to neurocognitive effects of THC and alcohol in heavy cannabis users. Psychopharmacology. 2011 Mar 1;214(2):391-401.

was supported by a meta-analysis of 120 studies, which concluded that at the same dose infrequent cannabis users show more impairment effects than frequent users.[54]

This effect has been demonstrated in experimental studies comparing impairment as measured by neurocognitive tests in infrequent versus frequent cannabis users. Ramaekers (2008) defines frequent users as those consuming cannabis four or more times a week, and infrequent users as using cannabis three or less times a week.[55] They found that while infrequent users showed impairment on a variety of neurocognitive tests after being administered cannabis, frequent users showed no significant impairment effect at the same dose (a single 13% THC cigarette). A similar study by Desrosiers (2015) also measured impairment using neurocognitive tests, and came to the same conclusion when frequent (4 or more times a week) and infrequent (2 or less times a week) cannabis users were administered a single 6.8% THC cigarette.[56]

Tolerance to impairment effects was also noted in an on-road study of driving ability.[57] In this study, regular cannabis users (who mostly used cannabis daily, but at least used cannabis 4 times a week) and occasional cannabis users (who used cannabis 5-36 times in a year) were administered 10 and 20mg of oral THC on separate occasions prior to participating in an on-road driving session. They found that while impairment as measured by SDLP was seen in both groups, the magnitude of the impairment effect was stronger in occasional cannabis users. Also, there was greater variability in effect amongst the regular users, suggesting differing degrees of tolerance.

While tolerance is mostly a factor of dose, it may also be related to the strain of cannabis used. Different strains of cannabis have different ratios of cannabinoids and terpenoids, and tolerance to the psycho-activity of one strain that is used repeatedly may not be present with the use of an another strain that has a different array of compounds.[58] This may be an additional factor to consider in relation to driving impairment.

iii. Mode of use

Given that cannabis is used primarily in 2 ways, inhalation (i.e. smoking or vaporizing) and oral ingestion (i.e. eating or drinking), and each of these methods triggers a unique physiological process in which cannabis is absorbed by the body, we must consider the relative effect of each method on driving capacity.

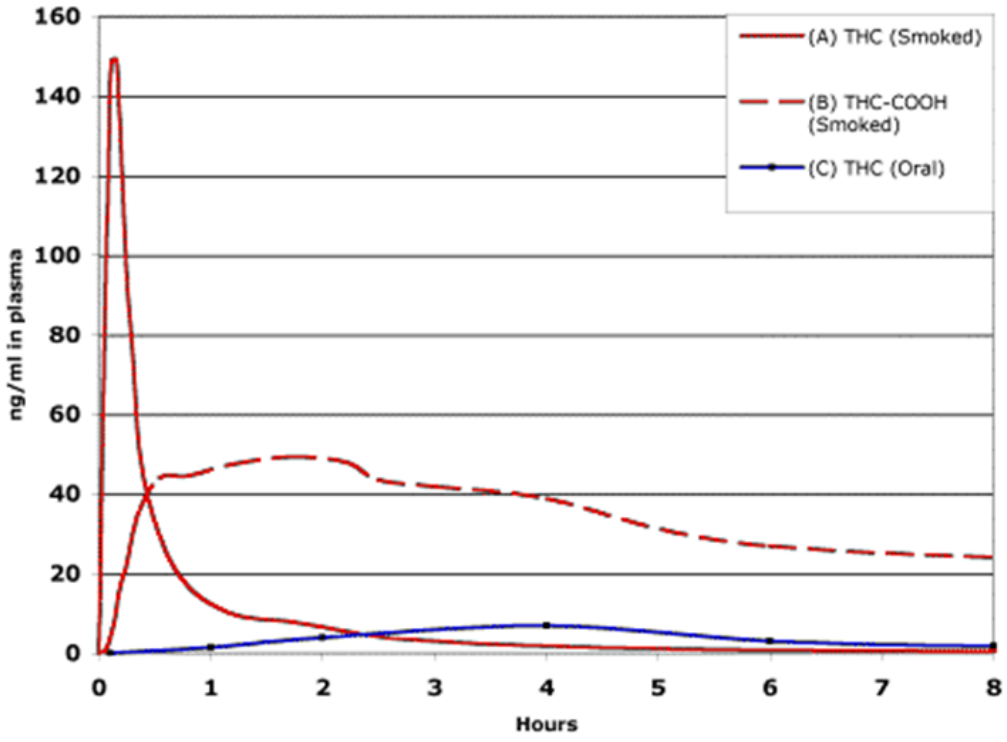
With regard to inhaling cannabis, it has been demonstrated that THC blood levels following inhalation rise rapidly, then fall over a 60 min. time frame. THC is lipophilic (it prefers to live in fat cells) and quickly moves out of blood into the body's fatty tissues. After that initial rapid decline in THC blood concentration, there is a gradual reduction in THC blood concentration over the next couple of hours, until it falls to very low levels by the 2½-3 hour time frame. But when cannabis is ingested orally, a different pattern of absorption occurs: a gradual increase until it reaches a peak concentration at 3-4 hours (note this peak concentration is lower than that observed with inhalation, however the effects can be experienced more strongly with ingestion since different metabolites are produced), followed by a gradual decrease over several hours. As summarized by one researcher: “(THC) also may be ingested

[54] Reisfield GM, Goldberger BA, Gold MS, DuPont RL. The mirage of impairing drug concentration thresholds: a rationale for zero tolerance per se driving under the influence of drugs laws. Journal of analytical toxicology. 2012 Jun 1;36(5):353-6.
[55] Ramaekers JG, Kauert G, Theunissen EL, Toennes SW, Moeller MR. Neurocognitive performance during acute THC intoxication in heavy and occasional cannabis users. Journal of psychopharmacology. 2008 Aug 21.

[56] Desrosiers NA, Ramaekers JG, Chauchard E, Gorelick DA, Huestis MA. Smoked cannabis' psychomotor and neurocognitive effects in occasional and frequent smokers. Journal of analytical toxicology. 2015 May 1;39(4):251-61.
[57] Bosker WM, Kuypers KP, Theunissen EL, Surinx A, Blankespoor RJ, Skopp G, Jeffery WK, Walls H, Leeuwen CJ, Ramaekers JG. Medicinal Δ9-tetrahydrocannabinol (dronabinol) impairs on-the-road driving performance of occasional and heavy cannabis users but is not detected in Standard Field Sobriety Tests. Addiction. 2012 Oct 1;107(10):1837-44.
[58] Russo EB. Taming THC: potential cannabis synergy and phytocannabinoid-terpenoid entourage effects. British journal of pharmacology. 2011 Aug 1;163(7):1344-64.

orally in medications, food, drinks, and hemp oil... producing lower and delayed peak blood concentrations and effects than with smoked THC".[59]

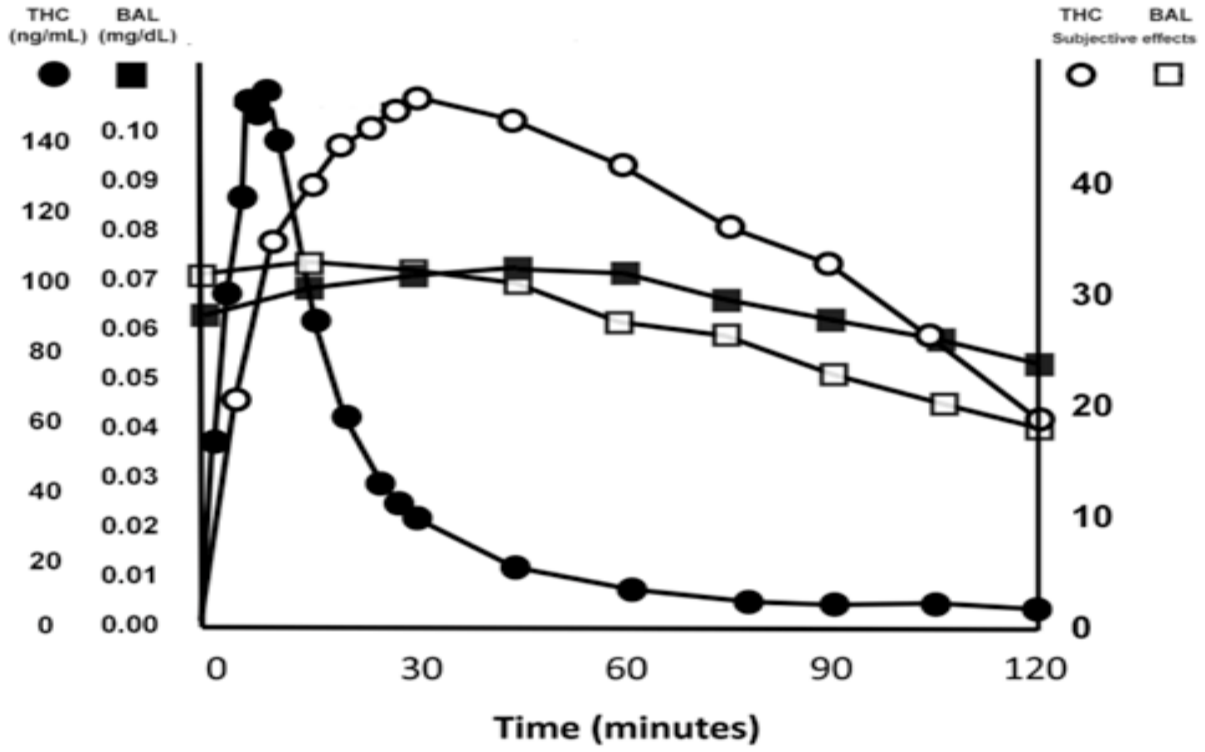
The chart below illustrates the absorption patterns for smoked and orally-ingested cannabis.



From http://www.canorml.org/healthfacts/drugtestguide/drugtestdetection.html#fn03
(A-B) Smoked dose based on data from M. Huestis , J. Henningfield and E. Cone (1992).[60]
(C) Oral dose based on data from B. Law et al (1984).[61]

Complicating the picture is that the peak impact of THC from inhalation is delayed after its peak blood concentration. The chart below helps to visualize this process.[62] Ergo, even when the blood level is falling quickly, the experiential effect is *increasing*, and does not decrease substantially until the second hour post-inhalation.

[59] Milman G, Schwope DM, Schwilke EW et al. Oral fluid and plasma cannabinoid ratios after around-the-clock controlled oral Δ9-tetrahydrocannabinol administration. Clinical Chemistry. 2011 Nov 1;57(11):1597-606.
[60] Huestis MA, Henningfield JE, Cone EJ. Blood cannabinoids. I. Absorption of THC and formation of 11-OH-THC and THCCOOH during and after smoking marijuana. Journal of analytical Toxicology. 1992 Sep 1;16(5):276-82.
[61] Law B, Mason PA, Moffat AC, Gleadle RI, King LJ. Forensic aspects of the metabolism and excretion of cannabinoids following oral ingestion of cannabis resin. Journal of Pharmacy and Pharmacology. 1984 May 1;36(5):289-94.
[62] Sewell RA. "Is It Safe to Drive While Stoned? Cannabis and Driving: An Erowid Science Review". Erowid.org. Feb 4, 2010. Erowid.org/plants/cannabis/cannabis_driving7.shtml



Serum levels of ethanol (black squares) lag behind subjective effects (white squares) because tolerance develops very quickly. Subjective effects of THC (white circles) lag behind serum levels (black circles) because THC moves into the brain more slowly than alcohol does. BAL=Blood Alcohol Level. (Adapted from Portans et al. (1989), Cocchetto et al. (1981), Huestis et al. (1992).)

Given that inhaling cannabis yields a very different absorption pattern from that obtained with oral ingestion, one would expect different patterns of driving skill impairment from these two modes of cannabis use. For inhalation, one would expect that driving skills would be significantly impaired for at least the next hour and probably the next two hours. For oral ingestion, one would expect driving skill impairment to last up to 6 hours after cannabis use.

iv. Use with other substances

The relationship between use of cannabis and alcohol in relation to driving is a complex one. It is important to maintain perspective on the relative danger associated with cannabis and alcohol: alcohol has been shown to have a much higher level of negative impact upon driving ability and to contribute substantially more to motor vehicle crashes than does cannabis.[63] For example, one study in Australia found that while approximately 20% of drivers who had been involved in a crash had BAC above the legal limit of 0.05 g/100mL, only 5% were positive for cannabis, and of that 5% one-third were also positive for alcohol.[64]

Some studies have found an additively impairing effect for cannabis and alcohol. Increased cognitive, psychomotor, and actual driving performance impairment when alcohol and cannabis are used

[63] Hels T, Lyckegaard A, Simonsen KW, Steentoft A, Bernhoft IM. Risk of severe driver injury by driving with psychoactive substances. Accident Analysis & Prevention. 2013 Oct 31;59:346-56.
[64] Baldock MR, Lindsay VL. Examination of the role of the combination of alcohol and cannabis in South Australian road crashes. Traffic injury prevention. 2015 Jul 4;16(5):443-9.

concurrently has been observed in driving simulator studies and epidemiological studies.[65,66] Raemakers et al. found in an on-road study that low doses of THC in combination with low doses of alcohol severely impaired driving.[67] In their study, a 100 µg/kg dose of THC resulted in a measured SLDP that rose from 2.7cm with only THC to 5.3cm with the addition of 0.04g/dL of alcohol, and the measured SDLP for a 200 µg/kg dose of THC rose from 3.5cm to 8.5cm with the addition of 0.04g/dL of alcohol. In contrast, the study found that a 0.04g/dL dose of alcohol alone had a measured SDLP of 2.2 cm. These changes were significant and support the conclusion that impairment by cannabis and alcohol has an additive effect. In contrast, another study found that in low severity crashes there does not appear to be an interactive effect from the combination of alcohol and other drugs, including cannabis; alcohol, whether alone or in combination with other drugs is the largest contributor to these crashes.[68]

The evidence also suggests that the consumption of alcohol makes individuals more prone to risky behaviour and removes their ability to use compensatory behaviour such as slower driving and increased following distance.[69] Individuals are also more likely to consume higher amounts of alcohol when used concurrently with cannabis, increasing their impairment.[70]

The effects of using cannabis in conjunction with other substances are less studied. It is also difficult to predict the effects of the multitude of combinations of drugs. However, a review of epidemiological studies of crash risk that looked at drivers who had multiple drugs detectable in their system suggested that overall, mixing of drugs is associated with a greater risk of being in a road traffic accident.[71]

Summary and Conclusions

Cannabis use has been shown to have short-term negative impacts upon a set of cognitive functions relevant to driving capacity: reaction time, motor coordination, divided attention, short term memory and decision-making under time-pressured and informationally-complex conditions. It has further been shown that cannabis use has a short-term negative impact upon driving performance as measured by driving simulation techniques, manifested primarily in difficulty with maintaining lateral road position within one's lane. The negative impact of cannabis use upon driving performance is dose-related, increasing with increased dosage of cannabis. However, the degree of impairment is also related to an individual's cannabis use history, and regular users of cannabis (generally those who use cannabis 4 or more times a week) are more likely to be tolerant to the impairment effects of cannabis. It is notable that the negative impacts of cannabis upon driving performance are substantially less than those of alcohol. Unlike alcohol use, cannabis use does not predispose to aggressive or violent behavior, which can affect driving ability. Use of cannabis and alcohol in combination creates an additive risk, although alcohol is the largest contributor to these crashes. While more research is needed to quantify the effect of use of cannabis and other drugs, it appears that in general mixing of drugs is associated with a greater crash risk.

[65] Downey LA, King R, Papafotiou K, Swann P, Ogden E, Boorman M, Stough C. The effects of cannabis and alcohol on simulated driving: influences of dose and experience. Accident Analysis & Prevention. 2013 Jan 31;50:879-86..

[66] Ramaekers JG, Berghaus G, van Laar M, Drummer OH. Dose related risk of motor vehicle crashes after cannabis use. Drug and alcohol dependence. 2004 Feb 7;73(2):109-19.

[67] Ramaekers JG, Robbe HW, O'Hanlon JF. Marijuana, alcohol and actual driving performance. Human Psychopharmacology Clinical and Experimental. 2000 Oct 1;15(7):551-8.

[68] Lacey, J. H., Kelley-Baker, T., Berning, A., Romano, E., Ramirez, A., Yao, J., Moore, C., Brainard, K., Carr, K., & Pell, K., & Compton, R. (2016, December). *Drug and Alcohol Crash Risk: A Case Control Study* (Report Number DOT HS 812 355). Washington, DC: National Highway Traffic Safety Administration (NHTSA).

[69] Sewell RA, Poling J, Sofuoglu M. The effect of cannabis compared with alcohol on driving. American journal on addictions. 2009 Jan 1;18(3):185-93.

[70] Subbaraman MS, Kerr WC. Simultaneous versus concurrent use of alcohol and cannabis in the national alcohol survey. Alcoholism: Clinical and Experimental Research. 2015 May 1;39(5):872-9.

[71] Gjerde H, Strand MC, Mørland J. Driving under the influence of non-alcohol drugs—an update. Part I: Epidemiological studies. Forensic Science Reviews. 2015 Jul;27(2):89-113.

