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MUARC BASELINE RESEARCH PROGRAM TO ASSESS THE IMPACT OF DRUG USE ON ROAD SAFETY

REPORT 1 - REVIEW OF INTERNATIONAL LITERATURE ON DRUG-DRIVING AND COUNTERMEASURE OPPORTUNITIES

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MUARC Baseline Research Program to Assess the Impact of Drug Use on Road Safety: Report 1 – Review of International Literature on Drug-driving and Countermeasure Opportunities

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Abstract:

This report examines five key topics regarding drug-driving: 1) prevalence and 2) trends in the use of illicit drugs, drug-driving and crashes; 3) estimates of crash risk associated with drug-driving; 4) attitudes, motivations and perceptions associated with driving under the influence of drugs; 5) countermeasures designed to address drug-driving, including legislation, enforcement, education and behaviour change programs. The intent was to provide a deeper understanding of drug-driving from which drug-driving countermeasures could be identified. This review focussed on the three illicit drugs under which it is currently an offence to have present in the body in Victoria, namely amphetamine/methamphetamines, ecstasy (MDMA) and cannabis (marijuana/THC).

A comprehensive review of recent literature was conducted to address these topic areas. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols (PRISMA-P) statement, research published in the 1995 – 2015 period was examined. The sub-section that examined crash risk included a series of later meta-analysis papers given their importance in understanding the association between drug use, crash risk and crash culpability.

This report provides a comprehensive examination of contemporary issues relating to drug-driving in Victoria. Based on the collective body of research examined, a series of focused countermeasures have been identified.

Key words:

Drug-driving; literature review, road safety, crash risk, risk factors, drug-use prevalence, cannabis, methamphetamine, MDMA, enforcement, education, treatment, countermeasures

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FOREWORD

The Monash University Accident Research Centre (MUARC) *Program to Assess the Impact of Drug Use on Road Safety* was sponsored by the Department of Justice and Community Safety, the Department of Transport, the Transport Accident Commission (TAC), and Victoria Police through the MUARC Baseline program.

This research program was established to provide insight into drug use within the community and to explore motivations underlying drug-driving behaviour. The program also explored community attitudes and support for countermeasures to address drug-driving in Victoria, Australia.

The findings of the overall program are presented across three reports, as follows:

Report 1 is a literature review that provides a summary of national and international research in the area of drug-driving, with a focus on available evidence related to crash-risk and effective countermeasures known to reduce drug-driving. Primary research published between 1995 – 2015 was examined with meta-analysis published up to 2019 also included.

Report 2 documents findings from analyses of available Victorian hospitalisation and offence data related to drug-driving. This report is particularly focused on describing demographics of drug drivers and riders, along with drug type and crash-related characteristics. *Note: this report is for internal use only due to data restrictions and privacy adherence requirements.*

Report 3 details the findings from a series of stakeholder engagement interviews, in addition to a community-based survey designed to better understand community drug use, along with the scale, motivation and patterns of drug-driving in Victoria. Further, community acceptance and support for a range of drug-driving countermeasures were also examined.

Taken together, the report series provides a comprehensive overview and assessment of the impact of drug-driving on road safety in Victoria, Australia. Where relevant, recommendations for the application of effective countermeasures to reduce the incidence and impact of drug-driving on injury and fatalities are made. Further, policy implications are discussed in addition to avenues for future research.

Keywords: Drug-driving; literature review, road safety, crash risk, risk factors, drug-use prevalence, cannabis, methamphetamine, MDMA, enforcement, education, treatment, countermeasures

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LIST OF ABBREVIATIONS

AOD	Alcohol and Other Drugs
BAC	Blood Alcohol Concentration
BI	Brief Interventions
BZP	Benzodiazepines
CBD	Cannabidiol
CNS	Central Nervous System
DUIC	Driving Under the Influence of Cannabis
DUICA	Driving Under the Influence of Cannabis and Alcohol
DUICO	Driving Under the Influence of Cannabis and Other Drugs (+/- alcohol)
EMDEs	Electronic Music Dance Events
EDRS	Ecstasy and Related Drugs Reporting System
HR-Vic	Harm Reduction Victoria
'ice'	Powder or crystallised form of methamphetamine (aka: shabu)
IDRS	Illicit Drug Reporting System
KPEs	Key Peer Educators
LSD	Lysergic acid diethylamide (aka: Acid)
MA	Methamphetamine
MDMA	Commonly known as Ecstasy; 3,4-Methylenedioxymethamphetamine
MI	Motivational Interviewing
MUARC	Monash University Accident Research Centre
NHSDA	National Household Survey on Drug Abuse
NTRI	National Trauma Research Institute (The Alfred)
P.A.R.T.Y.	Prevent Alcohol and Risk-Related Trauma in Youth
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PWID	People Who Inject Drugs
RDT	Random Drug Testing
REU	Regular Ecstasy Users

RPU	Regular Psychostimulant Users
RT	Relaxation Training
SIA	Standard Impairment Test
TAC	Transport Accident Commission
THC	Tetrahydrocannabinol: the principal psychoactive constituent of cannabis, also known as Δ^9-tetrahydrocannabinol

EXECUTIVE SUMMARY

BACKGROUND AND AIMS

It is widely accepted that drug-driving represents a threat to achieving reductions in the number of people killed and seriously injured on our roads. With this in mind, the Monash University Accident Research Centre (MUARC) *Baseline Research* partners established a research program that would provide inputs to inform current drug-driving road safety policy and programs.

In meeting this aim, the *Research Program* sought to:

- Provide a targeted review of the association between drug use and crash risk using literature and reports published since 1995 (up to 2015), including review papers and relevant expert group position papers where possible.
- Explore motivations for drug use among specific parts of the driving population.
- Quantify the extent of drug-driving in Victoria through an examination of offence data and hospitalisation data.
- Examine the attitudes of Victorian drivers toward drug-driving, including their use of alcohol and other drugs, as well as their attitude toward road safety countermeasures.

The *Research Program* was developed by the MUARC in partnership with the Department of Transport, the Transport Accident Commission, the Department of Justice and Community Safety, and Victoria Police.

The *Research Program* consisted of three distinct components with a report produced for each. The three components were:

- Component 1: The conduct of a literature review focussed on the prevalence of drug-driving, the crash risks associated with drug-driving, and countermeasure solutions. The intention was to identify countermeasures that could be effective in reducing drug-driving behaviour in Victoria.
- Component 2: Analysis of data to enumerate the magnitude of illicit drug-driving and illicit drug-related crashes in Victoria.
- Component 3: The conduct of a population-based survey of the Victorian community with the view toward understanding alcohol and drug-use patterns, drug-driving behaviour, perceptions of the effectiveness of specific countermeasures and the level of support for each.

Taken together, this series of reports provides a detailed examination of the current drug-driving problem in Victoria, and ways that this can be addressed.

This report relates to Component 1 of the Research Program.

SCOPE AND METHODS

A systematic review of the drugs and driving literature published from January 1995 to August 2015 was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols (PRISMA-P) statement. A series of more recent meta-analysis papers were also included, given their importance in understanding the association between drug use, crash risk and crash culpability.

The literature review addressed five key research questions:

1. How prevalent is drug use and drug-driving in Victoria and Australia, and related to this what is the prevalence of drugs in fatal and serious injury crashes in Victoria and Australia?
2. What are the trends and patterns associated with drug use, drug-driving, and drug-driving related fatality and serious injury crashes in Victoria and Australia?
3. What is the crash risk associated with drug-driving?
4. What are the attitudes, motivations and perceptions associated with drug-driving among those who take drugs and drive?
5. What countermeasures are in place or have been identified that could prevent drug-driving and drug-driving related trauma?

This Review focussed on the three illicit drugs under which it is currently an offence to have present in the body in Victoria, namely:

- Amphetamines / Methamphetamines.
- Cannabis (marijuana/THC).
- Ecstasy (MDMA).