5. Factors associated with driving after cannabis use

Although cannabis use has been shown to effect cognitive function and motor coordination in ways that may have a negative impact on driving ability, it is still not clear whether cannabis use in isolation contributes more to accidents than other factors also related to cannabis users who decide to drive after using cannabis. Several interrelated demographic, personality and lifestyle factors have been shown to be associated with the decision to drive after using cannabis, and while not suggesting a causal link, can shed light on who engages in this behaviour and under what circumstances this behaviour is most likely to occur:

a. Demographic characteristics

Some demographic characteristics have been shown to increase the likelihood of DACU, in particular age (younger) and gender (male).[72-74] However, it must be noted that the age/gender relationship to cannabis use and driving is not particularly strong in regards to the frequency of engaging in this activity.[75]

b. Use with other substances

Several studies have shown an association between use of cannabis in combination with other drugs and likelihood of DACU. Cannabis use along with use of other illicit or non-medical drug use in past year has been found to be positively and significantly associated with higher frequency of cannabis use and driving activity.[76] The more types of drugs used also appears to increase the likelihood of reporting past-year DACU.[77] One study found that simultaneous use of cannabis with alcohol approximately doubled the odds of drunk driving.[78]

c. Frequency of use and dependence

Frequency of cannabis use has been found to be positively associated with self-reports of DACU. In one study, the use of cannabis at least weekly was found to increase the likelihood of DACU in a multi-site sample of university students in Canada.[79] However, this study did not control for the amount being used, and 'use after was driving' was defined as within 4 hours after use, which may not actually be risky use since most of the effects have dissipated by then. Another study looking at the association between frequency of cannabis use and driving within one hour after use, found a positive association between

[72] Jones CG, Swift W, Donnelly NJ, Weatherburn DJ. Correlates of driving under the influence of cannabis. Drug and alcohol dependence. 2007 Apr 17;88(1):83-6

[73] Matthews A, Bruno R, Johnston J, Black E, Degenhardt L, Dunn M. Factors associated with driving under the influence of alcohol and drugs among an Australian sample of regular ecstasy users. Drug and alcohol dependence. 2009 Feb 1;100(1):24-31.

[74] Terry P, Wright KA. Self-reported driving behaviour and attitudes towards driving under the influence of cannabis among three different user groups in England. Addictive behaviors. 2005 Mar 31;30(3):619-26.

[75] Fischer B, Ivsins A, Rehm J, Webster C, Rudzinski K, Rodopoulos J, Patra J. Factors Associated with High-Frequency Cannabis Use and Driving among a Multi-site Sample of University Students in Ontario 1. Canadian journal of criminology and criminal justice. 2014 Feb;56(2):185-200.

[76] Fischer B, Ivsins A, Rehm J, Webster C, Rudzinski K, Rodopoulos J, Patra J. Factors Associated with High-Frequency Cannabis Use and Driving among a Multi-site Sample of University Students in Ontario 1. Canadian journal of criminology and criminal justice. 2014 Feb;56(2):185-200.

[77] Jones CG, Swift W, Donnelly NJ, Weatherburn DJ. Correlates of driving under the influence of cannabis. Drug and alcohol dependence. 2007 Apr 17;88(1):83-6.

[78] Subbaraman MS, Kerr WC. Simultaneous versus concurrent use of alcohol and cannabis in the national alcohol survey. Alcoholism: Clinical and Experimental Research. 2015 May 1;39(5):872-9.

[79] Fischer B, Ivsins A, Rehm J, Webster C, Rudzinski K, Rodopoulos J, Patra J. Factors Associated with High-Frequency Cannabis Use and Driving among a Multi-site Sample of University Students in Ontario 1. Canadian journal of criminology and criminal justice. 2014 Feb;56(2):185-200.

these factors.[80] This study also found that frequency of use was associated with self-reported risky driving behaviour.

Frequency of use is also an indicator of dependence, and individuals showing cannabis dependence have been found to be more than twice as likely to report DACU in the past year.[81] Similarly, individuals who had used cannabis before the age of 14 were found to be far more likely to be considered cannabis-dependent, and were 3 times more likely to report have engaged in DACU than individuals who began using after that age.[82]

d. Driving patterns and attitudes toward risk

Individual driving patterns and attitudes towards risk influence the likelihood of DACU. Studies investigating the relationship between reckless driving and DACU among young cannabis users, by means of self-report measures and direct observations through driving simulation equipment found that a propensity for reckless driving (self-reported and simulated driving behaviour) and self-reported sensation seeking were positively correlated with willingness to drive within one hour after using cannabis.[83,84] Bergeron and Paquette (2014) found that while self-report DACU is significantly associated with an increased risk of traffic tickets (e.g., for excessive speed or omitting a stop) and with self-report risky behaviors, it was not found to be a risk factor for motor vehicle accidents.[85] It must be noted that risky driving is not necessarily associated with accidents, and does not reflect on driving skills. Dangerous driving habits seem to be a confounding factor that may lead to an over-estimation of the DACU-related collisions among DACU drivers – i.e. it may be reckless driving that is associated with collisions rather than use of cannabis.

A study examining the relationship between wearing a seatbelt (an indicator of attitude towards safety in driving) and testing positive for the presence of drugs, for drivers involved in fatal crashes, found DACU to be moderately associated with failure to wear a seatbelt.[86] The Odds Ratios of a drug-using driver wearing a seatbelt, compared to drivers without drugs present, were: alcohol and cannabis (3.70), alcohol only (3.50), stimulants (2.13), depressants (2.09), narcotics (1.84) and cannabis only (1.55). Thus, while DACU is associated with failing to consistently apply this safety measure, the association is notably less than for other substances, suggesting that cannabis-only users are less prone to risky driving behaviours than are other drug users, in particular those who use cannabis and alcohol concurrently.

Finally, youth driving risk behaviors have been found to be associated independently with high-risk attitudes and experiences riding with peers who drink alcohol or use cannabis and drive. In one study, the risks were highest for the youth who report more frequent experiences of riding with adults who drink alcohol or use cannabis and drive.[87] The authors of that study conclude that prevention efforts should be expanded to include the adults and peers who are role models for new drivers, and to increase youths' awareness of their own responsibilities for their personal safety as passengers.

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[80] Bergeron J, Paquette M. Relationships between frequency of driving under the influence of cannabis, self-reported reckless driving and risk-taking behavior observed in a driving simulator. Journal of Safety Research. 2014 Jun 30;49:19-24.

[81] Jones CG, Swift W, Donnelly NJ, Weatherburn DJ. Correlates of driving under the influence of cannabis. Drug and alcohol dependence. 2007 Apr 17;88(1):83-6.

[82] Le Strat Y, Dubertret C, Le Foll B. Impact of age at onset of cannabis use on cannabis dependence and driving under the influence in the United States. Accident Analysis & Prevention. 2015 Mar 31;76:1-5.

[83] Bergeron J, Paquette M. Relationships between frequency of driving under the influence of cannabis, self-reported reckless driving and risk-taking behavior observed in a driving simulator. Journal of Safety Research. 2014 Jun 30;49:19-24.

[84] Richer I, Bergeron J. Driving under the influence of cannabis: Links with dangerous driving, psychological predictors, and accident involvement. Accident Analysis & Prevention. 2009 Mar 31;41(2):299-307.

[85] Bergeron J, Paquette M. Relationships between frequency of driving under the influence of cannabis, self-reported reckless driving and risk-taking behavior observed in a driving simulator. Journal of Safety Research. 2014 Jun 30;49:19-24.

[86] Liu C, Huang Y, Pressley JC. Restraint use and risky driving behaviors across drug types and drug and alcohol combinations for drivers involved in a fatal motor vehicle collision on US roadways. Injury epidemiology. 2016 Apr 1;3(1):1.

[87] Leadbeater BJ, Foran K, Grove-White A. How much can you drink before driving? The influence of riding with impaired adults and peers on the driving behaviors of urban and rural youth. Addiction. 2008 Apr 1;103(4):629-37.

e. Physical discomfort and motivation for driving

Physical discomfort and the importance of the reason for driving are factors that have been found to be predictive of DACU. A strong feeling of cannabis intoxication, and the related negative physical effects, are associated with a significant decrease in one's willingness to drive.[88,89] This may be related to the discomfort felt during driving while intoxicated, as some researchers found that THC primarily caused elevation in physical effort and physical discomfort during the drive, compared to alcohol, which tended to affect sleepiness level.[90] However, discomfort is not experienced by everyone; in another study, the majority of participants stated that they would drive even if they felt quite intoxicated by cannabis.[91] Increased willingness to drive after using cannabis has also been related to perceived importance of the task being accomplished through driving. If the driving is seen to be for unimportant purposes, individuals are less willing to do so while feeling intoxicated by cannabis.[92] Both physical discomfort and sensitivity to the importance of the reason for driving appear to be impacted by the level of intoxication.

Summary and Conclusions

Some of the factors associated with DACU, such as use with other substances, are also related to impairment that could affect driving ability. Other factors, such as frequency of use, while increasing the likelihood of driving after use, may mitigate impairment through tolerance levels (see Section 4). Yet other factors associated with DACU that do not have a direct impact on level of impairment (such as age, gender and attitude toward risk), may be independently related to accident risk, and thus represent broader targets for dangerous driving policies. While higher levels of cannabis intoxication may increase impairment levels, it may conversely reduce the likelihood of driving: the associated physical discomfort may dissuade some individuals from driving, particularly if the purpose for driving is considered unimportant.

[88] MacDonald S, Mann R, Chipman M, Pakula B, Erickson P, Hathaway A, MacIntyre P. Driving behavior under the influence of cannabis or cocaine. Traffic Injury Prevention. 2008 May 28;9(3):190-4.
[89] Ménétrey A, Augsburger M, Favrat B, Pin MA, Rothuizen LE, Appenzeller M, Buclin T, Mangin P, Giroud C. Assessment of driving capability through the use of clinical and psychomotor tests in relation to blood cannabinoids levels following oral administration of 20 mg dronabinol or of a cannabis decoction made with 20 or 60 mg Δ9-THC. Journal of analytical toxicology. 2005 Jul 1;29(5):327-38.
[90] Ronen A, Gershon P, Drobiner H, Rabinovich A, Bar-Hamburger R, Mechoulam R, Cassuto Y, Shinar D. Effects of THC on driving performance, physiological state and subjective feelings relative to alcohol. Accident Analysis & Prevention. 2008 May 31;40(3):926-34.
[91] Terry P, Wright KA. Self-reported driving behaviour and attitudes towards driving under the influence of cannabis among three different user groups in England. Addictive behaviors. 2005 Mar 31;30(3):619-26.
[92] Ménétrey A, Augsburger M, Favrat B, Pin MA, Rothuizen LE, Appenzeller M, Buclin T, Mangin P, Giroud C. Assessment of driving capability through the use of clinical and psychomotor tests in relation to blood cannabinoids levels following oral administration of 20 mg dronabinol or of a cannabis decoction made with 20 or 60 mg Δ9-THC. Journal of analytical toxicology. 2005 Jul 1;29(5):327-38.

6. Perceived risk of driving after cannabis use

It is important when developing messaging related to cannabis and driving to understand the perceptions of cannabis users regarding the level of risk associated with driving after cannabis use. This includes the risk of impairment, the risk of being involved in an accident, and the risk of legal repercussions. It is also important to understand how these perceptions may impact the likelihood that an individual would drive after using cannabis. Studies have looked at the perceptions of drivers in general and perceptions of cannabis users; both groups are important to address since drivers who currently do not use cannabis may one day begin using cannabis. It is also important to consider passengers' perceptions.

a. Perception of impaired driving ability

Studies of cannabis users' perceptions of the impact of cannabis use on driving seem to demonstrate a perception that use of cannabis, and the resulting intoxication, does not necessarily lead to impairment. In a study focusing on ecstasy users who were predominantly young males, of those who acknowledged having driven within one hour of using cannabis within the past six months, only 7% described their driving ability as having been quite impaired during that post-cannabis driving experience, 42% indicated that their driving ability had been slightly impaired, while about 50% believed there had been no impairment of their driving ability.[93] Similar results were found in another study where most cannabis users interviewed expressed the belief that cannabis use would impair driving ability only slightly or even promote better driving: only 12% believed their driving to be very much impaired; 58% believed their driving was only slightly impaired, 6% not at all impaired, and 24% actually thought their driving was improved.[94]

This distinction between intoxication from cannabis and the influence on ability to drive may explain why cannabis users in some studies stated that they would drive even if they felt quite intoxicated by cannabis, and would use cannabis while actually driving.[95,96] In a study looking at contextual issues associated with driving and drug use, including cannabis, interviewees also made the distinction between the influence of the drug and their ability to drive.[97] Emphasis was placed on the individual's ability to control the situation; some interviewees believed drug tolerance compensated for drug effects and that experience enabled them to manage drug use and maintain their driving abilities. Perceived behavioural control has been found to be a strong predictor of intentions to drive after alcohol use.[98,99]

However, unlike those driving after the use of alcohol, who tend to underestimate impairment, individuals driving after using cannabis tend to overestimate their degree of impairment.[100] Cannabis users are aware of the differing levels of impairment from the use of different substances, with cannabis

[93] Matthews A, Bruno R, Johnston J, Black E, Degenhardt L, Dunn M. Factors associated with driving under the influence of alcohol and drugs among an Australian sample of regular ecstasy users. Drug and alcohol dependence. 2009 Feb 1;100(1):24-31.
[94] Terry P, Wright KA. Self-reported driving behaviour and attitudes towards driving under the influence of cannabis among three different user groups in England. Addictive behaviors. 2005 Mar 31;30(3):619-26.
[95] Ronen A, Chassidim HS, Gershon P, Parmet Y, Rabinovich A, Bar-Hamburger R, Cassuto Y, Shinar D. The effect of alcohol, THC and their combination on perceived effects, willingness to drive and performance of driving and non-driving tasks. Accident Analysis & Prevention. 2010 Nov 30;42(6):1855-65.
[96] Terry P, Wright KA. Self-reported driving behaviour and attitudes towards driving under the influence of cannabis among three different user groups in England. Addictive behaviors. 2005 Mar 31;30(3):619-26.
[97] Davey J, Davies A, French N, Williams C, Lang CP. Drug driving from a user's perspective. Drugs: education, prevention and policy. 2005 Feb 1;12(1):61-70.
[98] Chan DC, Wu AM, Hung EP. Invulnerability and the intention to drink and drive: An application of the theory of planned behavior. Accident Analysis & Prevention. 2010 Nov 30;42(6):1549-55
[99] Moan IS, Rise J. Predicting intentions not to "drink and drive" using an extended version of the theory of planned behaviour. Accident Analysis & Prevention. 2011 Jul 31;43(4):1378-84.
[100] Robbe HW, O'Hanlon HF. Marijuana and Actual Driving Performance. Journal of Safety Research. 1995;4(26):255.

being seen as much less likely to impair driving ability than other drugs, especially alcohol.[101] The table below shows some of the differences highlighted between the effects of these two substances from a 2005 study.[102]

Differences and similarities in self-reported effect of cannabis and alcohol on driving (n=23)

Differences		Similarities
Cannabis	Alcohol	Both drugs
Makes you paranoid and tense	Makes you drive more dangerously	Impair attention
Makes you drive more slowly	Makes you feel too tired to concentrate	Make you more easily distracted
Makes car headlights too dazzling		Slow down your reactions
Makes you more cautious	Makes you overconfident	Affect your attention in general
Makes you more relaxed	Makes you more reckless	Alter your perception of speed
Makes you concentrate more	Makes you drive faster	Make you prone to daydreaming
Slows you down so it's safer	Impairs judgement at traffic lights	Affect your judgement in general
Makes you drive more carefully	Alters your perception of distance	
Makes driving more enjoyable	Makes you have less control of the car	
Stops you from speeding		
Makes you pay more attention	Impairs steering	
Makes you more in tune with the driving task	Impairs vision	
	Makes you forget where you're going	
Makes you take fewer risks		
	Makes you take more risks	

For items listed under differences, the separation between the proportions of "yes" and "no" responses exceeded 50% of the sample.

b. Perception of increased accident risk

While the available evidence indicates that there is a significant increase in risk of motor vehicle accident for 2-3 hours after consuming cannabis (see Section 3), studies suggests that some cannabis users have a different perception of risk. In one study examining perceptions of cannabis users regarding the risk of motor vehicle accident after cannabis use, 53% said driving after using cannabis would increase accident risk.[103] A 2009 study found 40% of cannabis users believed that driving after using cannabis would increase their risk of motor vehicle accident, with a later study by the same researchers, in 2014, found that only 34% hold that belief.[104,105] A similar result was found in a 2016 study, with 38% of cannabis users believing there would be increased risk of accident from DACU; by contrast, 58% of all drivers believed that accident risk would be increased by cannabis use.[106] Interestingly, 92% of all drivers stated the belief that it is unacceptable to drive within one hour after using cannabis. 98% believed it was unacceptable to drive after using both marijuana and alcohol.

[101] Kelly E, Darke S, Ross J. A review of drug use and driving: epidemiology, impairment, risk factors and risk perceptions. Drug and alcohol review. 2004 Sep 1;23(3):319-44.
[102] Terry P, Wright KA. Self-reported driving behaviour and attitudes towards driving under the influence of cannabis among three different user groups in England. Addictive behaviors. 2005 Mar 31;30(3):619-26.
[103] Jones CG, Swift W, Donnelly NJ, Weatherburn DJ. Correlates of driving under the influence of cannabis. Drug and alcohol dependence. 2007 Apr 17;88(1):83-6.
[104] Matthews A, Bruno R, Johnston J, Black E, Degenhardt L, Dunn M. Factors associated with driving under the influence of alcohol and drugs among an Australian sample of regular ecstasy users. Drug and alcohol dependence. 2009 Feb 1;100(1):24-31.
[105] Matthews AJ, Bruno R, Dietze P, Butler K, Burns L. Driving under the influence among frequent ecstasy consumers in Australia: Trends over time and the role of risk perceptions. Drug and alcohol dependence. 2014 Nov 1;144:218-24.
[106] Arnold LS, Tefft BC. Driving Under the Influence of Alcohol and Marijuana: Beliefs and Behaviors, United States, 2013-2015. Washington (DC): AAA Foundation for Traffic Safety; 2016 May.

It is interesting to note that the belief that DUI alcohol will cause an accident is much higher than that for DACU, accurately reflecting the elevated risk for alcohol. For example, the proportion of participants in one study who perceived that having an accident while DUI was 'likely' or 'very likely' was significantly higher for alcohol, at 76%, relative to all other substances; the proportion for cannabis was 40%. [107]

c. Factors that impact perception of accident risk

Beliefs regarding the driving risk associated with cannabis use are influenced by several factors including age, gender, use of cannabis, and driving behavior. One recent study found that individuals over 40 years old are most likely to believe that using cannabis within an hour before driving significantly increases the risk of motor vehicle accident, compared to those in the 18 to 30 age range; those aged 18-24 were most likely to indicate that such use does not affect risk, those aged 25-30 were most likely to indicate that it decreases crash risk, and those over 75 were most likely to indicate they didn't know how such use affects risk. Not surprisingly, the belief that driving within one hour after use is unacceptable also increases with age.[108]

A small but significant influence of gender on the association of DACU and accident risk has been demonstrated in a recent AAA Foundation for Traffic Safety report, with female drivers more likely to believe that using cannabis within an hour of driving increases crash risk, and male drivers more likely to believe such use does not affect or decreases crash risk.[109] This report also showed that drivers who reported using cannabis in the past year were less likely to believe using cannabis increases risk of MVA than those who didn't use cannabis in the past year (37.9% vs. 60.5%), and were much more likely to believe it does not affect crash risk (29.4% vs. 3.7%) or decreases crash risk (16.1% vs. 2.3%). In terms of driving behavior, drivers who reported that they drive less carefully than other drivers were the least likely to believe that using marijuana within an hour of driving increases crash risk, and were the most likely to believe that such use does not affect crash risk.

d. Perception of legal risk

Given that laws against drug driving may be viewed as a deterrent to this behaviour, it is worth knowing how cannabis users perceive the likelihood of being subjected to legal sanctions if driving post-cannabis use. Several studies have determined that the large majority of cannabis users (70-80%) perceive a very low risk of being apprehended for post-cannabis driving.[110-112] The perception of risk may also be related to a low level of knowledge about the laws, as well as low lifetime experience of saliva testing.[113,114]

In one study that interviewed cannabis users, there was agreement that the likelihood of being apprehended for drug driving by police was minimal.[115] Of interest, interviewees in that study appeared to

[107] Matthews A, Bruno R, Johnston J, Black E, Degenhardt L, Dunn M. Factors associated with driving under the influence of alcohol and drugs among an Australian sample of regular ecstasy users. Drug and alcohol dependence. 2009 Feb 1;100(1):24-31.
[108] Arnold LS, Tefft BC. Driving Under the Influence of Alcohol and Marijuana: Beliefs and Behaviors, United States, 2013-2015. Washington (DC): AAA Foundation for Traffic Safety; 2016 May.
[109] Arnold LS, Tefft BC. Driving Under the Influence of Alcohol and Marijuana: Beliefs and Behaviors, United States, 2013-2015. Washington (DC): AAA Foundation for Traffic Safety; 2016 May.
[110] Jones CG, Swift W, Donnelly NJ, Weatherburn DJ. Correlates of driving under the influence of cannabis. Drug and alcohol dependence. 2007 Apr 17;88(1):83-6.
[111] Matthews A, Bruno R, Johnston J, Black E, Degenhardt L, Dunn M. Factors associated with driving under the influence of alcohol and drugs among an Australian sample of regular ecstasy users. Drug and alcohol dependence. 2009 Feb 1;100(1):24-31.
[112] Matthews AJ, Bruno R, Dietze P, Butler K, Burns L. Driving under the influence among frequent ecstasy consumers in Australia: Trends over time and the role of risk perceptions. Drug and alcohol dependence. 2014 Nov 1;144:218-24.
[113] Arnold LS, Tefft BC. Driving Under the Influence of Alcohol and Marijuana: Beliefs and Behaviors, United States, 2013-2015. Washington (DC): AAA Foundation for Traffic Safety; 2016 May.
[114] Matthews AJ, Bruno R, Dietze P, Butler K, Burns L. Driving under the influence among frequent ecstasy consumers in Australia: Trends over time and the role of risk perceptions. Drug and alcohol dependence. 2014 Nov 1;144:218-24.
[115] Davey J, Davies A, French N, Williams C, Lang CP. Drug driving from a user's perspective. Drugs: education, prevention and policy. 2005 Feb 1;12(1):61-70.

base their assessment of impairment on fear of detection as opposed to an evaluation of safe vehicle usage, such that they preferred to use cannabis before driving rather than bring the cannabis with them and risk getting caught with it in their possession. The authors concluded that the illegality of drug driving was subsumed by illegality of drug use.

e. Correlation of perception of risk with driving after cannabis use

As one might expect, those who do not believe that driving post-cannabis use is risky are more likely to have driven after the use of cannabis than are those who perceive increased risk. Studies of cannabis users have found that the belief that DACU does not increase accident risk predicted likelihood of past DACU, such that participants who felt they were not at increased risk of accident when DACU were more likely to report past-year DACU. [116-118] In one study, 51% of those who hadn't engaged in DACU thought having an accident was likely or very likely while DACU, compared to 24% who had engaged in DACU.[119] Similarly, in another study, the majority of participants reported that they would be likely to continue DACU even if they were convinced it increased their accident risk.[120]

In regards to the correlation of perceptions of legal risk with DACU activity, some studies have found that those who have engaged in DACU are more likely to perceive there to be a higher likelihood of getting caught. In one study, 36% of those who hadn't engaged in DACU perceived it likely or very likely to get caught by police compared to 21% of those who had engaged in DACU in the past 6 months.[121] The percentages pertaining to perception of getting caught for driving after drinking alcohol were much higher for both those who had and hadn't engaged in that behaviour (76% vs. 68%). Knowledge of law also appears to be related to DACU activity: drivers who reported having driven within an hour of using marijuana in the past year were less likely to believe that their state had a *per se* law for marijuana than those who did not report this behaviour (29.8% vs. 46.9%), and were more likely to believe that their state did not have such a law (15.1% vs. 2.1%).[122] However, despite this significant difference in perception of legal risk for those who have engaged in DACU and those who haven't, legal risk perception was not found to contribute significantly to DACU, with crash risk perception being a more important contributor. [123,124] In one study indicating that perception of legal risk does not deter DACU, a high expectation of getting ticketed or charged in the next 12 months was found to be associated with engaging more frequently in DACU activity.[125] Conversely, in another study, participants reported that increasing the certainty but not severity of punishment would produce reductions in DACU.[126]

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[116] Jones CG, Swift W, Donnelly NJ, Weatherburn DJ. Correlates of driving under the influence of cannabis. Drug and alcohol dependence. 2007 Apr 17;88(1):83-6.

[117] Kelly E, Darke S, Ross J. A review of drug use and driving: epidemiology, impairment, risk factors and risk perceptions. Drug and alcohol review. 2004 Sep 1;23(3):319-44.

[118] Matthews AJ, Bruno R, Dietze P, Butler K, Burns L. Driving under the influence among frequent ecstasy consumers in Australia: Trends over time and the role of risk perceptions. Drug and alcohol dependence. 2014 Nov 1;144:218-24.

[119] Matthews A, Bruno R, Johnston J, Black E, Degenhardt L, Dunn M. Factors associated with driving under the influence of alcohol and drugs among an Australian sample of regular ecstasy users. Drug and alcohol dependence. 2009 Feb 1;100(1):24-31.

[120] Jones C, Donnelly N, Swift W, Weatherburn D. Preventing cannabis users from driving under the influence of cannabis. Accident Analysis & Prevention. 2006 Sep 30;38(5):854-61.

[121] Matthews A, Bruno R, Johnston J, Black E, Degenhardt L, Dunn M. Factors associated with driving under the influence of alcohol and drugs among an Australian sample of regular ecstasy users. Drug and alcohol dependence. 2009 Feb 1;100(1):24-31.

[122] Arnold LS, Tefft BC. Driving Under the Influence of Alcohol and Marijuana: Beliefs and Behaviors, United States, 2013-2015. Washington (DC): AAA Foundation for Traffic Safety; 2016 May.

[123] Jones CG, Swift W, Donnelly NJ, Weatherburn DJ. Correlates of driving under the influence of cannabis. Drug and alcohol dependence. 2007 Apr 17;88(1):83-6.

[124] Matthews AJ, Bruno R, Dietze P, Butler K, Burns L. Driving under the influence among frequent ecstasy consumers in Australia: Trends over time and the role of risk perceptions. Drug and alcohol dependence. 2014 Nov 1;144:218-24.

[125] Fischer B, Ivsins A, Rehm J, Webster C, Rudzinski K, Rodopoulos J, Patra J. Factors Associated with High-Frequency Cannabis Use and Driving among a Multi-site Sample of University Students in Ontario 1. Canadian journal of criminology and criminal justice. 2014 Feb;56(2):185-200.

[126] Jones C, Donnelly N, Swift W, Weatherburn D. Preventing cannabis users from driving under the influence of cannabis. Accident Analysis & Prevention. 2006 Sep 30;38(5):854-61.

Summary and Conclusions

The evidence shows that many cannabis users make a distinction between intoxication from cannabis and its influence on their ability to drive. Most consider their driving to be only slightly impaired, and some believe it may be improved. These differences may reflect actual differences in individuals' impairment levels. Cannabis users also have a perception that tolerance levels and experience enable them to control their driving behavior despite intoxication. Likewise, there is a prominent perception that DACU does not increase the risk of accidents, with more than 50% of cannabis users holding that belief. However, there is still a low level of acceptance of driving within an hour after using cannabis. Beliefs regarding driving risk are influenced by age, gender, use of cannabis, and driving behaviour. Those who believe that driving post-cannabis use is not risky are more likely to have driven after using cannabis. It may be that those who have a lower perception of risk are more likely to engage in DACU regardless of their impairment level, or it may be that those who engage in that behaviour indeed are less impaired by their use of cannabis, and are making decisions based on an accurate assessment of their impairment. Most cannabis users perceive a low level of legal risk and have a low level of knowledge about the laws; these are both correlated to DACU activity. However, perception of legal risk does not does contribute significantly to DACU or its frequency; rather, perception of accident risk is a more important contributor. Legalization provides a good opportunity to shift the concern with illegality of the substance itself to the illegality and risks of DACU.

7. Detection of cannabis-related impaired driving

In most countries of North America and Europe, legal systems give police the role of identifying impairment of driving capacity by alcohol or other drugs. Identification of drug-related impairment, through impairment testing and biological testing, is intended to provide a critical tool for identifying dangerous drivers before accidents happen or imposing penalties for the consequences of accidents caused by impaired drivers. These tests are also meant to act as deterrents to engaging in driving after use of drugs.

a. Observational impairment testing

Impairment testing involves *screening* for drug impairment with roadside testing followed by *confirmation* through a process of careful testing by a trained expert (a police officer trained to detect impairment related to substance use).[127]

The most widely used driving impairment screening test is the Standardized Field Sobriety Test (SFST).[128] The SFST is used for roadside screening; it was developed for the detection of driving impairment related to alcohol use and has in recent years been extended to impairment related to use of other drugs, including cannabis. It involves three observational tests administered by police officers at roadside: Horizontal Gaze Nystagmus (involuntary jerking of the eyes), Walk and Turn and One Leg Stand. Confirmation of cannabis-related impairment is done by a Drug Recognition Expert at the police station via a more detailed evaluation (confirmation) (known as the DRE or DEC procedure). The DRE includes observation of "a variety of readily observable signs and symptoms that are accepted in the medical community as reliable indicators of drug influence" including pulse, blood pressure, body temperature, pupil size, reaction to light, psychomotor function, ocular tracking, smooth pursuit and nystagmus.[129]

Extensive research has been conducted to establish the validity of these procedures, both using data from "field" situations in which drivers were apprehended for suspicion of drug-influenced driving and from laboratory studies using simulators (designed to recreate the conditions of driving and require the same set of skills – see Section 4). The field research is subject to inherent biases, rendering its findings questionable (See Appendix A). By contrast, laboratory research is able to control for these biases (for example, ensuring that raters have access only to data from the test rather than information such as indications of cannabis use, which creates the risk of confirmation bias) and objectively assess the validity of these procedures. It must be noted however that laboratories are artificial environments and so cannot fully predict behaviour in natural settings.

A number of validation studies have been done, examining the *sensitivity* of these procedures to (a) the presence or level of THC or (b) behavioral impairment in a driving simulation task; as well as *specificity*, ability to accurately identify when THC was not present or impairment was not evident.[130-133] A detailed discussion of the research literature concerning validation of these observational tests of impairment is

[127] Wille SM, Ramírez-Fernández MD, Samyn N, De Boeck G. Conventional and alternative matrices for driving under the influence of cannabis: recent progress and remaining challenges. Bioanalysis. 2010 Apr;2(4):791-806.
[128] Porath-Waller AJ, Beirness DJ. An examination of the validity of the standardized field sobriety test in detecting drug impairment using data from the drug evaluation and classification program. Traffic injury prevention. 2014 Feb 17;15(2):125-31. Page 125.
[129] Talpins SK, Hayes C. Drug Evaluation and Classification (DEC) Program: Targeting Hardcore Impaired Drivers. American Prosecutors Research Institute; 2004.
[130] Beirness DJ, LeCavalier J, Singhal D. Evaluation of the drug evaluation and classification program: a critical review of the evidence. Traffic injury prevention. 2007 Oct 25;8(4):368-76.
[131] Bosker WM, Kuypers KP, Theunissen EL, Surinx A, Blankespoor RJ, Skopp G, Jeffery WK, Walls H, Leeuwen CJ, Ramaekers JG. Medicinal Δ9-tetrahydrocannabinol (dronabinol) impairs on-the-road driving performance of occasional and heavy cannabis users but is not detected in Standard Field Sobriety Tests. Addiction. 2012;107(10):1837-44.
[132] Shinar D, Schechtman E. Drug identification performance on the basis of observable signs and symptoms. Accident Analysis & Prevention. 2005 Sep 30;37(5):843-51.
[133] Stough D, Boorman M, Ogden E, Papafotiou K. An evaluation of the Standardised Field Sobriety Tests for the detection of impairment associated with cannabis with and without alcohol. National Drug Law Enforcement Research Fund; 2006.

presented in Appendix A. A clear finding emerges from this literature: while these observational tests may indeed identify impairment, they fail to meet minimal standards for sensitivity or specificity for identifying impairment related to cannabis use. As such, these tests do not satisfy fundamental criteria of test validity, especially given that these tests have serious implications for individuals designated as impaired and are meant to be used as tools to improve road safety.

b. Biological testing

An alternative to observational testing to detect driving impairment in individuals who may have used cannabis is biological testing to specify a level of cannabis in the blood that has been reliably linked to impaired driving capacity. In this case, the cannabis level in blood or oral fluid is used as a proxy for impairment, much as breathalyzer findings are used as a proxy in drivers suspected of alcohol-related impairment.

i. Blood testing

This involves testing whole blood or serum/plasma for a set concentration of THC that has been shown to indicate impairment of safe driving capacity in most individuals. Plasma is the liquid component of blood after all the cells and platelets have been removed, while plasma also has the coagulation factors removed.[134] Plasma and serum will have a concentration of THC twice that of the original whole blood sample. This allows physiological measurement to be used as a proxy for functional impairment and avoids many of the methodological issues found with observational impairment testing. This approach has been used with alcohol for many years: establishing a level of alcohol in the body that leads to impaired driving capacity in most individuals, then identifying drivers with a blood-alcohol level above the established criterion. Certain physiological measurements may be taken at the roadside and serve as screening procedures (i.e., a breathalyzer) while all other measurements are carried out at the police station or hospital (i.e., blood test). Use of Blood Alcohol Level as a proxy for functional impairment has proven successful in managing the risk associated with intoxicated driving and it is incorporated into legislation in many jurisdictions.[135] Laws that specify a level of a substance considered unsafe for driving are known as *per se* laws, "which make it a criminal offense for an individual to have a specified amount of drug or metabolite in his or her body while operating a motor vehicle."[136]

One line of research has been devoted to determining whether there is a level of measurable cannabis within the body corresponding to the set .05 level for alcohol, that is to identify a "danger cut-off".[137] Amounts that have been found to be associated with substantial driving impairment, particularly in occasional users, range from 2-5 ng/ml in whole blood or 7-10 ng/mL in serum.[138] This includes a margin of error to prevent “misclassification of drivers presenting with THC residues from previous cannabis use" and to "spare drivers with low but measurable THC concentrations caused by passive exposure… or oral intake of low THC doses for medicinal purposes."[139,140]

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[134] “Plasma and Serum.” *Boundless Biology*. Boundless, 08 Aug. 2016. Retrieved 06 Nov. 2016 from https://www.boundless.com/biology/textbooks/boundless-biology-textbook/the-circulatory-system-40/components-of-the-blood-225/plasma-and-serum-850-12095/

[135] Hingson R, Heeren T, Winter M. Effects of recent 0.08% legal blood alcohol limits on fatal crash involvement. Injury Prevention. 2000 Jun 1;6(2):109-14.