This review examined national and international research for all research questions. Drug use prevalence and trends focussed on Victorian and Australian data. The review identified a large volume of research on the attitudes and motivations associated with drug-driving, with much of this being conducted in Australia.

At the outset, drug-driving was defined as operating a vehicle on the road following recent use of, and/or impairment by one or more of the three drugs of interest in this review. Although the definition of 'recent' use varies across research studies, 'recent use' typically refers to drug-use 1-3 hours prior to driving. Within this window, acute drug intoxication is highly evident. It is also noted however that the impairing effects of drugs can last longer, with the duration of psychoactive effects varying across different substances, mode of use, dose, and user profile.

PREVALENCE, TRENDS AND PATTERNS OF: DRUG USE, DRUG-DRIVING AND DRUG-DRIVING CRASHES

Chapter 3 of this Report reviewed the prevalence of, and trends in, drug use in the general population, in the driving population, and in those who have had a crash whilst operating a motor vehicle. Prevalence refers to the proportion of individuals in a population who use drugs or who drive on drugs or who crash whilst on drugs within a given period of time. Prevalence studies provide an indication of the extent and size of the drug-driving problem. The research was limited to that conducted in Australia since this provides important information about where and how resources should be directed for countermeasure development within the local context.

Drug use

Information about drug use prevalence and patterns of use within the general population provides an important contextual framework for understanding the prevalence of drug-driving.

At the time of the literature review, the largest available survey on the patterns of alcohol and illicit drug use was the National Drug Strategy Household Survey (NDSHS, 2014). The 2013 survey had a sample of 23,855 persons aged 14 years and over across all Australian States and Territories, while the updated 2016 survey (AIHW, 2017) included 23,772 persons 14 years and older.

Recent illicit drug use, defined as being in the last 12 months, was 14.3% in 2013 and 15% in 2016 in Victoria. A higher proportion of males reported recent use (17.4%) than females (12.8%). Nationally, the percent reporting use of illicit drugs in the past 12-months increased marginally, from 15% to 15.6% (males: 18.3%, females: 13%). In 2016, the highest self-reported recent use was for respondents living in the Northern Territory (21.6%) followed Tasmania (17.4%) and Western Australia (16.8%) and South Australia (16.8%).

In all Australian jurisdictions persons aged 20–29 years were the most likely to report use of an illicit drug in the past 12 months. Using Victoria as an example, in 2013 27.4% of persons aged 20-29 years reported having used an illicit drug in the past 12 months, with this increasing slightly to 29.8% in 2016. This proportion was nearly twice that of the persons aged 30 – 39 years of age (2013:16.5%; 2016: 16.2%).

Per the AIHW survey, in 2016, the most common drug used recently in Victoria was cannabis (2013: 9.1%; 2016: 9.9%), followed by ecstasy (2013: 2.4%; 2016: 2.4%) and meth/amphetamine (2013: 1.9%; 2016: 1.5%). A higher proportion of males reported recent cannabis use (13%) than females (7%), equal proportions reported recent use of MDMA (2.5%), and a slightly higher proportion of males (1.8%) reported recent use of meth/amphetamines than females (1.2%). Regarding amphetamines, 42% of users had consumed 'ice' and 36% used the powder form. These patterns were generally the same across all states and territories.

The AIHW also reported that there were higher levels of support for education and treatment (47%) for those found in possession of drugs and less support for sanctions, although 24% stated that possession of meth/amphetamine should result in a prison sentence. Of direct relevant to the present project, 15.1% of respondents stated that they had driven under the influence of illicit drugs with this being more common among males (18.5%) than females (12.0%); the percent of respondents reporting drug-driving was lower in 2015 than previously (2013: 15.9%; 2007: 21%. Unfortunately, percentage breakdowns for drug-driving across States and respondent demographics was not provided in the AIHW report or data tables.

Drug-driving and drug-driving crashes

The prevalence of drug-driving and in fatal and serious injury crashes provides an important indication of the extent and size of the drug-driving problem.

At the time of writing there was little published data available on the prevalence of drugs in driving. The most recent Victorian estimate (2007) of illicit drug use and driving was 2.4%; this was estimated by the presence in oral fluid given roadside screening. Estimates in other Australian states ranged between 2% of the screened population in New South Wales (2011) and 5% of the screened population in Western Australia (2009).

Very few studies have reported prevalence estimates for individual drugs. In an important analysis, Drummer et al (2007) reported a rate of 1.3% for ecstasy, 0.66% for cannabis and 2.1% for methamphetamine in Victoria. The combined use of THC and methamphetamine was found in 0.6% of Victorian drivers.

Self-report studies consistently show that THC was the most commonly surveyed drug within the general driving population. In contrast, roadside studies of oral fluid test results show that methamphetamine was the most commonly detected drug, followed by THC. To an extent the findings from roadside oral fluid studies may reflect differences in the length of time that drugs remain at detectable levels in saliva and device sensitivity to particular substances. As such the higher proportions of methamphetamine detections found in roadside tests may not be reflective of usage in terms of absolute numbers of users in the community. It follows then that some drivers may not be detected when driving with concentrations below the sensitivity of the cut off threshold for the roadside screening device; this appears to be especially relevant for THC (Drummer et al., 2007).

Self-reported drug-driving prevalence was relatively low among the general population; however, it was consistently much higher in other samples including regular and injecting drug users, rave/nightclub attendees and long-haul truck drivers. For THC, drug-driving in the general population ranged between 11-12% (cf. 15% in AIHW survey above for all drugs), but between 26-57% in regular injecting drug users and between 46-52% in rave/nightclub attendees. Similarly, methamphetamine use was much higher among regular injecting users, with estimates between 25% and 53% compared to 7% to 14% in the general population.

Currently, neither the peer reviewed literature nor the grey literature captures information on trends in drug-driving prevalence within the general population of Victoria or Australia using consistent data sources and collection methods. Report 2 of this Research Program seeks to address this gap for Victoria.

The only regular surveys of drug-driving prevalence and patterns over time in Australia are focussed on sentinel samples of specific drug user groups, namely the Illicit Drug Reporting System (IDRS) and the Ecstasy and Related Drugs Reporting System (EDRS). Among regular ecstasy users in Victoria there was a significant reduction between 2007 and 2013 in the prevalence of driving under the influence of ecstasy (from 63% to 34%) and cannabis (from 63% to 43%). Among regular injecting drug users there was a significant reduction in the prevalence of driving under the influence of methamphetamine (from 33% to 13%) over the period 2007-2013. The percentage of participants who drove on benzodiazepines increased significantly among Victorian participants (from 16% to 23%), while the percentage of respondents driving under the influence of cannabis remained stable (from 53% to 45%).

Only twelve studies examined the prevalence of drug use in fatal and/or serious traffic crashes, with almost 60% having been conducted over ten years ago. In Victoria, the prevalence of THC in fatal crashes ranged from 10.5% to 13.5% and from 7.6% to 36% in serious injury crashes. The involvement of amphetamines in serious crashes ranged from 4.1% to 12%. Methamphetamine and ecstasy use were reported in only the single study in 2012, with an estimated prevalence of 3.1% and 0.8% respectively in serious injury crashes. These trends are examined in detail in Report 2.

Crash risk

Chapter 4 reviewed epidemiological studies that have examined crash risk associated with driving under the influence of illicit drugs. Table E.1 shows the number of studies examined, with the key results being the odds ratios relating to drug-use and crash risk.

At the outset, and based on the literature, it can be stated that the high association between meth/amphetamine and crash risk is clear and uncontroversial. This is also the case for stimulants. The studies examined did not report separately on the crash risk associated with driving under the influence of ecstasy or methamphetamines, with ecstasy (MDMA) largely being grouped in the stimulant category and methamphetamine in the amphetamine category.