[136] Wong K, Brady JE, Li G. Establishing legal limits for driving under the influence of marijuana. Injury epidemiology. 2014 Oct 29;1(1):26. P. 2

[137] Wille SM, Ramírez-Fernández MD, Samyn N, De Boeck G. Conventional and alternative matrices for driving under the influence of cannabis: recent progress and remaining challenges. Bioanalysis. 2010 Apr;2(4):791-806.

[138] Hartman RL, Huestis MA. Cannabis effects on driving skills. Clinical chemistry. 2013 Mar 1;59(3):478-92.

[139] Grotenhermen F, Leson G, Berghaus G, Drummer OH, Krüger HP, Longo M, Moskowitz H, Perrine B, Ramaekers JG, Smiley A, Tunbridge R. Developing limits for driving under cannabis. Addiction. 2005 Dec 1;102(12):1910-7. P. 1916.

[140] Wolff K, Brimblecombe R, Forfar JC, Forrest AR, Gilvarry E, Johnston A, Morgan J, OSSELTON M, Read L, Taylor D. Driving under the influence of drugs: report from the Expert Panel on Drug Driving.

With regard to designated legal limits, some jurisdictions have set per se levels for cannabis in relation to driving that are consistent with this recommendation (e.g., in Colorado the legal THC limit in whole blood is 5 ng/mL).[141] In certain other jurisdictions, such as Australia, a zero tolerance policy is in effect, "a special form of the per se law in which the legal limit is set at zero or the minimum reliably detectable level."[142]

Experts have been split with regard to these two approaches. One group of experts, as noted above, call for a per se "danger level" concentration shown to be indicative of impairment according to epidemiological and laboratory evidence. Others have challenged this view, advocating a per se limit at the *minimum detectable* level.

For example, a research group affiliated with the AAA Foundation for Traffic Safety examined data from drivers who had been arrested for suspected driving under the influence of cannabis and who then received an evaluation of drug-induced impairment by a DRE, as described above.[143] The researchers compared results of the DRE exam to THC concentration on blood testing: "we evaluated whether the… indicators from the DRE exam could predict THC concentration above or below a 5 ng/mL threshold and they could not": they conclude that no threshold for THC concentration is a meaningful indicator of impairment since DRE-evaluated impairment is not related to THC concentration. However, our previous discussion of the DRE examination concluded that it is not a valid indicator of cannabis-related impairment, so one would not expect it to be sensitive to different levels of THC concentration. In fact, the lack of relationship between DRE-rated impairment and THC blood concentration is consistent with the argument that the DRE is invalid for assessment of cannabis-related impairment.

These authors further observe that, of those arrested for "suspected impaired driving" who showed only THC (no other drugs or alcohol), only 49% had THC blood concentrations above the 5 ng/mL level – the authors take this as further evidence against the feasibility of a quantitative threshold for cannabis impairment. However, this is not the only way to interpret this finding, nor indeed the most plausible: one might equally suggest that police officers are responding to driver characteristics marginally related to actual driving impairment (for example, young males with bloodshot eyes, smell of cannabis, drug paraphernalia or presence of drug)[144] so that half of the arrested drivers are not actually impaired.

Other researchers as well have argued forcefully against the feasibility of determining a threshold of THC concentration denoting driving impairment.[145,146] They argue that drug impairment cannot be determined by specific concentrations (as it can be for alcohol) because:

- *Frequent users of cannabis develop tolerance, resulting in "less impairment among frequent users than infrequent users at a given THC dose".*[147]
- *There may be a poor correlation between concentration of cannabis at the time of driving and subsequent blood testing*. That is, THC concentrations may be much less at the time of blood collection than at the time of the index event. (Note that while this is a pragmatic difficulty, it not

[141] Lacey J, Brainard K, Snitow S. Drug per se laws: A review of their use in States. 2010 Jul.
[142] Wong K, Brady JE, Li G. Establishing legal limits for driving under the influence of marijuana. Injury epidemiology. 2014 Oct 29;1(1):26. P. 3.
[143] Logan B, Kacinko SL, Beirness DJ. An Evaluation of Data from Drivers Arrested for Driving Under the Influence in Relation to per se Limits for Cannabis (May 2016). Washington, DC: American Automobile Association Foundation for Traffic Safety. 2016.
[144] Jones AW, Holmgren A, Kugelberg FC. Driving under the influence of cannabis: a 10-year study of age and gender differences in the concentrations of tetrahydrocannabinol in blood. Addiction. 2008 Mar 1;103(3):452-61. P. 458.
[145] DuPont R. Marijuana Use is a Serious Highway Safety Threat: 5 ng/ml Marijuana Impairment Limits Give Drivers a Free Pass to Drive Stoned. Institute for Behavior and Health, Inc., http://www.ibhinc.org/pdfs/IBHCommentaryMarijuanaandDrugged-Driving61013.pdf 2013]
[146] Reisfield GM, Goldberger BA, Gold MS, DuPont RL. The mirage of impairing drug concentration thresholds: a rationale for zero tolerance per se driving under the influence of drugs laws. Journal of analytical toxicology. 2012 Jun 1;36(5):353-6.
[147] Reisfield GM, Goldberger BA, Gold MS, DuPont RL. The mirage of impairing drug concentration thresholds: a rationale for zero tolerance per se driving under the influence of drugs laws. Journal of analytical toxicology. 2012 Jun 1;36(5):353-6.

a meaningful objection to the identification of threshold concentration levels indicative of impairment).

- *Epidemiological studies have shown variable results regarding the relationship between cannabis concentration in the blood and measured impairment.*[148]
- *A significant proportion of cannabis-using drivers have consumed a combination of alcohol and cannabis, which has an additive effect*. This points to the need for measurement of both cannabis and alcohol concentrations rather than constituting an argument against using threshold levels of cannabis blood concentration to indicate impairment.
- *Only drivers who are impaired in driving capacity will be apprehended for testing: "*drivers are tested for drugs only after they are arrested for DUI, or alternatively, if they are involved in serious or fatal crashes".[149]

Other researchers argue against zero-tolerance laws based upon *minimal-detectable* levels of THC because:

- *Low levels of THC or its metabolites may be detected for a long time after use*, long after any impairing effects would be expected, so that individuals who are not in fact impaired by drug use would be subject to legal penalties.[150]
- *Forbidding any detectable levels of THC would be equivalent to treating all cannabis use as illegal*, contradicting the stated intention of the Canadian federal government to legalize cannabis use.[151]
- *Zero-tolerance laws may also target individuals passively exposed to cannabis smoke.*[152]

This research on blood testing remains at an early stage and is difficult to interpret so as to generate a precise comparison to the per se level set for alcohol. In order to establish a meaningful and appropriate per se level, this kind of data must be thoughtfully considered in light of anticipated costs and benefits to society.

ii. Oral fluid testing

Collecting oral fluid (OF) from drivers is a less invasive form of testing than taking a blood sample. It has been suggested that drivers be subject to saliva testing at the roadside with the aim of detecting cannabis-related impairment.[153-155]

There have been notable advancements in available technology for measuring THC levels in saliva[156], however while these tests have shown high levels of specificity, sensitivity is still relatively low.[157-160]

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[148] Armentano P. Cannabis and psychomotor performance: A rational review of the evidence and implications for public policy. Drug testing and analysis. 2013 Jan 1;5(1):52-6.

[149] DuPont R. Marijuana Use is a Serious Highway Safety Threat: 5 ng/ml Marijuana Impairment Limits Give Drivers a Free Pass to Drive Stoned. Institute for Behavior and Health, Inc., http://www.ibhinc.org/pdfs/IBHCommentaryMarijuanaandDrugged-Driving61013.pdf 2013. p.3.

[150] Armentano P. Should per se limits be imposed for cannabis? Equating cannabinoid blood concentrations with actual driver impairment: practical limitations and concerns. Humboldt Journal of Social Relations. 2013 Mar 1;35(1).

[151] Armentano P. Should per se limits be imposed for cannabis? Equating cannabinoid blood concentrations with actual driver impairment: practical limitations and concerns. Humboldt Journal of Social Relations. 2013 Mar 1;35(1).

[152] Cone JC et al. (2015). Non-Smoker Exposure to Second-hand Cannabis Smoke. I. Urine Screening and Confirmation Results Journal of Analytical Toxicology. 39:1–12.

[153] Asbridge M., Ogilve, R. A Feasibility Study of Roadside Oral Fluid Drug Testing. 2015 http://www.madd.ca/media/docs/feasibility-roadside-oral-fluid-drug-testing.pdf

[154] Chamberlain E, Solomon R, Murie A. Reforming Canada's new drug-impaired driving law: The need for per se limits and random roadside screening. International Conference on Alcohol, Drugs and Traffic Safety (T2013), 20th, 2013, Brisbane, Queensland, Australia 2013 Aug.

[155] Toennes SW, Steinmeyer S, Maurer HJ, Moeller MR, Kauert GF. Screening for drugs of abuse in oral fluid—correlation of analysis results with serum in forensic cases. Journal of analytical toxicology. 2005 Jan 1;29(1):22-7.

A challenge for assessing possible impairment from OF has been to establish a clear relationship between measured levels of THC, or its derivatives (e.g. THCCOOH or 11-OH- THC) or other cannabinoids (e.g. CBD, CBN) in oral fluid and levels of blood concentration. This is necessary, because most of the empirical data upon which presumptions of likely impairment have been based involved THC concentration in blood.

It appears that OF testing is subject to several confounding variables, and to extremely high inter-individual variability.[161,162] Overall, the research evidence demonstrates a low correlation between oral fluid and blood concentrations, suggesting oral fluid concentrations of THC **cannot** be extrapolated to blood concentrations. Milman et al. summarize the findings as follows:

> Dose, route, and frequency of cannabis exposure; smoking topography; time since last use; and OF-collection method also influence cannabinoid OF concentrations. Because of the high interindividual variation, the required equilibration time for cannabinoids in plasma and OF, and the differences in cannabinoid disposition in these 2 matrices, predicting plasma cannabinoid concentrations from OF concentrations cannot be scientifically supported.[163]

Thus, it is not possible to set a *per se* level for oral fluid that would indicate likely impairment. A detailed examination of research evidence bearing on this issue is presented in Appendix B.

It is important to note that oral fluid primarily detects THC or other cannabinoids from oral contamination from smoke. In some cases, the OF concentration could be quite high due to deposits in mouth from the use of an oral spray (e.g. Sativex)[164], or even passive environmental contamination.[165,166]

The window of detection is an important factor for assessing possible impaired driving, since impairment tends to occur in the first couple of hours after inhalation. This is of particular concern for more regular cannabis users, for whom detection of cannabinoids in OF may not reflect recent use since they have higher initial concentrations of OF THC than occasional smokers, and low concentrations can be detectable for days in chronic users.[167-169]

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[156] Beirness DJ, Smith DA. An assessment of oral fluid drug screening devices. Canadian Society of Forensic Science Journal. 2016 Dec 1:1-9.

[157] Arnold LS, Scopatz RA. Advancing Drugged Driving Data at the State Level: Synthesis of Barriers and Expert Panel Recommendations. Washington (DC): AAA Foundation for Traffic Safety; 2016 March.

[158] Blencowe T, Pehrsson A, Lillsunde P, Vimpari K, Houwing S, Smink B, Mathijssen R, Van der Linden T, Legrand SA, Pil K, Verstraete A. An analytical evaluation of eight on-site oral fluid drug screening devices using laboratory confirmation results from oral fluid. Forensic Science International. 2011 May 20;208(1):173-9.

[159] Fierro I, González-Luque JC, Álvarez FJ. The relationship between observed signs of impairment and THC concentration in oral fluid. Drug and alcohol dependence. 2014 Nov 1;144:231-8.

[160] Verstraete AG. Oral fluid testing for driving under the influence of drugs: history, recent progress and remaining challenges. Forensic Science International. 2005 Jun 10;150(2):143-50.

[161] Yacoubian GS, Wish ED. A comparison between instant and laboratory oral fluid analysis among arrestees. Journal of psychoactive drugs. 2006 Jun 1;38(2):207-10.

[162] Lee D, Huestis MA. Current knowledge on cannabinoids in oral fluid. Drug testing and analysis. 2014 Jan 1;6(1-2):88-111.

[163] Milman G, Schwope DM, Schwilke EW, Darwin WD, Kelly DL, Goodwin RS, Gorelick DA, Huestis MA. Oral fluid and plasma cannabinoid ratios after around-the-clock controlled oral Δ9-tetrahydrocannabinol administration. Clinical chemistry. 2011 Nov 1;57(11):1597-606.

[164] Molnar A, Fu S. Techniques and technologies for the bioanalysis of Sativex®, metabolites and related compounds. Bioanalysis. 2016 Apr;8(8):829-45.

[165] Lee D, Huestis MA. Current knowledge on cannabinoids in oral fluid. Drug testing and analysis. 2014 Jan 1;6(1-2):88-111.

[166] Verstraete AG. Oral fluid testing for driving under the influence of drugs: history, recent progress and remaining challenges. Forensic Science International. 2005 Jun 10;150(2):143-50.

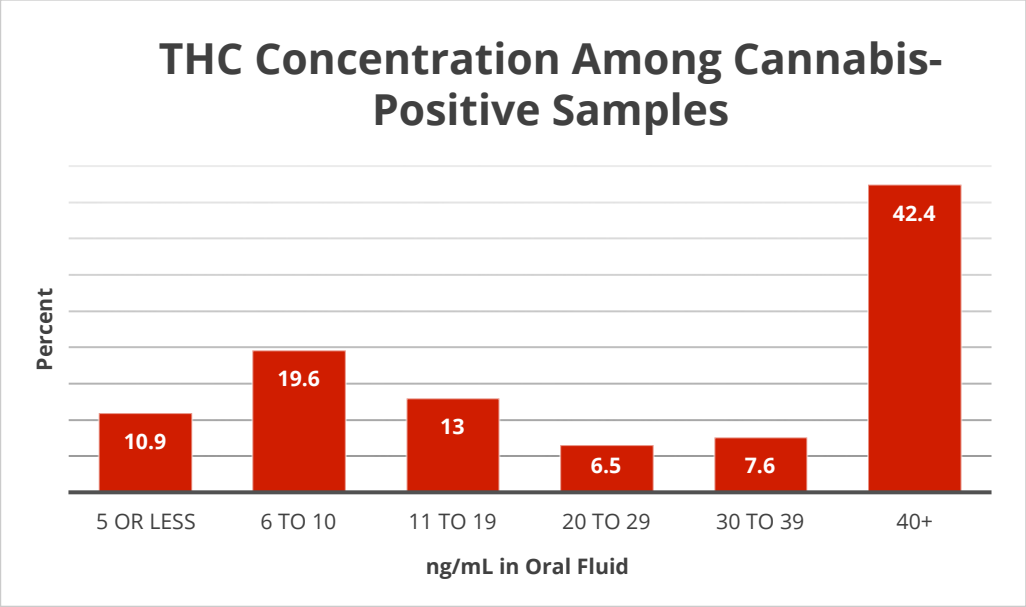
[167] Anizan S, Milman G, Desrosiers N, Barnes AJ, Gorelick DA, Huestis MA. Oral fluid cannabinoid concentrations following controlled smoked cannabis in chronic frequent and occasional smokers. Analytical and bioanalytical chemistry. 2013 Oct 1;405(26):8451-61.

[168] Lee D, Milman G, Barnes AJ, Goodwin RS, Hirvonen J, Huestis MA. Oral fluid cannabinoids in chronic, daily cannabis smokers during sustained, monitored abstinence. Clinical chemistry. 2011 Aug 1;57(8):1127-36.

[169] Lee D, Huestis MA. Current knowledge on cannabinoids in oral fluid. Drug testing and analysis. 2014 Jan 1;6(1-2):88-111.

Studies suggest that the detection of CBN and CBD would improve test interpretation in DUID, since these cannabinoids have a shorter window of detection than THC – however a lack of their detection does not necessarily mean no consumption has taken place.[170-172] Additionally, a high OF/plasma THC ratio and a high OFTHC/THCCOOH ratio (i.e. >10) may indicate recent cannabis smoking.[173] Increasing cut-off concentrations can also shorten detection windows.[174] Of note, study findings suggest that OF testing for THC will detect recent smoked but not recent oral THC intake, since ingested cannabis results in lower OF concentrations relative to plasma.[175,176]

The finding that THC levels in oral fluid cannot be extrapolated to blood levels is notable when we review the conclusions made from the 2010 BC Roadside Survey. Consider the following chart from that report (THC concentrations in oral fluid of cannabis-positive drivers):



[170] Anizan S, Milman G, Desrosiers N, Barnes AJ, Gorelick DA, Huestis MA. Oral fluid cannabinoid concentrations following controlled smoked cannabis in chronic frequent and occasional smokers. Analytical and bioanalytical chemistry. 2013 Oct 1;405(26):8451-61.
[171] Lee D, Milman G, Barnes AJ, Goodwin RS, Hirvonen J, Huestis MA. Oral fluid cannabinoids in chronic, daily cannabis smokers during sustained, monitored abstinence. Clinical chemistry. 2011 Aug 1;57(8):1127-36.
[172] Desrosiers NA, Lee D, Schwope DM, Milman G, Barnes AJ, Gorelick DA, Huestis MA. On-site test for cannabinoids in oral fluid. Clinical chemistry. 2012 Oct 1;58(10):1418-25.
[173] Milman G, Schwope DM, Schwilke EW, Darwin WD, Kelly DL, Goodwin RS, Gorelick DA, Huestis MA. Oral fluid and plasma cannabinoid ratios after around-the-clock controlled oral Δ9-tetrahydrocannabinol administration. Clinical chemistry. 2011 Nov 1;57(11):1597-606.
[174] Lee D, Huestis MA. Current knowledge on cannabinoids in oral fluid. Drug testing and analysis. 2014 Jan 1;6(1-2):88-111.
[175] Milman G, Schwope DM, Schwilke EW, Darwin WD, Kelly DL, Goodwin RS, Gorelick DA, Huestis MA. Oral fluid and plasma cannabinoid ratios after around-the-clock controlled oral Δ9-tetrahydrocannabinol administration. Clinical chemistry. 2011 Nov 1;57(11):1597-606.
[176] Molnar A, Fu S. Techniques and technologies for the bioanalysis of Sativex®, metabolites and related compounds. Bioanalysis. 2016 Apr;8(8):829-45.

The researchers who conducted this roadside survey state that “Using oral fluid as the test medium provides THC concentrations that are reflective of the concentration of THC in blood”. They conclude that "THC concentrations reported indicate that the vast majority of drivers who have used cannabis have consumed sufficient cannabis to impair their ability to operate a vehicle safely."[177] However, if the oral fluid levels cannot be extrapolated to blood levels, then nothing can be concluded either about blood levels or about the likely impairment of the cannabis-positive drivers in this study.

c. Implications for medical use

Expert panels explicitly looking at biological testing took into account the risk of inadvertently entangling medicinal cannabis users in the net of legal enforcement, setting per se levels to minimize that risk.[178]

Others note that zero tolerance laws would criminalize those using cannabis in a controlled manner for medicinal purposes.[179] In many jurisdictions, it is understood that using a drug prescribed by their physician should not be the basis for a criminal charge: "The suggested legislative limits will not be applicable to drivers with a valid prescription for the detected drugs, where…the drugs have been taken as prescribed."[180]

To maintain perspective on medicinal use in relation to driving consider this discussion of how to apply driving impairment criteria to the use of benzodiazepines, another psychotropic drug used medicinally:

> There is significant evidence that benzodiazepines affect negatively driving ability. Suggestions on how the problem of driving under the influence of benzodiazepines should be faced are made. Both physicians and pharmacists should advise their patients of the impairing effects of benzodiazepines, particularly in relation to drowsiness and sedation, and the implication of these effects on driving skills. Zero tolerance legislation for benzodiazepines seems impracticable as these drugs are used extensively. The implementation of per se legislation by adopting legal limits would more properly secure traffic safety.[181]

It is also important to note that medical cannabis users use cannabis, like other medications, to address symptoms, like reducing pain or relieving anxiety. This symptom management allows them to function normally, and some may feel it enables them to drive more safely.

Forms of medical cannabis, like other prescription drugs, have warning labels which include information on impairment and driving. For example, the following safety information is given for the cannabinoid medication Sativex:

"Patients should be advised that if they do drink alcohol while using Sativex the additive CNS effects may impair their ability to drive or use machines, and increase the risk of falls.”[182]

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[177] Beirness, D.J., & Beasley, E.E. Alcohol and drug use among drivers: British Columbia Roadside Survey 2010. Ottawa, ON: Canadian Centre on Substance Abuse. 2011. P. 13.

[178] Grotenhermen F, Leson G, Berghaus G, Drummer OH, Krüger HP, Longo M, Moskowitz H, Perrine B, Ramaekers J, Smiley A, Tunbridge11 R. Developing science-based per se limits for driving under the influence of cannabis (DUIC). Findings and recommendations by an expert panel. Hürth, Germany: Nova-Institut. 2005 Sep.

[179] Marijuana Policy Project. Driving Under the Influence Laws and Medical Marijuana Patients: Zero Room for “Zero Tolerance”. N.d. Washington, DC. Retrieved from www.mpp.org

[180] Vindenes V, Jordbru D, Knapskog AB, Kvan E, Mathisrud G, Slørdal L, Mørland J. Impairment based legislative limits for driving under the influence of non-alcohol drugs in Norway. Forensic Science International. 2012 Jun 10;219(1):1-1. P. 8.

[181] Papoutsis I, Khraiwesh A, Nikolaou P, Spiliopoulou C, Athanaselis S. Benzodiazepines and driving pharmacological and legal aspects. Eur J Forensic Sci. Jan-Mar. 2016;3(1):1.

[182] Electronic Medicines Compendium (EMC.). Sativex Oromucosal Spray. Datapharm Ltd. 2016. https://www.medicines.org.uk/emc/medicine/23262

There is also additional safety information provided for Sativex by the electronic Medicine Compendium (eMC). The information given that pertains to impairment and driving is as follows:

> Effects on ability to drive and use machines:
>
> Sativex may produce undesirable effects such as dizziness and somnolence which may impair judgement and performance of skilled tasks. Patients should not drive, operate machinery or engage in any hazardous activity if they are experiencing any significant CNS effects such as dizziness or somnolence. Patients should be aware that Sativex has been known to cause a few cases of loss of consciousness.
>
> (UK Only)
>
> This medicine can impair cognitive function and can affect a patient's ability to drive safely. This class of medicine is in the list of drugs included in regulations under 5a of the Road Traffic Act 1988. When prescribing this medicine, patients should be told:
>
> - The medicine is likely to affect your ability to drive
> - Do not drive until you know how the medicine affects you
> - It is an offence to drive while under the influence of this medicine
> - However, you would not be committing an offence (called 'statutory defence') if:
>   - The medicine has been prescribed to treat a medical or dental problem and
>   - You have taken it according to the instructions given by the prescriber and in the information provided with the medicine and
>   - It was not affecting your ability to drive safely

Summary and Conclusions

A considerable body of research has evaluated observational impairment tests under controlled conditions and has demonstrated that they fail to meet minimal standards for sensitivity or specificity. These tests do not satisfy the fundamental criteria for test validity, particularly where there are serious implications for individuals designated as impaired.

An alternative to use of observational tests to detect impaired driving capacity in individuals who may have used cannabis is to specify a blood concentration of cannabis (generally defined as a certain concentration of THC in whole blood or blood serum) that has been reliably linked to impaired driving capacity. This approach allows physiological measurement to be used as a proxy for functional impairment. The research data supports the specification of a threshold level of THC concentration in blood that may be taken to indicate driving impairment, with *7-10 ng/mL in serum* as a defensible level. This level has been recommended by expert panels and it is designed to minimize the risk of entangling medicinal cannabis users in the net of legal enforcement. Medical cannabis medications, like other prescription medications, can use label warnings and advice from a medical professional to educate the patient about the medicine's effect on their driving ability. However, blood testing remains at an early stage and is difficult to interpret so as to generate a precise comparison to the per se level set for alcohol.

A recent development has been the testing of oral fluid, with the hope that it could serve as a roadside test that would be a proxy for impairment through its correlation with blood levels of THC. However, research has shown that oral fluid concentrations of THC cannot be extrapolated to blood concentrations so that it is not possible to set a *per se* level for oral fluid that would indicate likely impairment due to cannabis use. To establish a meaningful and appropriate per se level for biological testing, this kind of data must be thoughtfully considered in light of anticipated costs and benefits to society.

8. Risk mitigation

Cannabis users employ different approaches to mitigate potential risks of DACU. Some, recognizing the risk, use behavioural strategies ranging from not driving to employing compensatory driving tactics, to substituting alcohol for cannabis. Norms have also been developed in the cannabis-use culture that promote such behavioural strategies.

a. Behaviours related to driving

Behavioural strategies to minimize potential risks associated with DACU include waiting a certain amount of time before driving, employing driving practices believed to compensate for potential impairment and using alternate transportation options.

i. Waiting time

One way to mitigate potential risks of cannabis-impaired driving is ensuring a minimum interval of time between cannabis use and driving. Researchers and policymakers have recommended varying lengths of time between use of cannabis and driving, based on their understanding of the demonstrated risks and the margin of safety they believe should be allowed. Some reviews recommend a minimum interval of 3 to 4 hours between cannabis use and driving, since acute impairment from cannabis use typically clears by that time.[183,184] Others note the majority of impairment occurs in the first 2 hours, and suggest that as a recommended time to wait.[185,186] On the other end of the spectrum, one review concluded that it was recommended that patients using cannabis for medical reasons should abstain from driving for 8 hours after use if they observe a subjective "high".[187] In interviews of recreational users of cannabis, many reported delaying driving after using cannabis, but few would allow an interval greater than 30 minutes--their major concern was to avoid legal consequences rather than to avoid a crash; they used it before driving so they wouldn't have to take it with them.[188]

In relation to alcohol, advice for drinking and driving suggests that it takes a healthy liver an hour to metabolize one standard drink. It is recognized that other factors must also be taken into consideration for alcohol-related impairment, such as weight, gender and amount of food in stomach. Likewise, with cannabis, the specific product consumed, the dosage, potency, mode of ingestion, use of other substances, as well as user characteristics will influence impairment.[189] It should be noted that in regards to inhaled cannabis, the effects are relatively short-lived and subtle compared to alcohol impairment. We found no data indicating whether users recognize the different waiting times relevant for oral ingestion vs. inhalation, reflecting the unique pharmacokinetics of these modes of use. Additionally, cannabis users should

[183] Armentano P. Cannabis and psychomotor performance: A rational review of the evidence and implications for public policy. Drug testing and analysis. 2013 Jan 1;5(1):52-6.
[184] Fischer B, Ivsins A, Rehm J, Webster C, Rudzinski K, Rodopoulos J, Patra J. Factors Associated with High-Frequency Cannabis Use and Driving among a Multi-site Sample of University Students in Ontario 1. Canadian journal of criminology and criminal justice. 2014 Feb;56(2):185-200.
[185] Fischer B, Dawe M, McGuire F, Shuper PA, Capler R, Bilsker D, Jones W, Taylor B, Rudzinski K, Rehm J. Feasibility and impact of brief interventions for frequent cannabis users in Canada. Journal of substance abuse treatment. 2013 Jan 31;44(1):132-8.
[186] Ramaekers JG, Moeller MR, van Ruitenbeek P, Theunissen EL,Schneider E, Kauert G (2006) Cognition and motor control as a function of Delta9-THC concentration in serum and oral fluid: limitsof impairment. Drug Alcohol Depend 85(2):114–122.
[187] Neavyn MJ, Blohm E, Babu KM, Bird SB. Medical marijuana and driving: a review. Journal of medical toxicology. 2014 Sep 1;10(3):269-79.
[188] Davey J, Davies A, French N, Williams C, Lang CP. Drug driving from a user's perspective. Drugs: education, prevention and policy. 2005 Feb 1;12(1):61-70.
[189] Fischer B, Ivsins A, Rehm J, Webster C, Rudzinski K, Rodopoulos J, Patra J. Factors Associated with High-Frequency Cannabis Use and Driving among a Multi-site Sample of University Students in Ontario 1. Canadian journal of criminology and criminal justice. 2014 Feb;56(2):185-200.

be aware of the cumulative effects of use with alcohol and other prescription or nonprescription drugs.[190]

ii. Driving practices

Some cannabis users decide to drive after using cannabis despite intoxication, with the belief that they are able to compensate for any impairment through driving practices. Some strategies they use to compensate are driving more slowly, passing less, taking fewer risks, maintaining greater concentration, and leaving more space between themselves and cars in front of them.[191-194] Indeed, individuals assessed post-cannabis use in some driving simulation studies did show a marked tendency to drive more slowly and in a more cautious manner to compensate for their perceived impairment.[195] This is effective, until task complexity increases, when it may no longer be sufficient to overcome risk.[196] Combining marijuana with alcohol reduces the ability to use such strategies effectively, and results in impairment even at doses that would be insignificant for either drug alone.[197]

Habitual users seem more likely to apply compensatory strategies (reduced driving speed, extra caution) to mitigate negative impacts.[198-200] While some cannabis users believe drug tolerance compensates for drug effects and that experience enables them to manage drug use and maintain their driving abilities,[201] at least one study found that regular cannabis users displayed more driving errors than non-regular cannabis users.[202]

iii. Transportation options

Cannabis users can mitigate risks from driving after cannabis use by making wise decisions about transportation options. Deciding not to drive after using cannabis and choosing alternate transportation options is, of course, the safest approach, and many cannabis users endorse this response.[203] It appears, however, that the more frequently a person uses cannabis, the more likely they will drive after using

[190] Neavyn MJ, Blohm E, Babu KM, Bird SB. Medical marijuana and driving: a review. Journal of medical toxicology. 2014 Sep 1;10(3):269-79.
[191] Ménétrey A, Augsburger M, Favrat B, Pin MA, Rothuizen LE, Appenzeller M, Buclin T, Mangin P, Giroud C. Assessment of driving capability through the use of clinical and psychomotor tests in relation to blood cannabinoids levels following oral administration of 20 mg dronabinol or of a cannabis decoction made with 20 or 60 mg Δ9-THC. Journal of analytical toxicology. 2005 Jul 1;29(5):327-38.
[192] Huestis MA. Cannabis(Marijuana)- Effects on Human Behavior and Performance. Forensic science review. 2002 Jan;14(1):15-60. P.43.
[193] Senate Special Committee on Illegal Drugs. Cannabis: Our position for a Canadian public policy. Parliament of Canada, 2003. Retrieved from http://www.parl.gc.ca/content/sen/committee/371/ille/rep/repfinalvol1part4-e.htm#TOP
[194] Sewell RA, Poling J, Sofuoglu M. The effect of cannabis compared with alcohol on driving. American journal on addictions. 2009 Jan 1;18(3):185-93.
[195] Ronen A, Gershon P, Drobiner H, Rabinovich A, Bar-Hamburger R, Mechoulam R, Cassuto Y, Shinar D. Effects of THC on driving performance, physiological state and subjective feelings relative to alcohol. Accident Analysis & Prevention. 2008 May 31;40(3):926-34.
[196] Hartman RL, Huestis MA. Cannabis effects on driving skills. Clinical chemistry. 2013 Mar 1;59(3):478-92.
[197] Sewell RA, Poling J, Sofuoglu M. The effect of cannabis compared with alcohol on driving. American journal on addictions. 2009 Jan 1;18(3):185-93.
[198] Desrosiers NA, Ramaekers JG, Chauchard E, Gorelick DA, Huestis MA. Smoked cannabis' psychomotor and neurocognitive effects in occasional and frequent smokers. Journal of analytical toxicology. 2015 May 1;39(4):251-61.
[199] Ramaekers JG, Kauert G, Theunissen EL, Toennes SW, Moeller MR. Neurocognitive performance during acute THC intoxication in heavy and occasional cannabis users. Journal of psychopharmacology. 2008 Aug 21.
[200] Schwope DM, Bosker WM, Ramaekers JG, Gorelick DA, Huestis MA. Psychomotor performance, subjective and physiological effects and whole blood Δ9-tetrahydrocannabinol concentrations in heavy, chronic cannabis smokers following acute smoked cannabis. Journal of analytical toxicology. 2012 Jul 1;36(6):405-12.
[201] Davey J, Davies A, French N, Williams C, Lang CP. Drug driving from a user's perspective. Drugs: education, prevention and policy. 2005 Feb 1;12(1):61-70.
[202] Downey LA, King R, Papafotiou K, Swann P, Ogden E, Boorman M, Stough C. The effects of cannabis and alcohol on simulated driving: influences of dose and experience. Accident Analysis & Prevention. 2013 Jan 31;50:879-86.
[203] Ménétrey A, Augsburger M, Favrat B, Pin MA, Rothuizen LE, Appenzeller M, Buclin T, Mangin P, Giroud C. Assessment of driving capability through the use of clinical and psychomotor tests in relation to blood cannabinoids levels following oral administration of 20 mg dronabinol or of a cannabis decoction made with 20 or 60 mg Δ9-THC. Journal of analytical toxicology. 2005 Jul 1;29(5):327-38.

cannabis, or be a passenger with someone who has used cannabis and alcohol, rather than use alternatives.

A study exploring the use of different forms of transport to and from nightlife environments and the relationships between traffic risk behaviors, drunkenness, and drug consumption found that individuals using cannabis most frequently are most likely to use a private automobile to attend, and leave, recreational nightlife: this is particularly true for men.[204] The authors conclude that when designing initiatives to increase the use of public transport, it may not be enough to ensure a good availability of public transport at night, but initiatives should also influence the personal and social values associated with use of a private car (i.e., being adult, higher social status, increased possibilities to get a sexual partner, etc.).