In contrast, the association between cannabis use and crash risk was found to be highly inconsistent. Hence, this has proved to be a highly contested area of academic research. However, recent meta-analysis studies demonstrate a clear and increased crash risk associated with cannabis use, which also extends to crash culpability.

While research demonstrates that cannabis is the most commonly used drug, it was generally associated with the lowest crash risk among the illicit drugs reviewed. Per Table E.1, crash risk estimates (Odds Ratio's) range from 1.0 (no difference) to approximately 4 times higher crash risk than non-alcohol and other drug (AOD) use. Amphetamines and stimulants (not all specified) were associated with the highest crash risk.

TABLE E.1 SUMMARY OF FINDINGS ON DRIVING UNDER THE INFLUENCE OF DRUGS AND CRASH RISK

Study Information	Cannabis	Amphetamines	Stimulants - unspecified
No. studies published 1995 - 2015 included in review	40	10	6
Published last 10 years (%)	75%	80%	66.7%
No. case-control	19	9	3
No. cohort	9		
No. responsibility	10	1	3
No. case-crossover	2	0	0
% studies increase risk	50%	80%	66.7%
Risk estimate range (odds ratio)	**1-4***	**8.9-54.8**	**2.27-8.83**
% studies no difference in crash risk	50%	20%	33.3%
No. studies assessing dose-response relationship	4	0	0
% studies dose-response relationship found	100%	N/A	N/A
No. studies assessing polydrug use	2	2	0
% studies increased risk for polydrug use	100%	100%	N/A
Studies using biological specimens	25 (62.5%)	9 (90%)	6 (100%)
Controlled for other drug use	21 (84%)	8 (88.9%)	3 (50%)
Controlled for all key confounding variables besides other drug use	0	0	0
Controlled for age and gender	25 (100%)	9 (100%)	6 (100%)
Using equivalent drug cut off concentrations	13 (52%)	5 (55.6%)	1 (16.7%)
Measuring blood in cases & controls	8 (32%)	2 (22.2%)	2 (33.3%)
Measuring blood in cases & oral fluid in controls	8 (32%)	5 (55.6%)	1(16.7%)
Measuring urine in cases & controls	4 (16%)	1 (11.1%)	0
Measuring mixed specimens in cases (blood or sweat or urine) & oral fluid in controls	4 (16%)	1 (11.1%)	3 (50%)
Measured drug use after crash (4 hours maximum)	6 (24%)	5 (55.5%)	1 (16.7%)

*refer to text for findings from meta-analysis

The amount of drug used, or dose – which also relates to purity or drug concentration, is important to consider. The few studies that examined the effect of drug dose on crash risk did so in relation to cannabis, and all identified a dose response relationship. That is, the higher the detected level, the higher the crash risk.

Most studies that examined the effect of polydrug use on crash risk generally only reported outcomes for each additional drug taken. The small number of studies that specified drug type consistently showed that crash risk was higher when other drugs (including alcohol) were taken with each of cannabis, amphetamines and cocaine than when each of these drugs was taken alone.

Although crash risk associated with alcohol use was not the focus of this review, there is consistent evidence that alcohol use at levels above 0.05 is associated with a higher crash risk than most other drug or drug type combinations, and moreover, crash risk tends to be even higher when alcohol is used concurrently (e.g., see Elvik 2013).

The studies that examined the effect of age and gender on crash risk generally found a higher crash risk among males and younger road users. Given the greater focus on studies measuring crash risk in drivers, there was limited available information on whether crash risk varies according to road user type.

Relatively little is known about any isolated effects on crash risk of drug use frequency (i.e. occasional versus regular versus dependent/addict), and whether habitual drug use influences crash risk in ways that are different from naive users. The one well designed study on this topic, which focused only on cannabis use, indicated that there was a strong significant association between habitual use and car crash injury after adjusting for acute use prior to driving and a number of other important confounding factors. The mechanism by which habitual drug use increases the risk of car crash injury is unknown, but it may reflect the engagement by habitual drug users in other risk-taking behaviours that increase their risk of crashing, or a lack of compensatory strategies that are reportedly used by ad-hoc cannabis users.

As stated above, the quality of research studies examining the association between illicit drugs and driving is highly variable. Depending on the nature of these methodological limitations, crash risk estimates can be over or underestimated. Identified issues include: failing to control for drug and/or alcohol use besides the drug/s under investigation; use of different biological samples across cases (crash-involved drivers) and controls (non-crashed drivers) - particularly urine which provides a measure of past rather than recent drug use; a failure to measure drug use concentrations, relying instead on a dichotomous marker of drug use or use of non-equivalent cut off concentrations in cases and controls; high refusal rates among cases and controls; and a failure to control for key confounding variables including age, gender, kilometres driven, drug use history, dose of drug, health status (co-morbidity), and place of residence.

Due to the complexity in measuring crash risk associated with driving under the influence of drugs, it is difficult to avoid all of these methodological limitations, even in well designed, large-scale epidemiological studies. Hence, the assessment of these known limitations is crucial in understanding the reliability and validity of crash risk estimates. It is accepted that estimates of crash risk derived from carefully designed studies are likely to be more reliable than those that are based on poorly designed and/or poorly controlled studies.

Taking this further, studies that combine the findings of multiple research studies, each assessed for quality, offer a way to quantify crash risk. These studies are known as meta-analysis. Since 2012, there have been four important meta-analysis conducted, three of which specifically examined the association between cannabis and crash risk and/or culpability.

As stated above, the association between amphetamine use and crash use has been consistently demonstrated, with the risk of crash involvement being more than five times higher, with meta-analysis confirming this association.

Meta-analysis for cannabis and driving report a crash risk, or odds ratio, in the range of 1.32 to just under 2.0. This indicates an increased crash risk of 32% higher to as much as a doubling of crash risk.

By way of example, in the most recent meta-analysis, Rogeberg et al (2018) reports a combined odds ratio of 1.32 (1.09-1.59) for cannabis and crash risk. This indicates that the odds of crash involvement associated with cannabis intoxication is estimated to be 32% higher than no cannabis being present; interpreting the statistical confidence intervals means that this increased risk could be as low 9% higher to 59% higher. Notably, the crash risk estimate associated with cannabis use was higher when the included studies were assessed to be of 'high quality' (OR: 1.53, 95% CI: 1.11-2.09), whilst those studies assessed to be of medium or low quality were associated with a lower – albeit non-statistically significant — increase in crash risk. Other reported estimates (in the same study) of the association between cannabis use and crash risk are higher, notably the case-control point estimate was 1.82 (95% CI: 1.19 – 2.79). The authors of this work described their results as being '…consistent with low-to-moderate risk increases across all subgroups of studies' (p.968).

Importantly, much of the debate surrounds the magnitude of the increased crash risk, not whether such as risk exists at all. There are three points to make here: 1) in the context of the Victorian Towards Zero Strategy, any demonstrable and statistically significant increase in crash risk due to any given factor is cause for concern; 2) the point estimates for odds ratios represents the *average risk,* hence, this will be higher for particular driver sub-groups, and this could be effected by drug concentration (purity), as well as frequency of use, and 3) there is clear evidence that having a higher concentration of illicit substances leads to even higher crash risk. It is also known the users of illicit substances frequently use more than one drug, including alcohol, which leads to a demonstrably significant increase in crash risk.

In summary, the findings from this literature review demonstrate differences in the magnitude of the increased risk of being involved in a crash across different drug types. It remains imperative then to consider the crash risk associated with specific substances when determining appropriate countermeasures. With respect to cannabis (THC), notwithstanding the wide variation in crash risk estimates - much of which can be explained by differences in study design, there is a general consensus in the literature that the crash risk associated with recent cannabis use ranges from 1.3 – 2 times that of non-use, with the most recent meta-analysis reporting a point estimate of 1.32, with confidence intervals ranging from 1.09 to 1.59. For methamphetamine, the increased crash risk is significant and is consistently reported to be upwards of 5 times the crash risk associated with non-use of alcohol or other drugs.