It is also important to address choices made by passengers. One study we looked at examined the decision to ride with a cannabis-influenced driver and found that this to be most likely for age groups under 45, particularly those aged 18-24; those over 65 were least likely to drive with someone who had used cannabis.[205] It was also found that those who had themselves driven while cannabis-influenced were 6 times more likely to ride with a cannabis-influenced driver; the factor that most influenced this decision was scoring as moderate/high risk on a scale of cannabis use, with an eightfold increase in willingness to drive with a cannabis-influenced driver. There was also a strong association between riding with a drunk driver and riding with a cannabis-influenced driver.

b. Substitution for alcohol and other drugs

Given the much higher risk associated with driving after the use of alcohol and other drugs, it is a meaningful source of risk mitigation for drivers to replace these substances with cannabis. There is survey evidence indicating that this kind of substitution occurs fairly often with regards to alcohol, as well as illicit substances and prescription drugs, including heroin, pharmaceutical opiates, and crack cocaine.[206-214]

[204] Calafat A, Blay N, Juan M, Adrover D, Bellis MA, Hughes K, Stocco P, Siamou I, Mendes F, Bohrn K. Traffic risk behaviors at nightlife: drinking, taking drugs, driving, and use of public transport by young people. Traffic injury prevention. 2009 Mar 31;10(2):162-9.
[205] Cartwright J, Asbridge M. Passengers' Decisions to Ride With a Driver Under the Influence of Either Alcohol or Cannabis. Journal of Studies on Alcohol and drugs. 2011 Jan;72(1):86-95.
[206] Aharonovich E, Garawi F, Bisaga A, Brooks D, Raby WN, Rubin E Australian Institute of Health and Welfare 2001 National Drug Strategy Household Survey: First results. Canberra (Australia) Australian Institute of Health and Welfare; 2002. Report No.: PHE35.
[207] Aharonovich E, Garawi F, Bisaga A, *et al*. Concurrent cannabis use during treatment of comorbid ADHD and cocaine dependence: effects and outcome. Am J Drug Alcohol Abuse 2006;32:629–35.
[208] Lucas P. Cannabis as an adjunct to or substitute for opiates in the treatment of chronic pain. Journal of psychoactive drugs. 2012 Apr 1;44(2):125-33.
[209] Lucas P, Reiman A, Earleywine M, McGowan SK, Oleson M, Coward MP, Thomas B. Cannabis as a substitute for alcohol and other drugs: A dispensary-based survey of substitution effect in Canadian medical cannabis patients. Addiction Research & Theory. 2013 Oct 1;21(5):435-42.
[210] Lucas P, Walsh Z, Crosby K, Callaway R, Belle-Isle L, Kay R, Capler R, Holtzman S. Substituting cannabis for prescription drugs, alcohol and other substances among medical cannabis patients: The impact of contextual factors. Drug and Alcohol Review. 2016 May 1;35(3):326-33.
[211] Mikuriya TH. Cannabis as a substitute for alcohol: a harm-reduction approach. Journal of Cannabis Therapeutics. 2004 Feb 26;4(1):79-93.
[212] Ramesh D, Owens R, Kinsey S, Cravatt B, Sim-Selley L, Lichtman A Effects of chronic manipulation of the endocannabinoid system on precipitated opioid withdrawal. Poster presented at: The 21st Annual International Cannabinoid Research Society Symposium on the Cannabinoids; 2011; St. Charles, IL
[213] Reiman A. Cannabis as a substitute for alcohol and other drugs. Harm Reduction Journal. 2009 Dec 3;6(1):1.
[214] Scavone JL, Sterling RC, Weinstein SP, Van Bockstaele EJ. Impact of cannabis use during stabilization on methadone maintenance treatment. Am J Addict 2013;22: 344–51.

Although the occurrence of substitution in the specific context of driving has not been well examined, an encouraging data pattern has emerging from US states that have legalized cannabis: individuals, especially young males, are to some extent substituting cannabis for alcohol, and this pattern appears to be linked to significantly lower levels of fatality due to motor vehicle crashes.[215] A substitution of alcohol by cannabis appears to be encouraged in more liberal cannabis environments, but cannabis may become a complement for alcohol in more stringent alcohol environments.[216] Given that simultaneous use of cannabis and alcohol can exacerbate driving risks, this is an important distinction.

c. Normalization and culture of responsible use

A subculture of cannabis users, developed in a context of illegality and stigma, has relied on peer information about safe and effective use. Part of this subculture is an identity of cannabis users that focuses on responsible use, with the aims of destigmatizing users and differentiating cannabis use from use of other substances seen as more harmful. These norms can be viewed as preventative measures, which may be even more accessible in a legalized environment, and may help mitigate driving risks.

i. Responsible use norms

Some norms and rituals have been developed in the cannabis subculture, with a focus on responsible use.[217] A study of older adults, in a normalized context (San Francisco Bay Area), found cannabis users made harm reduction choices based on preferred cannabis derivatives and routes of administration, as well as "why, when, where, and with whom to use".[218] Participants in this study described responsible and controlled use as moderation of quantity and frequency of cannabis use, use in appropriate settings, and respect for non-users; cannabis use was usually reserved for leisure-time, so that it "fit in" and did not interfere with other aspects of their lives. Participants also portrayed frequent use patterns in the framework of self-control by indicating settings where they abstained. In another study looking at cannabis user lore, which consists of 'best practices' for safe and effective use of cannabis, traffic was a situation that was considered unfit for cannabis use.[219] Of particular interest cannabis users' identity and self-concept as "responsible" was found to encourage controlled cannabis use. As seen below, the cannabis legalization movement has focused on creating norms of responsible use as part of their efforts, including in their definition of responsible use imperatives to not drive while impaired by cannabis, and more generally paying heed to appropriate settings for use:

[215] Anderson DM, Hansen B, Rees DI. Medical marijuana laws, traffic fatalities, and alcohol consumption. Journal of Law and Economics. 2013 May;56(2):333-69.
[216] Subbaraman MS. Substitution and Complementarity of Alcohol and Cannabis: A Review of the Literature. Substance use & misuse. 2016 May 10:1-6.
[217] National Organization for the Reform of Marijuana Laws. NORML Principles of Responsible Cannabis Use http://norml.org/pdf_files/NORML_Principles_of_Responsible_Cannabis_Use.pdf 4/11/2003
[218] Lau N, Sales P, Averill S, Murphy F, Sato SO, Murphy S. Responsible and controlled use: Older cannabis users and harm reduction. International Journal of Drug Policy. 2015 Aug 31;26(8):709-18.
[219] Reinarman C, Cohen P. Lineaments of cannabis culture: Rules regulating use in Amsterdam and San Francisco. Contemporary Justice Review. 2007 Dec 1;10(4):393-410.

NORML

Working to Reform Marijuana Laws

Principles of Responsible Cannabis Use

When marijuana is enjoyed responsibly, subjecting users to harsh criminal and civil penalties provides no public benefit and causes terrible injustices. For reasons of public safety, public health, economics and justice, the prohibition laws should be repealed to the extent that they criminalize responsible marijuana use.

By adoption of this statement, the NORML Board of Directors has attempted to define "responsible cannabis use."

…….

II. No Driving

The responsible cannabis consumer does not operate a motor vehicle or other dangerous machinery while impaired by cannabis, nor (like other responsible citizens) while impaired by any other substance or condition, including some medicines and fatigue.

Although cannabis is said by most experts to be safer than alcohol and many prescription drugs with motorists, responsible cannabis consumers never operate motor vehicles in an impaired condition. Public safety demands not only that impaired drivers be taken off the road, but that objective measures of impairment be developed and used, rather than chemical testing.

III. Set and Setting

The responsible cannabis user will carefully consider his/her set and setting, regulating use accordingly.

"Set" refers to the consumer's values, attitudes, experience and personality, and "setting" means the consumer's physical and social circumstances. The responsible cannabis consumer will be vigilant as to conditions -- time, place, mood, etc. -- and does not hesitate to say "no" when those conditions are not conducive to a safe, pleasant and/or productive experience.

The National Organization for the Reform of Marijuana Laws (www.norml.org)

ii. De-stigmatization and differentiation

There is evidence of a norm of responsible use in Canada, where irresponsible use, vs. use in and of itself, remains stigmatized and moderate or 'conscientious consumption' is destigmatized.[220] It is hypothesized that the norm of responsible use came about through attempts by cannabis users to reduce stigma by demonstrating normal functioning in their everyday lives.[221] A study examining how stigma associated with cannabis use affects individuals who use cannabis for therapeutic purposes found that one of the strategies employed by individuals to manage associated stigma was using cannabis responsibly.[222] Lau et al (2015) note that "by reducing risks and increasing positive use outcomes participants constructed patterns of consumption as non-deviant or ''normal" with specific references to acknowledged risks and problems experienced by people who misused cannabis." On the other hand, there may also be some denial of risks in response to stigmatization.

[220] Duff C, Asbridge M, Brochu S, Cousineau MM, Hathaway AD, Marsh D, Erickson PG. A Canadian perspective on cannabis normalization among adults. Addiction Research & Theory. 2012 Aug 1;20(4):271-83.

[221] Lau N, Sales P, Averill S, Murphy F, Sato SO, Murphy S. Responsible and controlled use: Older cannabis users and harm reduction. International Journal of Drug Policy. 2015 Aug 31;26(8):709-18.

[222] Bottorff JL, Bissell LJ, Balneaves LG, Oliffe JL, Capler NR, Buxton J. Perceptions of cannabis as a stigmatized medicine: a qualitative descriptive study. Harm reduction journal. 2013 Feb 16;10(1):1.

Some cannabis users view cannabis use as symbolically opposed to the dominant alcohol culture, and want to differentiate cannabis use from the loss of control and negative outcomes that are commonly attributed to alcohol use. Interviewees in one study regarded cannabis as a safer alternative to alcohol, illicit drugs, and pharmaceuticals.[223] Indeed, some legalization campaigns, such as in Colorado, have emphasized the importance of allowing responsible adults to make an intelligent choice to use cannabis as a safer alternative to alcohol. This symbolic meaning of cannabis use, as a safer and healthier choice, is based in evidence and may influence patterns and practices of use (see b. above).

iii. Normalization as prevention

Some researchers believe that preventative measures may prove to be more effective than formal legal prohibitions and additional extensive resources in roadside enforcement in reducing cannabis-impaired driving.[224-226] One study concluded that the potential for prevention was demonstrated by the fact that about half of the study sample reported at least one incident in the past year where they considered driving after cannabis use and then decided against it.[227] The study however did not account for the reasons for their decision, which could be pursued by future research. The authors also suggest that norms may not be strong enough reasons for young drivers to refrain from this activity, particularly those who are more frequent cannabis users. However, other researchers believe that the cultural norms of controlled and responsible use, established through supporting users to be thoughtful, well-prepared, and aware of the means and best settings for using cannabis, can create an environment where risks can be minimized and the benefits maximized.[228]

iv. Legal vs. illegal context

Evidence suggests that cannabis users with access to a regulated market (for example medical cannabis dispensaries in California) were better equipped to practice harm reduction.[229] In contrast, some of the norms that developed in the context of legal prohibition of cannabis were linked to the primary concern of getting apprehended, and these norms may have been contrary to driving safety concerns. For example, Davey et al (2005), heard from some of the people they interviewed that they used cannabis immediately before driving so they to avoid the risk getting caught in the possession of cannabis if they took it out with them; in this sense "the illegality of drug driving was subsumed by illegality of drug use".[230]

Another outcome of the legal prohibition of cannabis is that cannabis users may prefer lay risk assessments to expert assessments of risk; lay assessments reflect common experiences of peer groups

[223] Lau N, Sales P, Averill S, Murphy F, Sato SO, Murphy S. Responsible and controlled use: Older cannabis users and harm reduction. International Journal of Drug Policy. 2015 Aug 31;26(8):709-18.
[224] Dalgarno P, Shewan D. Reducing the risks of drug use: The case for set and setting. Addiction Research & Theory. 2005 Jun 1;13(3):259-65.
[225] Duff C. Drugs and youth cultures: Is Australia experiencing the 'normalization' of adolescent drug use? Journal of youth studies. 2003 Dec 1;6(4):433-47.
[226] Fischer B, Ivsins A, Rehm J, Webster C, Rudzinski K, Rodopoulos J, Patra J. Factors Associated with High-Frequency Cannabis Use and Driving among a Multi-site Sample of University Students in Ontario 1. Canadian journal of criminology and criminal justice. 2014 Feb;56(2):185-200.
[227] Fischer B, Ivsins A, Rehm J, Webster C, Rudzinski K, Rodopoulos J, Patra J. Factors Associated with High-Frequency Cannabis Use and Driving among a Multi-site Sample of University Students in Ontario 1. Canadian journal of criminology and criminal justice. 2014 Feb;56(2):185-200.
[228] Dalgarno P, Shewan D. Reducing the risks of drug use: The case for set and setting. Addiction Research & Theory. 2005 Jun 1;13(3):259-65.
[229] Lau N, Sales P, Averill S, Murphy F, Sato SO, Murphy S. Responsible and controlled use: Older cannabis users and harm reduction. International Journal of Drug Policy. 2015 Aug 31;26(8):709-18.
[230] Davey J, Davies A, French N, Williams C, Lang CP. Drug driving from a user's perspective. Drugs: education, prevention and policy. 2005 Feb 1;12(1):61-70.

and emphasize relative ease with which risks associated with cannabis use might be managed.[231] Experts, on the other hand, may be seen by cannabis users to have perpetuated 'reefer madness' myths in order to support cannabis prohibition, and to have produced messaging that did not resonate with their experience and created stigma.

Summary and Conclusions

In recognition of potential impairment from cannabis use, drivers who use cannabis employ behavioral strategies to mitigate these risks. Waiting to drive until the effects of cannabis have subsided is one tactic. While evidence shows that the majority of the impairment occurs in the first 2 hours and is cleared in 3-4 hours, as with alcohol, other factors must be taken into consideration when establishing recommended waiting times for driving after cannabis use, such as dosage and potency and mode of administration. As with alcohol, another tactic to reduce risk for both drivers and passengers is the use of other modes of transportation. More frequent users of cannabis feel that their experience with and tolerance to cannabis mitigates their level of impairment, and individuals who drive after using cannabis may employ techniques that they believe make them safer drivers, such as driving slower and taking less risks. These techniques may be effective as long as the tasks required are not too complex. The practice of substituting alcohol and other drugs for cannabis may reduce the likelihood of driving after using these substances; although cannabis use is associated with an elevated driving risk, it is much less problematic than these other substances. Different legal frameworks for cannabis and alcohol impact whether there is a substitution effect or complementary effects; given that simultaneous use of cannabis and alcohol can exacerbate driving risks, this is an important policy issue. While policies many have some impact on behaviours, the cannabis culture has been an important part of prevention through norms that encourage responsible use, with the aim of reducing stigma and differentiating itself from alcohol culture. The cannabis-use culture, developed in the context of prohibition, is a trusted source of information about potential risks. The imminent re-legalization of cannabis provides further opportunities for prevention of harms through acknowledging the norms that distinguish between responsible and irresponsible use; with the removal of the threat of criminalization, users can shift their focus from the risks of illegality to potential risks associated with impairment, including the risk of driving while impaired by cannabis.

[231] Duff C, Asbridge M, Brochu S, Cousineau MM, Hathaway AD, Marsh D, Erickson PG. A Canadian perspective on cannabis normalization among adults. Addiction Research & Theory. 2012 Aug 1;20(4):271-83.

9. Public health education

While drinking and driving has been the subject of mass media campaigns,[232] cannabis use and driving has yet to receive the same attention. Public health education on cannabis use has historically emphasized abstinence, focusing on the harms of cannabis use. This section reviews the effectiveness of public health education messages with the goal of informing public health education messaging on cannabis use and driving.

a. What has been tried

Public education on cannabis use has generally consisted of anti-cannabis PSAs and intervention--based public health education.[233-235] Moffat (2013) reviewed public education campaigns to provide young people with information concerning cannabis use and its risks, finding that conflicting messages have been given to young people: on the one hand, public health messages emphasize the harms associated with cannabis use while messaging from peers and family places much less emphasis on potential harms and portrays cannabis use as relatively low risk.[236] In particular, it is notable that public service announcements have strongly emphasized the dangers of cannabis use and focus on discouraging cannabis use, under a framework where cannabis was an illicit drug.[237]

In Colorado, where cannabis has been legalized, there have been some public education campaigns focusing on cannabis use and driving promoted by the Colorado Department of Transportation.[238] Their 2016 campaign, consisting of billboard signs, posters, and radio and TV ads, has the tagline "Don't Drive High" and uses imagery that combines imagery of car crashes with cannabis.[239] However, this messaging doesn't give drivers any information about how to know when they are impaired or about measures they can take to drive safely. In contrast, the campaign's poster on impaired driving that is targeted towards prescription drug users, which features a prescription bottle and a set of car keys, does provide information in the form of text on the poster on ways that the reader can become informed of the impairment effects of their medications – the poster states: [240]

> "Some drugs purchased at a pharmacy, whether they're prescribed by a doctor or bought over-the-counter, can be just as dangerous for drivers as alcohol.

[232] Elder RW, Shults RA, Sleet DA, Nichols JL, Thompson RS, Rajab W, Task Force on Community Preventive Services. Effectiveness of mass media campaigns for reducing drinking and driving and alcohol-involved crashes: a systematic review. American journal of preventive medicine. 2004 Jul 31;27(1):57-65.

[233] Fischer B, Dawe M, McGuire F, Shuper PA, Capler R, Bilsker D, Jones W, Taylor B, Rudzinski K, Rehm J. Feasibility and impact of brief interventions for frequent cannabis users in Canada. Journal of substance abuse treatment. 2013 Jan 31;44(1):132-8.

[234] Kang Y, Cappella JN, Fishbein M. The effect of marijuana scenes in anti-marijuana public service announcements on adolescents' evaluation of ad effectiveness. Health communication. 2009 Aug 31;24(6):483-93.

[235] Noar SM, Palmgreen P, Zimmerman RS, Lustria ML, Lu HY. Assessing the relationship between perceived message sensation value and perceived message effectiveness: Analysis of PSAs from an effective campaign. Communication studies. 2010 Jan 14;61(1):21-45.

[236] Moffat BM, Jenkins EK, Johnson JL. Weeding out the information: an ethnographic approach to exploring how young people make sense of the evidence on cannabis. Harm reduction journal. 2013 Nov 27;10(1):1.

[237] Kang Y, Cappella JN, Fishbein M. The effect of marijuana scenes in anti-marijuana public service announcements on adolescents' evaluation of ad effectiveness. Health communication. 2009 Aug 31;24(6):483-93.

[238] Colorado Department of Transportation. Campaign Materials – Drugged Driving Posters 2016 campaign. https://www.codot.gov/safety/alcohol-and-impaired-driving/druggeddriving/campaign-materials.html

[239] Colorado Department of Transportation. Campaign Materials – Drugged Driving Posters 2016 campaign. https://www.codot.gov/safety/alcohol-and-impaired-driving/druggeddriving/assets/2016-campaign-materials/hits-billboard.jpg

[240] Colorado Department of Transportation. Campaign Materials – Drugged Driving Posters 2016 campaign.https://www.codot.gov/safety/alcohol-and-impaired-driving/druggeddriving/assets/2016-campaign-materials/dui-poster-espanol.pdf

> The effects of prescription medication vary widely, depending not just on the drug but on the person taking it. Some drugs can impair coordination and slow reaction time; others can hurt your ability to judge distances or can cause drowsiness.
>
> Driving under the influence of drugs—including some prescription medications—can result in DUI charges. A doctor's prescription is no defense against drugged driving charges. Look for warning labels or ask your pharmacist if you are in doubt about a drug's capacity for impairment."

As discussed in Section 6, safety warnings such as these are an important part of education for patients using prescriptions, including cannabinoid medications. This information can be reinforced by medical professionals upon prescribing the medication to a patient.

Washington ran a campaign in the summer of 2014 after the legalization of cannabis took place that aimed to remind the public that impaired driving is illegal, using the phrase "Drive high, get a DUI".[241] It featured a number of TV ads that showed people doing activities while impaired, and the message was that while those activities were legal now, driving while impaired was not. Again, these messages lacked any information on measures viewers could take to be safe. It is unclear how effective this campaign was at behaviour change, since no formal evaluation was done to determine its impact on DACU in Washington drivers.

MADD also ran a series of commercials with the tagline "If you're high, you can't drive" which featured individuals who had used cannabis hallucinating and seeing inanimate objects, such as a Bob Marley head, coming to life, telling them not to drive.[242] As seen in the comments under the video on YouTube, this experience is widely seen as unrealistic and ridiculous by viewers.

b. Effectiveness

There have been studies looking at how viewers respond to public health education materials on cannabis use, which speaks to their impact and effectiveness in promoting behaviour change. An innovative approach involving a brief intervention to highlight the risks of cannabis use in an evidence-based and balanced manner has shown positive impacts, reducing certain potentially problematic aspect of cannabis use, including cannabis-impaired driving.[243,244] This intervention used "short, fact-based, and non-judgemental" language to provide the participants with either oral or written information about cannabis-related health risks. With respect to driving, the written information booklet advises the reader to be aware of the time and place of cannabis use, and not to drive or perform other risky activities while impaired. It gives guidelines for how long to wait after cannabis use before driving (2 hours for smoking and at least 6 for eating) but also emphasizes that the individual uses their judgement. The study observed a decrease of driving within 2 hours of cannabis use by one-third in participants who were exposed to the evidence-based intervention (both the oral and written cannabis information) compared to controls at 6 months and 12 months.

While not focused specifically on driving, there are many examples of anti-cannabis ads which have proven to be ineffective once they were released – one good example is the "Stoner Sloth" campaign put out in Australia. In this campaign, a series of ads represented youth who used cannabis as literally becoming sloths and being unable to perform daily activities, such as writing school tests and passing the salt at the dinner table, with the tagline "You're worse on weed." The ads were widely ridiculed and, as one

[241] Washington Traffic Safety Commission. Campaign to highlight "Drive High, Get a DUI". Jun 18 2014. Retrieved from http://wtsc.wa.gov/News/campaign-to-highlight-drive-high-get-a-dui/
[242] MADD. If you're high, you can't drive. [YouTube upload]. https://www.youtube.com/watch?v=E923Ajb9kJw
[243] Fischer B, Jones W, Shuper P, Rehm J. 12-month follow-up of an exploratory 'brief intervention' for high-frequency cannabis users among Canadian university students. Substance abuse treatment, prevention, and policy. 2012 Apr 26;7(1):1.
[244] Fischer B, Dawe M, McGuire F, Shuper PA, Capler R, Bilsker D, Jones W, Taylor B, Rudzinski K, Rehm J. Feasibility and impact of brief interventions for frequent cannabis users in Canada. Journal of substance abuse treatment. 2013 Jan 31;44(1):132-8.

article pointed out, this was just another example of how shaming youth behaviour is ineffective at resonating with youth.[245] In contrast, another study found that ads depicting cannabis use realistically and giving clear alternatives to the behaviour they were trying to prevent were perceived to be more effective by viewers.[246]

The ad effectiveness also depends on the target audience. DACU is associated with other risky behaviours, representing a group of high-sensation-seeking individuals who partake in other risky driving behaviours.[247] This group of individuals respond to messaging that is presented in an arousing and unconventional format, in contrast to traditional road safety messaging that emphasizes rational decision-making.

Youth are another important target audience. One systematic study of school-based drug interventions programs emphasized the importance of interventions that draw on the social influence of youth peer groups by focusing on changing social norms and using creative modes of delivery, including interactive methods that allow the exchange of ideas and knowledge and the use of peer leaders.[248]

In another study, Kang et al (2009) found that the use of cannabis-related scenes (defined as the presence of cannabis, holding a cigarette, or showing the act of smoking) in ads were rated by youth as being less likeable:

> "The major finding of the study was that marijuana scenes in anti-marijuana public service announcements negatively affected ad liking and thought valence toward the ads among adolescents who were at higher levels of risk for marijuana use. This negative impact was not reversed in the presence of strong anti-marijuana arguments."[249]

c. Credibility

Another factor in how well public education messages are received is credibility. This has to do with how viewers perceive the organization that is putting out the ad, as well as the quality of the message and the ad itself.

Messages that imply uncertainty or inconsistency are more likely to be perceived as less credible.[250,251] Viewers are also influenced by their peers in how credible they view the information presented in an ad – this is especially true for youth.[252,253] Another interesting study found that anti-cannabis ads posted on

[245] Nudd, T. Australia's 'Stoner Sloth' Anti-Marijuana Campaign Is an Instant and Classic Fail. AdWeek, Dec 20 2105. Retrieved from http://www.adweek.com/adfreak/australias-stoner-sloth-anti-marijuana-campaign-instant-and-classic-fail-168702

[246] Noar SM, Palmgreen P, Zimmerman RS, Lustria ML, Lu HY. Assessing the relationship between perceived message sensation value and perceived message effectiveness: Analysis of PSAs from an effective campaign. Communication studies. 2010 Jan 14;61(1):21-45.

[247] Bergeron J, Paquette M. Relationships between frequency of driving under the influence of cannabis, self-reported reckless driving and risk-taking behavior observed in a driving simulator. Journal of safety research. 2014 Jun 30;49:19-e1.

[248] Cuijpers P. Effective ingredients of school-based drug prevention programs: A systematic review. Addictive behaviors. 2002 Dec 31;27(6):1009-23.

[249] Kang Y, Cappella JN, Fishbein M. The effect of marijuana scenes in anti-marijuana public service announcements on adolescents' evaluation of ad effectiveness. Health communication. 2009 Aug 31;24(6):483-93.

[250] Moffat BM, Jenkins EK, Johnson JL. Weeding out the information: an ethnographic approach to exploring how young people make sense of the evidence on cannabis. Harm reduction journal. 2013 Nov 27;10(1):1.

[251] Porath-Waller AJ, Brown JE, Frigon AP, Clark H. What Canadian youth think about cannabis. Ottawa. Canadian Centre on Substance Abuse. 2013 Sep.

[252] Chabrol H, Chauchard E, Mabila JD, Mantoulan R, Adèle A, Rousseau A. Contributions of social influences and expectations of use to cannabis use in high-school students. Addictive Behaviors. 2006 Nov 30;31(11):2116-9.

[253] Elder RW, Shults RA, Sleet DA, Nichols JL, Thompson RS, Rajab W, Task Force on Community Preventive Services. Effectiveness of mass media campaigns for reducing drinking and driving and alcohol-involved crashes: a systematic review. American journal of preventive medicine. 2004 Jul 31;27(1):57-65.

Youtube were perceived as less credible by viewers if they were shown the negative comments that had been posted by other viewers.[254]

The viewers' past use of cannabis also affects how credible they perceive health education messaging about cannabis to be. One study that showed both users and non-users of cannabis public health education ads about cannabis found that those who had used cannabis were more skeptical that the ads would be effective, and suggests that this may be due to how they weigh the credibility of the messages in the ads against their own experience.[255]

For youth in particular, cannabis use behaviour is influenced by their social context, and one study suggested that interventions which address the social context of cannabis use by engaging the credibility of peer groups would be more effective than traditional fear-based messaging.[256]

Summary and Conclusions

Public health education efforts have historically focused on harms of cannabis use and strongly discouraged cannabis use. The mass media campaigns that do exist for cannabis use are often ineffective due to a continued reliance on fear-based messaging or portrayal of scenarios that are highly unrealistic or derogatory, eliciting mockery from the intended audience, and there are few examples of campaigns that have focused on driving. High sensation seekers and youth are key target groups who do not respond positively to traditional fear-based messaging. Maintaining a clear and consistent message that is relatable to cannabis users' personal experience and those of their peers improves the credibility of messaging. The evidence shows that non-judgmental, factual, and concise messages are more effective at promoting cannabis use-related behaviour changes, including change in DACU.

[254] Walther JB, DeAndrea D, Kim J, Anthony JC. The influence of online comments on perceptions of anti-marijuana public service announcements on YouTube. Human Communication Research. 2010 Oct 1;36(4):469-92.

[255] Cho H, Boster FJ. First and third person perceptions on anti-drug ads among adolescents. Communication Research. 2008 Apr 1;35(2):169-89.

[256] Lewis TF, Thombs DL, Olds RS. Profiles of alcohol-and marijuana-impaired adolescent drivers. Addiction Research & Theory. 2005 Apr 1;13(2):145-54.

APPENDIX A:
Detailed examination of validity and reliability of observational testing for cannabis impairment

Identification by the Standardized Roadside Sobriety Test (SFST) and Drug Recognition and Evaluation (DRE) test as "drug-impaired" may result in legal charges and penalties with significant impacts on employability and other social outcomes. Cannabis users need to be given objective information about the nature of these impairment tests, their quality and potential consequences. Providing this information helps to establish the credibility of a cannabis/driving education campaign. To establish the quality of the screening and confirmation process for determining drug-associated impairment of driving capacity due to cannabis use, one must ask: is this process reliable in relation to determining impairment from cannabis use (does it generate adequate levels of agreement between raters on the screening and confirmation tests); and is it valid (has it been shown to accurately detect and measure cannabis-impaired driving capacity)?

1. Reliability of Observational Testing of Cannabis Impairment

The standard way to demonstrate the reliability of observational tests like the SFST and DRE is to compare the scores given by pairs of well-trained raters (interrater agreement). Where reliability is adequate, there will be a high proportion of agreement between the raters as to whether the characteristic (cannabis-related impairment of driving capacity) is present: the standard statistics used to characterize agreement are Rate of Agreement between the raters and the Kappa index.

We were able to find one study providing data on interrater agreement for the SFST in relation to driving after cannabis use (DACU).[1] This study was carried out using research volunteers who were given low or high dosage THC and then received the SFST, which was rated both by a trained police officer and a trained researcher. Scores given by pairs of raters were compared.

Unfortunately, the degree of interrater reliability in the study cannot be determined since neither of the standard statistics (percentage agreement or Kappa) are reported. Only a chi-square statistic is provided, which indicates that raters were agreeing at a rate better than chance. But simply indicating that raters are able to agree significantly above chance is not an adequate or usual measure of agreement. Nonetheless, the researchers conclude that "the SFTSs are reliable tests of impairment." In our view, interrater reliability of this impairment test, based on published research, is unknown.

As for the DRE, we found a brief description of a reliability study carried out by researchers associated with the Canadian Centre for Substance Abuse.[2] Unfortunately, this study has not been published and there is minimal information available about its methodology. In a policy brief, it is described as follows:

> A random sample of certified DREs were each sent the same set of 23 completed drug influence evaluation forms from existing police cases. All identifying information and the original DRE's opinion about drug category were removed. Overall agreement among DREs on the category of drugs used was 71.2%. (p. 3)

More importantly, this approach to "reliability" does not answer the relevant question: do raters conducting the DRE evaluation reach highly similar conclusions about the cannabis-impairment of

[1] Stough D, Boorman M, Ogden E, Papafotiou K. An evaluation of the Standardised Field Sobriety Tests for the detection of impairment associated with cannabis with and without alcohol. National Drug Law Enforcement Research Fund; 2006.
[2] Beirness DJ, Beasley E, LeCavalier J. The accuracy and reliability of evaluations by drug recognition experts in Canada. In 18th Canadian Multidisciplinary Road Safety Conference 2008 Jun. http://www.ccsa.ca/Resource%20Library/CCSA-Drug-Evaluation-Classification-Program-Policy-Brief-2015-en.pdf

particular individuals? In the case of this research study (based upon the abbreviated description) one rater completed the observations and then a group of other DREs were asked to review the completed protocol – reliability of the actual testing procedure was not examined.

We conclude that interrater reliabilities of the SFST and DRE, in the context of determining cannabis-related impairment, have not been adequately determined.

2. Validity of Observational Testing of Cannabis Impairment

Research studies have attempted to demonstrate validity by showing that the SFST and DRE can identify individuals meeting one of several reference criteria: those who have or have not recently used cannabis; those classified as impaired in a driving simulation lab; or those with a defined level of THC on blood test. The defined level of THC may be one that is detectable (it is present), impairment-linked (the level has been empirically shown to indicate a likelihood of impaired driving capacity) or legally-indicated (the level is specified in legislation as tantamount to impairment). The success of this impairment testing is shown in its Sensitivity (i.e. are most individuals meeting the reference criterion identified as impaired by this test) and Specificity (are most individuals who fail to meet the reference criterion identified as non-impaired by this test). Generally, there is a trade-off between Sensitivity and Specificity: if the threshold for identification is raised, Specificity will increase but Sensitivity will decrease. Another way to demonstrate validity is to show a dose-response relationship (i.e., the degree of rated impairment reflects the dose of cannabis consumed).

Analysis of the validity and reliability of observational tests for cannabis-impairment may be conducted in the Field (i.e. carried out by police officers with actual drivers) or the Laboratory (a more rigorous determination made using volunteers and controlled testing conditions).

a. Field validation studies

It has been argued that field studies are more informative about the validity of the SFST/DRE than are controlled laboratory studies, due to the higher level of ecological validity (the degree to which research findings may be generalized to real-life settings). As stated in a review of studies evaluating DRE, "the experimental controls employed in a laboratory situation to enhance methodological rigour also create an artificial environment that differs considerably from field—i.e., enforcement—settings." [3]

However, there are fundamental methodological issues with field research that make these findings difficult to interpret. These methodological issues have been summarized by Kane (2013) with regard to the SFST, and apply equally to the DRE: [4]

1. In most field validation studies, there is a discrepancy between what the test (SFST or DRE) is meant to measure (*impairment* of driving capacity due to drug use) and the standard against which the test is evaluated (blood testing for *presence* of the drug):

> "Does drug in the blood or urine correctly classify people as drug impaired?" It may not. Low levels of drugs and metabolites are found in the body hours or even, depending on the drug, days after impairing effects have ended (p. 5).

2. The SFST/DRE make no clear distinction between impairment of driving capacity and side effects that may be apparent to a police officer: for example, blood-shot eyes may be associated with cannabis use and contribute to a finding of impairment, yet blood-shot eyes or dilated pupils are <u>not</u> conditions

[3] Beirness DJ, LeCavalier J, Singhal D. Evaluation of the drug evaluation and classification program: a critical review of the evidence. Traffic injury prevention. 2007 Oct 25;8(4):368-76.p. 375.
[4] Kane G. The methodological quality of three foundational law enforcement drug influence evaluation validation studies. Journal of negative results in biomedicine. 2013 Nov 4;12(1):1.

that impair driving ability (i.e. "The mere fact the presence of a drug may be identified by stereotypic physical side effects need not indicate the drug is causing mental impairment"[5]).

3. Police officers have access to information independent of findings from the SFST/DRE (a driver's statement of having used cannabis, physical evidence of cannabis such as smell, etc.): "It may be officers used these other facts to identify the presence of a drug in the subject's body, and used the presence of a drug to predict the presence of a drug." In one study, the majority of drivers suspected of drug-caused impairment confessed to having used a drug.[6] Thus, the SFST/DRE may appear to have high validity in predicting presence of a drug on blood testing, when in fact the prediction was made on the basis of a confession or other evidence of use rather than results of the observation.

4. The a-priori prevalence of substance use in a sample of drivers will greatly affect the apparent accuracy of tests like the SFST/DRE. For example, if one studied a sample of drivers pulled over for possible alcohol-impaired driving after closing hours outside a suburban bar, it might be that many drivers will have blood-alcohol levels above the legal limit. Simply by predicting a high blood-alcohol level for all drivers in this subgroup, police officers would appear to be extremely accurate. Prevalence rates for drug use vary considerably in real life samples, leading to considerable distortion of apparent accuracy rates. This is known as *sampling bias*.