Expressed with reference to alcohol and crash risk, the odds ratios of recent cannabis use are analogous to a BAC in excess of 0.05, while for methamphetamine the increased crash risk is analogous to that seen with a BAC in excess of 0.1. While these comparisons can be useful in articulating the risk of crash involvement given the well accepted risks associated with alcohol use in the scientific and broader community, the time-course, nature of impacts on cognitive, perceptual, and motor skills required for driving likely differ due to the differences in basic psychopharmacology.

From a policy perspective, a key factor in the impact of drug-use on road crashes at a population level is a product of the observed crash risk relationship and the prevalence of drug use in the community. Hence, any change in the policy settings that could see an increase in use would likely result in an increase in drug-related crashes, irrespective of the magnitude of the increased crash risk associated with specific drugs.

This has particular relevance in Victoria where methamphetamine use – and purity, has been seen to increase over the past decade, but remains a fraction of the number of cannabis users. While the number of users is relatively small, combined with the much higher crash risk (also due to increase in purity), there has been a large increase in meth/amphetamine-related crashes (see Baseline Report 2). As a contrast, the comparatively higher number of cannabis users combined with a lower, but still statistically significant increased crash risk, means cannabis-related drug-driving presents as a significant road safety concern.

With respect to current debates on the legalisation of recreational cannabis, it is pertinent here then to note observed increases in crashes associated with the legalisation of recreational cannabis in the United States. Here it is important to consider a) the idea drivers that would switch from alcohol consumption to cannabis consumption which is purportedly used more at home and hence there would be lower driving exposure (Rogeberg & Elvik, 2016a), and b) the observation that given the stated crash risk associated with cannabis (and prevalence estimates), cannabis impaired driving would have a minor impact on the total number of traffic crashes (Rogeburg, 2019). That the contrary has occurred could be a consequence of an increased number of cannabis users, and with this an increase in the number of new users who elect to drive, an increase in the frequency of cannabis use, an increase in the available concentration level of cannabis (THC) and/or the propensity of existing users to drive after use. With these US jurisdictions not having implemented a random roadside oral fluid test to detect drug-driving, the lessons for other jurisdictions are clear.

It is also relevant to note here the legalisation medicinal cannabis in some jurisdictions, including Victoria. With the area of medicinal cannabis and driving being very new, research in managing this potential risk is urgently required. It is imperative that these research findings inform guidelines on medical fitness to drive. Whilst it could be expected that the condition(s) for which medicinal cannabis is being used to treat is (are) already covered by fitness-to-drive guidelines, the use of prescribed medicinal cannabis for such conditions ought to be considered.

Finally, it is the case for all drugs, including illicit substances and prescription medications, that there is a need for an improved understanding of the dose-response relationship between blood concentration and crash risk. This has implications for roadside tests, the identification of drivers at particularly high risk, and the setting of threshold levels (as is done in Norway) were such a policy to be pursued. Irrespective of this, the current body of drug-driving research clearly points to an increased crash and crash culpability associated with the use of both amphetamine-class drugs and cannabis.

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ATTITUDES, MOTIVATIONS AND PERCEPTIONS ASSOCIATED WITH DRIVING UNDER THE INFLUENCE OF DRUGS

Research in many areas has shown that attitudes and perceptions towards risk are strong predictors of behaviour. Understanding these factors is therefore central to achieving desired behavioural change through the implementation of drug-driving countermeasures. Accordingly, four key questions were addressed in this review:

- Why do people drug-drive? (Motivations for drug-driving)
- What are the attitudes and perceptions associated with drug-driving?
- What factors are predictive of drug-driving?
- What are the most important predictors of drug-driving?

Motivations for drug-driving

In both recreational users and dependent drug-users, drug-driving was reportedly primarily undertaken for functional reasons where it was seen as part of the driver's every day or normal activity; drug-driving rarely occurs for the sole purpose of enjoyment or thrill seeking. Convenience and a lack of reliable or alternative transport options were the main reasons cited in studies of recreational (i.e.., not work-related) drug-driving, particularly among night club or dance / rave party attendees.

For dependent drug users, drug-driving was common. For this cohort driving was undertaken with the objective of obtaining or dealing drugs, and in many cases the car (or other vehicle) was considered to be a safe and comfortable place to use drugs following a 'deal'. For this group, any drug-driving prevention strategy will need to be considered within the context of the individuals overriding drug addiction problem. This group was unconcerned about the potential crash and legal risks associated with drug-driving, largely because the prime focus of their behaviour was to support a drug habit; notably this group commonly had previous contact with police and the judicial system. As such, education and enforcement are unlikely to be effective countermeasures when used in isolation.

For recreational drug users for whom drug-driving was not so integral to their lifestyle, enforcement supplemented with education are likely to be more effective. Improved transport options — including public transport — for those leaving clubs and hotels at night would also seem to be a fundamental requirement to reduce the incidence of drug-driving among this cohort.

Perceptions of driving impairment and crash risk associated with drug-driving

Most drug-drivers perceived that cannabis, ecstasy, and methamphetamine had no impact on their driving ability. This view was more commonly held by users of cannabis compared to users of other drugs. Of concern was that a small proportion of drug-drivers consistently reported positive effects of drugs on driving performance, including for meth/amphetamine.

Where asked, over half of all respondents perceived the risk of crash involvement to be 'unlikely' or 'very unlikely' for cannabis, ecstasy, and methamphetamine, compared to one-quarter of respondents when asked about alcohol. Importantly, low perceptions of driving impairment and crash risk were shown to significantly predict drug-driving.

Studies examining self-reported 'knowledge' of the effects of drugs on driving performance show that most knew only 'some' or 'very little' about the impact of drugs on driving performance. As a consequence, personal experience plays a large role in forming their current beliefs. For example, previous experiences of having avoided detection or a crash, or knowing of others who had, seemed to form the basis of a perception that the risks associated with drug-driving were low. Similarly, a subset of drivers' state that they are able to recognise some level of impairment, but they are able to compensate for this; these drivers also rate themselves as safer than if they, or others, had consumed alcohol.

The apparent lack of knowledge of the effects of drugs on driving performance and road safety reflects the need for education around the effects of drugs on driving and the ineffectiveness of compensatory behaviours. Cannabis should be targeted as a potential priority since it was more likely to be perceived as having no-to-little impact on driving ability compared to other drugs; at the same time, respondents reported being more 'knowledgeable' about its effects, and thus compensating for these effects whilst driving. Programs aimed at addressing this view ought to be a priority.

Perceptions of the risk of being detected by police for drug-driving

Studies examining the perceived risk of apprehension by police for drug-driving were limited to those conducted in Australia since the introduction of random roadside drug testing.

The risk of being caught for driving under the influence of drugs (cannabis, methamphetamines or ecstasy) was perceived to 'very unlikely' or 'unlikely' by the majority of drug-drivers. The perceived certainty, severity or swiftness of sanctions were not significant predictors of self-reported drug-driving behaviour, nor of the intention to drug-drive in the future. However direct punishment avoidance (i.e., having avoided apprehension) and vicarious punishment avoidance (i.e., knowing of others that have avoided apprehension) were predictors of drug-driving behaviour.

Taken together, these findings suggest that drug-drivers held stronger perceptions about the lack of potential punishments and the ease with which punishments or detection could be avoided than they did about the likelihood of getting caught.

More recently, research has suggested that there have been reductions in driving under the influence of ecstasy and methamphetamine, and that this has been linked to changes in attitudes towards the risk of police apprehension. Specifically, it has been reported that a greater proportion of drug-drivers in 2011 indicated that there was a higher likelihood of being apprehended when compared to 2007. However, attitudes towards driving under the influence of cannabis had not changed over this period despite the introduction of roadside saliva testing.