With regard to validity of the SFST, a recent Canadian field study examined performance of the SFST under real life conditions.[7] The authors noted that there had been little prior field research on the SFST:

> The validity of using the SFST as part of the DRE program has to a large extent been inferred from studies of the overall accuracy of the DRE to identify persons impaired by drugs other than alcohol. The problem with this approach is that the DRE program employs a much wider range of tests and measurements than the 3 tests of the SFST to identify drug impairment. Nevertheless, the SFST has come to be viewed as a general test of impairment, regardless of the substance responsible for the impairment (page 126).

The study derived "classification rates" in order to "provide an estimate of the success of the model in correctly predicting the outcome category." In this case, the aim would be to determine the success of this model in predicting which of four drugs (or no drug) were found in an individual's blood. The result was that a regression model developed from the SFST did distinguish the 4 drug categories, including cannabis, at a statistically significant level (i.e. better than chance). However, when this model was used to classify individuals into one of these drug categories based on results of the SFST, the rate of successful classification for cannabis, based on each of the three subtests of the SFST, ranged from 42% to 55%. This is not an impressive rate of classification accuracy. Moreover, the study found that individuals with THC present in blood showed no impairment on two of the three SFST subtests. Overall, results of the study indicate a low level of accuracy for the SFST in detecting individuals in whom THC is present, nor does it detect impairment. Despite these results, the authors inexplicably conclude that "findings observed in the current study provide support for the use of the SFST as a screening tool for law enforcement to identify impairment" in individuals who have used cannabis.

This same research group produced a review of field studies examining the validity of the DRE in predicting which individuals would be found to have THC present in blood testing: "These studies compare DRE judgments of suspected drug use by persons arrested for an impaired driving offence with

[5] Kane G. The methodological quality of three foundational law enforcement drug influence evaluation validation studies. Journal of negative results in biomedicine. 2013 Nov 4;12(1):1. P. 5.
[6] Adler EV, Burns M: Drug recognition expert (DRE) validation study. Phoenix: Arizona Governor's Office of Highway Safety; 1994. Colloquially called the Arizona DRE Validation study.
[7] Porath-Waller AJ, Beirness DJ. An examination of the validity of the standardized field sobriety test in detecting drug impairment using data from the drug evaluation and classification program. Traffic injury prevention. 2014 Feb 17;15(2):125-31.

the results of toxicological tests for the presence of psychoactive substances"[8] (Note that the studies reviewed did not validate the DRE against demonstrated impairment of driving capacity nor against a set level of THC concentration associated with demonstrable impairment.) The review concluded that field studies are quite supportive of the DRE program:

- There is moderately accurate detection of THC presence by the DRE: **Sensitivity** across the studies ranged from 60% to 94%.
- There is moderately accurate identification of cases where THC is not present: **Specificity** ranged from 73% to 86%.

These field studies point to the SFST as having a low degree of accuracy in detecting the presence of cannabis; and the DRE as having a moderate degree of accuracy in detecting the presence of cannabis. Neither study addressed detection of impairment.

A recent study examined the accuracy of the SFST/DRE combination in predicting the actual concentration of THC as established by blood testing.[9] Researchers examined data on nearly 363 drivers who were suspected of impaired driving and therefore given the SFST – about half of these also had the DRE testing procedure – and were later found positive for THC on blood testing. It was found that results of these "impairment" tests did not correlate significantly with levels of THC concentrations in whole blood.

It is worth noting a Norwegian study which examined their version of the DRE, the CTI (Clinical Test for Impairment) test which is conducted by a physician, comparing results of this test to the presence of THC in subsequent blood testing.[10] Across the usual range of coordination and cognition tasks, a very low level of Sensitivity was observed and there was no dose-response relationship. The most sensitive signs were "conjunctival injection, pupil dilation and reaction to light", which were identified in approximately 50% of those who were THC-positive in blood testing. These researchers conclude that:

"The present investigation shows that, even when including an extensive number of tests and observations, THC impairment is difficult to detect. Conversely, we required the presence of a drug concentration–effect relationship to indicate a causal relationship. This might have been a very stringent criterion, and one reason for the many negative findings. A second reason may be low sensitivity of the CTI. In conclusion, the Norwegian CTI did not offer sensitive tests or observations that revealed THC impairment reliably."[11]

It should be noted that this study evaluated only detection of THC *presence*, yet refers to impairment.

b. Laboratory studies

Validation of the SFST based on laboratory studies has proceeded via demonstrating either that it is able to identify individuals who have used cannabis or that it is able to identify individuals shown to be impaired by cannabis use on driving simulation testing or that there is a dose response relationship between amount of cannabis used and performance on the SFST.

[8] Ibid. P. 372

[9] Declues K, Perez S, Figueroa A. A 2-year study of Δ 9-tetrahydrocannabinol concentrations in drivers: examining driving and Field Sobriety Test performance. J Forensic Sci. 2016 Aug 1. doi: 10.1111/1556-4029.13168.

[10] Bramness JG, Khiabani HZ, Mørland J. Impairment due to cannabis and ethanol: clinical signs and additive effects. Addiction. 2010 Jun 1;105(6):1080-7

[11] Bramness JG, Khiabani HZ, Mørland J. Impairment due to cannabis and ethanol: clinical signs and additive effects. Addiction. 2010 Jun 1;105(6):1080-7. P. 1085.

Papafotiou et al (2005a) examined the ability of the SFST to identify individuals who had consumed cannabis, comparing rating of impairment on the SFST to measured blood levels of THC.[12] Results of this study were that the SFST would classify as impaired 23% of individuals who had received a low dose of THC and 46% of those receiving a high dose (a low level of Sensitivity). Of those who had received a placebo, 92.5% were identified as not impaired on the SFST (a high level of Specificity). A clear dose-response relationship between dose of THC and performance on the SFST was evident.

In another study, Papafotiou et al (2005b) examined the ability of the SFST to identify individuals classified as impaired on a driving simulation test.[13] For individuals administered a low dose of THC, of those classified as impaired on the simulation test 88.5% were correctly identified by the SFST (a high level of Sensitivity); but of those found to be not impaired on the simulation test, only 38.5% were correctly identified by the SFST (a low level of Specificity). For individuals administered a high dose of THC, those classified as impaired were correctly identified by the SFST 92% of the time (a high level of Sensitivity) but only 15.4% of those found not to be impaired were correctly identified by the SFST (an extremely-low level of Specificity).

Stough et al (2006) examined the ability of the SFST to identify individuals who had consumed cannabis.[14] Results of the study were that the SFST would classify as impaired almost 8% of those who had received low THC and a similar proportion of those who had received a high THC dose (an extremely-low level of Sensitivity); and would correctly identify 99% of those who had received a placebo (a high level of Specificity). This study also examined the ability of the SFST to identify those classified as impaired in a driving simulation task: of those who were demonstrably impaired on the simulation task, 33% were correctly classified by the SFST (a very low level of Sensitivity) while 88% of those who were not impaired on the simulation task were correctly classified by the SFST (a high level of Specificity).

Bosker et al (2012a) examined the ability of the SFST to identify individuals who had used cannabis, in a sample of heavy users of this drug. The SFST was able to correctly identify individuals who had used THC in 30% of cases (a very low level of Sensitivity).[15] In another study, these authors examined the ability of the SFST to identify individuals who had received THC (i.e. dronabinol).[16] Findings of this study did not show the SFST to accurately identify those who had received low or high doses of THC, and the authors concluded "The Standard Field Sobriety Test is not sensitive to clinically relevant driving impairment caused by oral tetrahydrocannabinol".

Beirness, LeCavalier and Singhal (2007) reviewed four laboratory studies that examined the validity of DRE. The reviewed studies shared the methodology of determining the accuracy with which the DRE could identify volunteer subjects who had received cannabis, versus those who had received placebo or another drug. Sensitivity to the presence of cannabis was 30-50% (very low), while Specificity ranged between 60 and 93 % (moderate to high).[17]

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[12] Papafotiou K, Carter JD, Stough C. An evaluation of the sensitivity of the Standardised Field Sobriety Tests (SFSTs) to detect impairment due to marijuana intoxication. Psychopharmacology. 2005;180(1):107-14.

[13] Papafotiou K, Carter JD, Stough C. The relationship between performance on the standardised field sobriety tests, driving performance and the level of Δ9-tetrahydrocannabinol (THC) in blood. Forensic science international. 2005;155(2):172-8.

[14] Stough D, Boorman M, Ogden E, Papafotiou K. An evaluation of the Standardised Field Sobriety Tests for the detection of impairment associated with cannabis with and without alcohol. National Drug Law Enforcement Research Fund; 2006.

[15] Bosker WM, Theunissen EL, Conen S, Kuypers KP, Jeffery WK, Walls HC, Kauert GF, Toennes SW, Moeller MR, Ramaekers JG. A placebo-controlled study to assess Standardized Field Sobriety Tests performance during alcohol and cannabis intoxication in heavy cannabis users and accuracy of point of collection testing devices for detecting THC in oral fluid. Psychopharmacology. 2012 Oct 1;223(4):439-46.

[16] Bosker WM, Kuypers KP, Theunissen EL, Surinx A, Blankespoor RJ, Skopp G, Jeffery WK, Walls H, Leeuwen CJ, Ramaekers JG. Medicinal Δ9-tetrahydrocannabinol (dronabinol) impairs on-the-road driving performance of occasional and heavy cannabis users but is not detected in Standard Field Sobriety Tests. Addiction. 2012;107(10):1837-44.

[17] Beirness DJ, LeCavalier J, Singhal D. Evaluation of the drug evaluation and classification program: a critical review of the evidence. Traffic injury prevention. 2007 Oct 25;8(4):368-76.

Shinar and Schectman (2005) examined the ability of trained officers to identify individuals dosed with cannabis, distinguishing them from individuals who had received placebo and from those who had received other drugs (alprazolam, codeine, or amphetamine).[18] They found that officers were minimally able to distinguish those who had or had not consumed cannabis, using the SFST: Sensitivity was poor, at 49%, while Specificity was moderate, at 69%. It is worth noting an additional statistic they computed, the Uncertainty coefficient, which measures "amount of relative uncertainty that is reduced about the drug that was administered by knowing the officer's response": A UC of 1 would mean that the officer's decision was completely informative as to which drug had been administered while a UC of 0 would mean that the officer's decision gave no useful information. For cannabis, the Uncertainty Coefficient was .02, indicating that the officer's decision about cannabis consumption, based on the SFST, had virtually no information value. It may also be noted that officers reported identifying cannabis as an impairing drug mainly from the sign of "raised pulse rate." Although cannabis does tend to raise the pulse rate, this is not in itself an indication of impairment and is a very ambiguous sign – there are a number of conditions that might cause a raised pulse rate while being examined by a police officer (notably, fear).

Despite the high value placed upon the SFST/DRE within the system of law enforcement related to driving under the influence of cannabis, it performs poorly when tested under controlled conditions. In none of the studies reviewed was there an appropriate balance between Sensitivity and Specificity: where one of these reached an appropriately high level, the other fell to an inappropriately low level. While it is understood that there is an identified need to have such an impairment test available to the legal system, neither the SFST nor the DRE meet that need in a manner that would satisfy basic requirements for any physical or behavioural test, which has significant consequences.

[18] Shinar D, Schechtman E. Drug identification performance on the basis of observable signs and symptoms. Accident Analysis & Prevention. 2005 Sep 30;37(5):843-51.

APPENDIX B:
The utility of oral fluid testing to detect cannabis-related impairment

As noted above, the challenge has been to establish a clear relationship between measured levels of THC in oral fluid and levels of blood concentration. The latter involves testing whole blood or serum/plasma for a set concentration of THC that has been shown to indicate impairment of safe driving capacity in most individuals. Plasma is the liquid component of blood after all the cells and platelets have been removed, while plasma also has the coagulation factors removed.[19] Plasma and serum will have a concentration of THC twice that of the original whole blood sample. Because the empirical data upon which presumptions of likely impairment have been based involved THC concentration in blood, it is necessary to establish an equivalence between oral fluid concentration and THC concentration in blood.

A study by Huestis and Cone in 2004 indicated that the ratio between oral fluid and blood serum for THC concentration was between 1 and 2.[20] That is, if the THC concentration ratio between oral fluid and blood serum is 1, then the THC concentration would be the same in oral fluid and blood; if the ratio is 2, the THC concentration in oral fluid would be double that in blood. However, Ramaekers et al (2006) found a very different result, a ratio between THC in oral fluid and blood serum falling between 10 and 30:

> the oral fluid/serum ratio in the present study differs markedly from that reported in another study (Huestis and Cone, 2004). In the present study THC levels in oral fluid were generally 10–30-folds higher as compared to corresponding THC levels in serum. In the study by Huestis and Cone (2004), THC concentrations in serum and oral fluid were very similar with oral fluid/serum ratios ranging between 0.5 and 2. It is presently unknown why these ratios differ so markedly in both studies but it may be related to between-subject variations in THC contamination of the oral cavity while smoking cannabis or differences in methods of collecting oral fluid.[21]

Several recent studies have supported the finding of an apparent high ratio between THC concentrations in oral fluid and blood, in the context of extreme variability. Wille et al (2009) examined the ratios between THC concentrations in oral fluid and whole blood in drivers suspected of drug induced impairment, finding the large degree of variability between individuals and a median ratio of THC concentration between oral fluid and whole blood of 15.[22] Lee et al (2013) examined the relationship between oral fluid and blood plasma THC concentration following controlled administration of cannabis by smoking or oral ingestion.[23] This study showed "a median of 6.1 with large inter-subject variability" for THC concentrations in oral fluid and whole blood in the first hour after intake – a ratio which gradually decreased, falling to a median of 2 by 17 hours post-administration. The ratio between oral fluid and blood plasma concentration was affected by a number of variables:

> The window of high OF/P THC [oral fluid to plasma THC concentration] ratios potentially encompasses the window of acute cannabis impairment, which may last for 3–6 h … however, the effects of Δtime, route of administration, dose, and inter-subject variability

[19] "Plasma and Serum." *Boundless Biology*. Boundless, 08 Aug. 2016. Retrieved 06 Nov. 2016 from https://www.boundless.com/biology/textbooks/boundless-biology-textbook/the-circulatory-system-40/components-of-the-blood-225/plasma-and-serum-850-12095/

[20] Huestis, M.A., Cone, E.J., 2004. Relationship of delta 9-tetrahydrocannabinol concentrations in oral fluid and plasma after controlled administration of smoked cannabis. J. Anal. Toxicol. 28, 394–399.

[21] Ramaekers JG, Moeller MR, van Ruitenbeek P, Theunissen EL, Schneider E, Kauert G. Cognition and motor control as a function of Δ 9-THC concentration in serum and oral fluid: limits of impairment. Drug and alcohol dependence. 2006 Nov 8;85(2):114-22. P. 120.

[22] Wille SMr, Raes E, Lillsunder P et al (2009) Relationship Between Oral Fluid and Blood Concentrations of Drugs of Abuse in Drivers Suspected of Driving Under the Influence of Drugs Ther Drug Monit 2009;31:511–519.

[23] Lee D, Vandrey R, Milman G et al. (2013). Oral fluid/plasma cannabinoid ratios following controlled oral THC and smoked cannabis administration Anal Bioanal Chem., 405(23): 7269–7279.

> limits the interpretive value of OF[oral fluid]/P[plasma] THC ratios. Direct prediction of plasma THC concentrations from OF concentrations is not appropriate regardless of drug delivery system.

A Norwegian study by Langel et al (2014) examined relative concentrations of THC in oral fluid and whole blood among "drivers suspected of driving under the influence, drivers stopped randomly at the roadside, and injured drivers admitted to hospital after a traffic accident".[24] The median value for the ratio between oral fluid and whole blood was 14.

In a carefully-designed lab study, Milman et al (2011) administered THC to a sample of experienced cannabis users: "Ten male daily cannabis smokers received around-the-clock escalating 20-mg oral Δ9 -tetrahydrocannabinol (THC, dronabinol) doses (40–120 mg/day) for 8 days."[25] This study, in line with prior findings, found such a high degree of variability that no meaningful equivalence could be established between oral fluid and blood plasma concentrations, leading the authors to conclude: "OF [oral fluid] cannabinoid concentrations cannot predict concurrent plasma concentrations."

The interpretation of THC concentrations in oral fluid, often measured at roadside in drivers suspected of impairment, is complex. Most of the studies described above compared THC concentrations in oral fluid to whole blood, yielding a median ratio in the range of 10-15 (with very high inter-individual variability). This might provide a rough indicator to guide interpretation of THC concentrations in oral fluid – but the extreme inter-individual variability renders any such interpretation meaningless. Researchers in this area have cautioned against calculating blood from oral fluid levels: the impairment levels established for blood concentrations of THC cannot be meaningfully extrapolated to oral fluid testing.

[24] Langel K, Gjerde H, Favretto D, Lillsunde P, Øiestad EL, Ferrara SD, Verstraete AG. Comparison of drug concentrations between whole blood and oral fluid. Drug testing and analysis. 2014 May 1;6(5):461-71.

[25] Milman G, Schwope DM, Schwilke EW, Darwin WD, Kelly DL, Goodwin RS, Gorelick DA, Huestis MA. Oral fluid and plasma cannabinoid ratios after around-the-clock controlled oral Δ9-tetrahydrocannabinol administration. Clinical chemistry. 2011 Nov 1;57(11):1597-606.

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