In sum, the findings in relation to perceptions of drug-driving enforcement present a significant challenge for road safety. Based on the collective research findings on perceptions of the risk of detection, steps to increase perceptions of the certainty of apprehension, increased testing frequency, and increased awareness of roadside drug testing enforcement could potentially lead to reductions in drug-driving.

The impact of behaviour and perceived 'non-legal' sanctions on drug-driving

Drug use patterns emerged as the most consistent predictors of drug-driving, with those who used drugs more frequently, those who had greater drug dependency issues, and those who used multiple drugs being more likely to drive whilst impaired than drug users without these patterns of use.

These drug use patterns emerged as more potent predictors of drug-driving than other factors including perceptions of enforcement, perceptions of impairment, and social sanctions (what one's peers think about drug-driving). These findings present a challenge for drug-driving enforcement as they suggest that past behaviours may be negating the deterrent impact suggested to stop the offending behaviour. However, it is important to point out that these concerns apply to a smaller group of dependent drug users for whom tackling the underlying drug use problem through targeted interventions programs is likely to be the most effective approach to reducing drug-driving.

Drug-driving countermeasures also need to consider peer group influences as peer-attitudes were strongly linked to drug-driving behaviour. Specifically, drug-driving was predicted by a permissive attitude within the social/peer network toward drug-driving behaviour among peers; that is, those whose friends perceived drug-driving to be favourable and whose friends drove under the influence of drugs were significantly more likely to drug-drive.

Personality factors, specifically risk-taking propensity and sensation-seeking should also be considered as targets for drug-driving interventions as these were shown to consistently predict drug-driving. Those who scored high on the measure of sensation-seeking and who exhibited risky driving behaviour, such as speeding and drink-driving, were more likely to drug-drive than those who scored low on the measure of sensation-seeking and did not engage in other risky driving behaviour.

Comparisons of the relative importance of legal and non-legal sanctions generally showed mixed results. In some studies, perceptions of the likelihood of being apprehended by police were stronger predictors of drug-driving than what one's peers thought about drug-driving. In other studies, the reverse was true. While this difference may be reflective of different respondent demographic and drug-use profile, further work is required to understand these results more fully.

DRUG-DRIVING COUNTERMEASURES

Chapter 6 set out to identify and describe countermeasures and approaches aimed at reducing drug-driving. Relatively few countermeasures have been developed to address drug-driving, with these largely inspired by drink-driving countermeasures. Of those that have been implemented to address drug-driving few have been evaluated for their effect on drug-driving and drug-driving related crashes.

Available countermeasures can be placed into one of four categories: legislation; enforcement; education and media campaigns, and specialised treatment programs.

Roadside drug testing (RDT)

To date – and to the authors knowledge, there have been no crash-based evaluations roadside drug testing programs in Australia or elsewhere. This gap needs to be addressed urgently.

While a small number of studies have indicated reductions in offending or the increased detection of drug-drivers, most research has focused on the potential benefits of RDT through process evaluations based on consultations or interviews with police organisations or by examining self-reported intentions to drive under the influence of illicit substances. Analyses of enforcement and/or detection data within Australia, including Victoria, have generally been positive and supportive of the RDT programs.

A number of studies have highlighted intentions of some drivers to continue offending in instances where perceived risk of detection is low, or where punishment avoidance is perceived to be common. These findings suggest that enforcement can be an effective deterrent to drug-driving, but only if it is widely implemented and highly publicised so that drug-drivers perceive a real threat of apprehension and sanction, which can include fines, vehicle impoundment, or a combination of other measures.

Social marketing and/or mass media campaigns

No publicly available evaluations of the effect of drug-related mass media/social marketing campaigns on drug-driving or drug-driving crashes in Australia were identified in this review.

Most evaluations focussed only on program reach and/or attitude change. Some of these campaigns were effective in raising awareness of the penalties and social consequences of drug-driving. However, in most cases the campaigns were unsuccessful in changing behaviour due to a perceived lack of enforcement accompanying the publicity campaigns. The relatively low level of drug-driving (compared to drink-driving) enforcement is an important barrier to achieving general drug-driving deterrence; this also limits the effectiveness of social marketing campaigns designed to educate the general public about the dangers and legal penalties associated with drug-driving.

Education programs

To date, there have been very few publicly available evaluations of drug-driver education programs on drug-driving behaviour or drug-driving related crashes.

The limited evidence that does exist suggests that teenagers whose parents had spoken with them about safe driving were less likely to drive whilst affected by cannabis compared to participants whose parents had not spoken with them about safe driving.

Evaluations of loss of licence programs designed to 'rehabilitate' drink-drivers suggest that the current drug-driving programs in Victoria may have limited capacity to change behaviour, especially for persons with substance-dependence issues.[1] Current drink- and drug-driver education programs have been criticised for having a "one size fits all" approach, with substance-dependent offenders, first-time and low-level offenders all completing the same education program. In lieu of this, a more effective system would be a streamed approach that would cater for the different offender groups and ensure that education and rehabilitation can be tailored to each type of offender. An important issue with the current licence restoration process is that assessment, rehabilitation or treatment is not undertaken at the time of the offence but at the time of re-licensing. This time lapse may weaken the benefit of any potentially positive effects of the intervention and/or increase the likelihood of re-offending during this period.

[1] A revised behaviour change program informed by best-practice principles for all drink and drug drivers was implemented in Victoria as of 30 April 2018, the efficacy of which is yet to be documented due to the lack of sufficient follow-up time.

Treatment programs

Evaluations of drug-driving treatment programs including brief interventions and motivational interview (MI) techniques have shown promising results. As such, these types of programs ought to be evaluated for both efficacy cost-effectiveness among drug-driving sub-groups.

Beyond drug-driving, treatment programs have however been demonstrated to be effective within clinical psychology and psychiatry, particularly those where cognitive-behavioural therapy is used. While important to note, the subject of efficacy of drug-treatment programs more broadly is beyond the scope of this review.

Therapeutic-justice models

It is now widely recognised that a purely sanctions-based approach for managing certain offender groups has its limits. This is particularly the case for alcohol and drug-dependent offenders where issues of drug-dependence are directly associated with offending. Drug Courts and similar Driving-While-Impaired (DWI) Courts were established specifically to take a more holistic view of managing offenders with the goal of reducing recidivism. These Courts combine a traditional sanction-based approach with a therapeutic approach so that underlying addiction and offending issues can be managed.

Based on the review undertaken here, it can be stated that the evidence base concerning the efficacy of Drug Courts and DWI courts on offender behaviour, including in reducing driving-related offending, is highly promising. For these reasons, these programs ought to be considered as a viable policy option in addressing drug-driving (and drink-driving) behaviour in Victoria and other jurisdictions in Australia.

It is stated however that effort needs to be made to ensure that these programs remain efficacious, are targeted appropriately, and refined where required to manage what would be a significant expansion given the number of drug-driving offenders detected in Victoria.

Identification of specific drug user groups for countermeasure development

An objective of this review was to identify countermeasures that would likely be successful in preventing drug-driving behaviour. While the suggested countermeasures outlined here are drawn from the published literature, it is important to note that many have not been formally evaluated with respect to reducing drug-driving. Indeed, this review highlights the fact that there have been very few evaluations of drug-driving countermeasures. That this is the case means that urgent attention is needed to establish the efficacy of different measures as they relate to reducing drug-driving.

Having noted this lack of evidence, it can be stated that a key requirement for developing effective drug-driving countermeasures is to identify the different drug user and drug-driving groups and to understand their characteristics, usage patterns and user sub-types. This is necessary to ensure appropriate targeting of specific countermeasures.

As well as a general focus on the entire driver population, specific driver sub-groups that require targeted countermeasures include young drivers; males; polydrug users; frequent (but non-dependent) drug users, and operators of commercial vehicles. Drug-drivers with specific issues including drug use dependency, poor mental health, criminal convictions and high sensation-seeking tendencies also need to be the focus for specific countermeasures. Reducing the incidence of drug-driving among these sub-groups is likely to be particularly challenging and it is likely that a range of interventions and novel approaches will be required.

While enforcement ought to remain the mainstay of drug-driving countermeasure programs, post-offence management of driving offenders is critical. A range of measures are detailed in the report, including combined-sanction-therapeutic based approaches, sanctions including vehicle impoundment, and tailored public education programs distributed across diverse media channels. Furthermore, it is suggested that expanded public transport, and/or the development of alternative transport modes, could also play a role in reducing drug-driving behaviour.

CONCLUSION

This report provides a detailed analysis of recent published literature on drug-driving. The purpose of this review was to provide the basis of future policy actions, and also to contextualise Report 2 (analysis of offence and crash data) and Report 3 (community survey) conducted under the MUARC Baseline Illicit Drugs and Driving Project.

The report highlights the findings from recent studies on the prevalence of drug-use, drug-driving behaviour and associated crash risk. In addition, this report examines attitudes, knowledge, motivations and predictors of drug-driving. This was done with the purpose of identifying measures that would likely be effective in mitigating drug-drive behaviour. While the report presents a range of measures to address drug-driving among drug-driving sub-groups, application of these must be considered within the context of the nature and type of drug use among drivers in a particular jurisdiction. This is particularly pertinent given the clear differences in crash risks associated with different illicit drugs, as well as differences in the motivations, attitudes and demographics of users of different substances.

Research consistently points to a high increased crash risk associated with amphetamine use and use of other stimulants. The high crash associated with amphetamines is uncontroversial and is uncontested. Given the magnitude of the increased crash risk, the negative impacts on road safety are likely to be significant, even in the context of a small number of users.

As a contrast, the crash risk associated with cannabis – whilst statistically significant, is nonetheless lower than for example amphetamines-and-related substances. Numerous studies have been conducted, the quality of which has been highly variable, ranging from low quality to very high quality. This, combined with inconsistent findings of the association between cannabis use and crash risk has resulted in considerable debate in the academic literature. However, with the publishing of a number of meta-analysis papers, it can be stated now that there is no such disagreement that cannabis use is in fact associated with a higher crash risk compared to non-use.

It can be stated that despite the crash risk association being lower for cannabis compared to amphetamines, combined with the larger cannabis user base, cannabis-affected driving poses as a significant threat to achieving reductions in road trauma. Whilst it has been estimated that up to 2% of the *entire crash problem (i.e., all severities including property-damage-only crashes)* and between 5% to 7% of hospitalisation crashes can be attributed to cannabis-related driving, any change in the number of users, their frequency of use, of the potency of the drug itself, through shifts in the illicit drug market and/or policy changes including legalisation of cannabis for recreational use and potentially medicinal use (where not prescribed appropriate and with adequate controls on driving), this percent will likely increase. The implications of these findings, and of their policy considerations, for the design of enforcement and other intervention programs are considerable.

While this report did not examine the technical aspects of roadside illicit drug detection, we make the point here that the detection threshold settings of both saliva screening and blood are critical to understand, as is the relationship of detectable levels and crash risk. Related to this is the technical aspects of drug pharmacokinetics, the time-course of impairment and elimination from the body, which differs for each particular substance. Public education programs addressing these concepts, whilst highly technical, would likely see an improved understanding of the rationale of roadside drug-testing laws. This could also pave the way for impairment-based testing and/or graded offences associated with detected drug concentration levels.

Given the findings of this review, future policy actions would be well served to consider the nature of drug use, preferences of users and their motivations for use, as well as their geographic distribution in the community in designing road safety and associated health-related harm minimisation and judicial programs. Indeed, multi-component programs that incorporate high levels of general and specific drug-driving deterrence, as well as a range of treatment and rehabilitation options post-detection based on the concept of therapeutic justice will be required to successfully address drug-driving behaviour.

Finally, we assert that a 'one-size-fits-all' approach will be less successful than a flexible system that accounts for individual differences in motivations for using drugs, the types of substances used, and the broader health needs of a subset of chronic and/or dependent drug users.

MONASH University

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1. INTRODUCTION

1.1 BACKGROUND

Drug-driving has risen in prominence since the *Inquiry into the Effects of Drugs (Other than Alcohol) On Road Safety in Victoria 1995*. This has arguably been a consequence of the increased availability of certain types of illicit drugs in the community, which, given changes in alcohol use, may have led to shifts in motivations for illicit drug use.

Illicit drugs, as well as some prescription medications, have a range of physical and psychoactive effects that can impact both cognitive processes and motor control. The key issue then is how the use of these substances impacts safe driving (Shinar, 2017). Through a large of number of studies, use of illicit drugs – including cannabis, meth-/amphetamines and ecstasy (MDMA) have been shown to be associated with increased crash risk.

With the State of Victoria's commitment to achieving zero serious injuries in road crashes, drug-driving represents a threat to achieving this goal. To address this concern, a program of research into drug-driving was established under the Monash University Accident Research Centre (MUARC) Baseline Research Program. The *Research Program* had the goals of understanding the magnitude of, and motivations for, drug-use to the extent that it is relevant to addressing drug-driving behaviour. It was considered that by identifying the different patterns of use, context of use, and underlying motivations for use, effective countermeasures to reduce drug-driving could be identified.

1.2 RESPONSE OF THE VICTORIAN ROAD SAFETY AGENCIES

The problem of drug-driving has been recognised for some time. In December 2004, the Victorian Government implemented a roadside drug testing trial under the *Road Safety (Drug-driving) Act 2003* where drivers were tested for amphetamines and cannabis (THC). This followed the Standard Impairment Test (SIA) that commenced in 2000. The roadside drug testing program was expanded under legislation in 2006 to include MDMA (i.e. ecstasy). The roadside drug testing program continues to this day.

In addition to enforcement operations, the Transport Accident Commission (TAC) initiated a series of public education programs to support the enforcement initiatives, with advertisement title themes including "Double Bus", "The Cell", "Swap" (tagline: If you drive on drugs, you're out of your mind"), and "Gran" (tagline: More Drug Tests, More Places, More Often) being used. Much of the approach has been inspired by the successful random breath test program for alcohol.

Despite the investment in the world-first roadside drug screening program, there is increasing concern about drug-driving behaviour in the road safety community. This has been driven in part by the surge in crystal methamphetamine ('ice') availability and use as documented in the 2014 Victorian *Inquiry into the Supply and Use of Methamphetamines in Victoria*. Per the 2019 *National Wastewater Drug Monitoring Program*, high use levels of illicit drugs, particularly methamphetamine and cannabis, persists in the community.

Given the above context, and the increased proportion of fatality crashes associated with drug-driving in Victoria (TAC, 2017), there is a need to identify countermeasures that are likely to be effective in addressing drug-driving behaviour. Understanding community attitudes toward drug-driving, and motivations for drug-driving behaviour more specifically, is important as both factors likely play a role in the acceptability and effectiveness of countermeasures aimed at addressing this behaviour.

1.3 AIMS AND OBJECTIVES

The overarching aim of the *Research Program* was to provide inputs that can be used to inform the development of an effective drug-driving road safety strategy for Victoria. To meet this aim, the *Program* will:

- Provide a state-of the art targeted review of the association between drug use and crash risk using key literature and reports, including review papers and relevant expert group position papers.
- Provide a targeted examination of current drug use and associated drug-driving behaviour in Victoria.
- Explore motivations for drug use among specific parts of the driving population.
- Examine the effectiveness of potential countermeasures to address drug-driving in Victoria.

The Research Program had three components:

- Component 1: Literature review and understanding current drug-driving enforcement and public education practices in Victoria. This component comprises two parts:
    1. Literature review.
    2. Examination of, and recommendations for, enforcement practices and public education programs in Victoria.
- Component 2: Scope and analysis (or incorporation) of hospitalisation and offence data relating to illicit drug use and drug-related crashes.
- Component 3: Understanding motivations, and community attitudes towards drug-driving and potential countermeasures to address this issue.

This report documents the findings of Component 1.

1.4 SCOPE OF THIS REPORT

This report was designed to be a comprehensive literature review of the published literature on the crash risk associated with drug-driving, the motivations underpinning drug-driving behaviour, and a review of available countermeasures.

In line with the current roadside drug testing regime in Victoria, the literature review places emphasis on research that relates to cannabis (THC), ecstasy (MDMA) and amphetamines, including 'ice' and 'speed'.

2. METHOD

2.1 APPROACH

A systematic review of the drugs and driving literature was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols (PRISMA-P) statement.

Approval from the Monash University Human Research Ethics Committee was not required.

2.2 RESEARCH QUESTIONS

The Review set out to address the following five questions:

1. How prevalent is drug use and drug-driving in Victoria and Australia, and what is the prevalence of drugs in fatal and serious injury crashes in Victoria and Australia?
2. What are the trends and patterns associated with: drug use, drug-driving and drug-driving fatal and serious injury crashes in Victoria and Australia?
3. What is the crash risk associated with drugs and driving?
4. What are the attitudes, motivations and perceptions associated with drug-driving among those who take drugs and drive?
5. What countermeasures are in place or have been proposed to prevent drug-driving and drug-driving related trauma?

Questions 1 and 2 were restricted to local and national literature only, while the remaining questions included both national and international research. While all questions were generally restricted to the peer reviewed literature, grey literature was included where it was considered relevant to the research question.

The focus of the review was on the three types of illicit drugs for which it is currently an offence to drive under the influence in Victoria and most other state of Australia, namely:

- Amphetamines / methamphetamines.
- Cannabis (marijuana/THC).
- Ecstasy (MDMA).

2.3 SEARCH STRATEGY

The following scientific databases for the disciplines of transport and injury prevention were searched from January 1995 to August 2015:

- Compendex.
- Scopus.
- OVID Medline.
- OVID Transport.
- Cochrane Library.
- Informit.
- Web of Science.
- EBSCO Host.
- EMBASE.
- PsychInfo.
- TRID.

Key research concepts were derived for each question (above). Key terms associated with these concepts were developed and additional terms were identified during individual database searches to create a master list. The

master list of terms was then applied to each database. The search terms as well as derivatives and synonyms of these terms were mapped to subject headings (where applicable). These terms were grouped using the Boolean operators 'and'/'or'. The full search with the final research concepts and key terms was conducted on August 8, 2015, for Questions 1-3 and August 12, 2015, for Questions 4-5. The key search concepts, terms and strategy for each research question are shown in the Appendix A and Appendix B.

2.4 DEFINITIONS

2.4.1 Drugs of interest in this Review

This section provides a brief overview of the drugs of relevance in this review, including their alternative names, a simple look at their effects on driving and, where known, their rate of metabolism within the body. Unless otherwise specified, the information has been sourced from the Australian Drug Foundation (http://www.druginfo.adf.org.au/). The information provided here is not intended to provide the reader with a detailed overview of the pharmacology of each drug, but to provide sufficient background to enable understanding of the information presented in the following chapters.

Amphetamines and methamphetamines

Amphetamines are central nervous system (CNS) stimulant drugs and are structurally similar to naturally occurring noradrenaline and dopamine. It has been stated that this class of drugs have high potential for abuse with chronic use being associated with drug tolerance and dependency (Campbell & Young, 2018).

Amphetamines is the 'parent' drug, or chemical compound for MDMA, methamphetamine ('ice', crystal meth) and methylphenidate; these are created by a change in the chemical structure and have distinct effects (Campbell & Young, 2018). Generically though, effects of stimulant drugs include increased heart rate; increased breathing (i.e., respiration); constriction of blood vessels; increased wakefulness and psychomotor activity, and appetite suppression.

Amphetamines may be in the form of a powder (also referred to as speed), tablets or capsules and may be swallowed, injected, smoked or snorted. Campbell and Young (2018) described amphetamines as 'potent psychostimulants' and readily cross the blood-brain barrier, meaning effects are rapid. The effects of amphetamines may be felt almost immediately (if injected or smoked) or within 30 minutes (if snorted or swallowed); this is due to

Effects of amphetamines include increased wakefulness; feel less fatigued; feel more alert; more energetic; confident; euphoria and feeling less bored (or excited). Per the Australian Drug Foundation Fact Sheet, with high doses people often experience a rapid flow of ideas and perceive they have increased physical and mental powers.

Campbell and Young (2018) note a range of negative effects, associated with repeated doses, including psychotic behaviour (with paranoia), aggression, and hallucinations.

Methamphetamine (MA) has more potent effects than amphetamine and is known to be extremely addictive. MA is taken orally, smoked, snorted, or dissolved in water or alcohol and injected. Smoking or injecting the drug delivers it very quickly to the brain, where it produces an immediate, intense euphoria. Because the pleasure also fades quickly, users often take repeated doses, in a "binge and crash" pattern.

Methamphetamine hydrochloride is a form of methamphetamine that has been processed into clear crystals that can be smoked. Its most common name is 'crystal meth' or 'ice'. The effects of ice can be felt in 3 to 7 seconds. It is sometimes swallowed (15 to 30 minutes to feel the effects) or snorted (3 to 5 minutes to feel the effects). The effects of ice can last around 6 hours.

Although difficult to predict exactly in what way and for how long, amphetamine-stimulants will affect the ability to drive safely; as a general guide these drugs can cause lapses of attention; disorientation; lack of coordination; difficulty reacting appropriately to safely control a vehicle; aggressive, dangerous driving; increased risk-taking; overconfidence in driving skills, and drowsiness or rebound fatigue (as the effects wear off). 'Come down' effects (exhaustion, difficulty concentrating, irritability and depression) after using amphetamine-type stimulants may also impair driving ability. The effects of amphetamine-type stimulants may last up to 12 hours, and the 'come down' effects, like exhaustion, mood swings and depression may continue for longer. Methamphetamine can generally be detected within the body for at least one day after initial use, however this is dose-dependent, impacted by purity (or concentration), and like all drugs differs across test matrix (i.e., oral fluid, blood, urine, hair).

Ecstasy (MDMA)

Like amphetamine to which is it structurally similar, MDMA (3,4-methylenedioxy-methamphetamine) is a stimulant drug. MDMA has both CNS stimulatory effects and hallucinogenic effects and is a popular recreational drug (Campbell and Young, 2018). The effects of ecstasy are usually felt about 20 minutes to an hour after it is taken, although this is dependent on purity which is known to vary widely. Duration of effects, whilst up to 6-hours, is also dependent on purity.

MDMA has a range of negative effects, including reduced sodium due to high water intake and exercise, which can have fatal outcomes, but prior to which nausea, headache and confusion occur. Other outcomes include kidney failure and severe cardiovascular complications (Campbell & Young, 2018).

As a general guide, ecstasy can cause the following effects when operating a vehicle: difficulty reacting appropriately and safely controlling a vehicle; risk-taking; over confidence in driving skills; aggressive and dangerous driving; and drowsiness. 'Come down' effects (exhaustion, mood swings and depression) after using ecstasy may also impair driving ability.

Other stimulants

In the context of the Literature Review, other stimulants include Methylphenidate (known as Ritalin), cocaine, and ephedrine, among others. All three of these have been known to be abused (Campbell and Young, 2018). Modafinil is another stimulant, commonly used for narcolepsy.

Cannabis (THC / marijuana)

Cannabis is a depressant drug, which means it slows down messages travelling between the brain and the body. When large doses of cannabis are taken, it may also produce hallucinogenic effects and has been associated with psychosis (Radhakrishnan et al., 2014).

Cannabis is the generic name given to marijuana, hashish and hash oil. It is sometimes referred to as THC (delta-9 tetrahydrocannabinol). However, cannabis is a complex substance, with as many as 70 cannabinoids with delta-9 THC being the main psychoactive component (Radhakrishnan et al., 2014). It is also important to distinguish cannabidiol (CBD), which does not, as presently understood, have any psychoactive effects, as well as other non-psychoactive metabolites including THC-COOH). Dependence can occur from sustained use.

Marijuana is the dried plant form of cannabis that is smoked in a joint or bong, this being the most common form in which the drug is used. Other less common forms of cannabis are hashish – the dried plant resin that is usually mixed with tobacco and smoked or added to foods and baked, such as cookies and brownies, and hash oil – the liquid that is usually added to the tip of a cigarette and smoked.

The effects of eating cannabis can be felt after about an hour, while the effects of smoking are usually felt within 7 – 8 minutes (Shinar, 2017). After smoking THC rapidly appears in saliva at high concentrations, but equally, has a very rapid half-life in saliva, such that an 'average' amount (or 'dose') can be cleared between 1-3 hours (Lee et al., 2012). It follows then that the detection threshold level in saliva screen devices is central to detection of drivers having 'used' THC recently.

These effects have been very well described and most commonly include confusion, euphoria, anxiety and sleepiness (Shinar, 2017). This can be seen as conceptual disorganization; fragmented and slowed thinking; perceptual alterations; alterations in sensory perception; feelings of unreality. Delusions, depersonalization, and derealisation can also occur, and is dependent on a range of factors (see Radhakrishnan et al., 2014 for a review). Transient cognitive impairment, including in attention, decision-making, memory, and verbal recall are most common when under the influence of THC. Physical effects included impaired balance and loss of co-ordination, which are emblematic of depressed motor control.

As a general guide, cannabis has been shown to cause the following effects when operating a vehicle: reduced coordination; slower reaction times; slower information processing; confusion; changes in vision, hearing, and perception of time-and-space. Although there is some evidence that drivers under the influence of cannabis tend to report exercising more caution following use of the drug, their experience of reality may be affected, thus, impairing their judgement and ability to drive safely.

Saliva and blood samples can most reliably be used to determine whether cannabis has been used recently. THC has a plasma (blood) half-life of 1 to 3 days (in occasional users) and much less in salvia (rapid, hours), but can be detected in other tissues in the body long after its immediate impairing effects have dissipated. One-off or occasional users are more likely to get rid of all cannabis from their system within a few days (measured via blood) compared to more frequent users due to the half-life of cannabis metabolites.

For regular, heavy users of cannabis, it takes an average of two weeks to one month for it to leave their system entirely although it can remain in the body two to three months; again, this timeframe is dependent on the assessment test matrix used (i.e., blood, urine, hair). Since cannabis can be detected long after its immediate psychoactive effects have worn off, it is critical that recent and past usage of THC can reliably be distinguished in studies measuring the effect of the drug on driving. Since urine only contains metabolites of THC (i.e., THC-COOH) which can remain in the body for weeks after use, it does not provide a measure of recent cannabis use (e.g., Gjerde et al., 2015).

The point concerning detectable THC levels in saliva, the acute effects of cannabis and associated impairment, and blood THC levels is important to consider. With respect to saliva-based THC screening devices, it has recently been reported that the THC capture amount is less than 100% of available THC in saliva, depending on the device (Wollf et al., 2017). A further consideration is the saliva-to-blood THC ratio when seeking confirmatory tests if using blood; Drummer reported that this ratio was 16-20: 1 (saliva THC-to-blood THC) (Drummer, cited in Wolff et al., 2017, Table 20, p.84). This is important to consider and central to the policy setting of zero tolerance or alternative approach of a consumption-impairment threshold-based approach (see Wolff et al., 2013, 2017 for a discussion of these concepts). It is of value to consider these technical pharmacokinetic concepts when in interpreting findings from the simulator-based studies, on-road test track studies, and findings from case-control and responsibility-based studies that are presented in detail in the following chapters.

Finally, for an excellent discussion on the epidemiology of cannabis, age of first use, why people choose to use cannabis, new issues such as medical marijuana, and prevention and control initiatives, the reader is referred to Anthony et al. (2016).

2.4.2 Drug-driving

Drug-driving is defined as operating a vehicle on the road following recent use of, and/or impairment by, one or more of the drugs of interest in this review. Although the definition of 'recent' use varies across studies, it typically ranges between 1-3 hours but can last up to 12 hours for meth/amphetamines and up to six hours for MDMA.

3 PREVALENCE AND TRENDS IN DRUG USE, DRUG-DRIVING AND DRUG-DRIVING CRASHES IN VICTORIA AND AUSTRALIA

3.1 OVERVIEW

This section reviews the prevalence of, and trends in, drug use in the general population, in the driving population and in those who crash whilst operating a motor vehicle on the road. In this context, prevalence refers to the proportion of individuals in a population who use drugs or who drive on drugs or who crash whilst on drugs within a given period of time. Prevalence studies provide an indication of the extent and size of the drug-driving problem. This section was limited to research conducted in Victoria (or Australia where Victorian data were unavailable) since this provides important information about where and how resources should be directed for countermeasure development within the local context.

The review was restricted to studies conducted from 1995 onwards and focused primarily on the three illicit drugs under which it is currently an offence to drive under the influence within most states of Australia, namely cannabis, ecstasy, amphetamines / methamphetamine. Key points from the key research papers are discussed below; further information on each study is provided in a series of Tables throughout this chapter (Table 3.1, Table 3.2).

3.2 DRUG USE PREVALENCE AND TRENDS

Information about drug use prevalence and patterns within the general population provides an important contextual framework for understanding the prevalence of drug-driving and drug use in traffic crashes and any changes in these behaviours over time.

At the time this *Literature Review* was undertaken, the largest available survey on the patterns of alcohol and illicit drug use was the National Drug Strategy Household Survey (NDSHS, 2014). The 2013 survey had a sample of 23,855 persons aged 14 years and over across all Australian States and Territories. Since the literature review was conducted, the 2016 National Survey was released (2017). Given the study inclusion criteria, the findings of the 2013 survey are kept here. However, it is worth noting that there was little change in the 2016 survey findings compared to those from 2013. Hence, unless otherwise specified, the section below presents a summary of the information from this survey for the drugs of relevance in the current review.

The NDHS 2013 survey found that over eight million people in Australia (42%) had ever used an illicit drug (including use of pharmaceutical drugs for non-medical purposes). Almost three million (15%) people had used an illicit drug in the 12 months before the survey, comparable with about 2.7 million (14.7%) in 2010. Recent illicit drug use in Victoria was slightly lower than the national average (at 14.3%) and the lowest in the nation along with New South Wales (at 14.2%). There was no significant change in illicit use of drugs across any jurisdiction between 2010 and 2013 and over the past decade.

The most commonly used drug both recently (i.e., within the last 12 months) and over the lifetime was cannabis, used by 10.2% and 35% of people, respectively. Ecstasy (10.9%) and hallucinogens (9.4%) were the second and third most common drugs for lifetime use, and painkillers/analgesics (3.3%) and ecstasy (2.5%) were the second and third most common for recent use. Amphetamines and methamphetamines were used by 7% of the population for lifetime use and 2.1% of the population for recent use. There was a significant decline in the use of ecstasy from 3% to 2.5% over the period 2010-2013, but the misuse of pharmaceuticals increased significantly from 4.2% to 4.7% over this period. Use of cannabis, meth/amphetamines, and cocaine remained relatively stable.

The most common drug used recently in Victoria was cannabis, used by 9.1% of persons, followed by ecstasy (used by 2.4% of persons) and methamphetamine (used by 1.9% of persons). This pattern was the same across all states and territories. Cannabis use was lowest in Victoria while ecstasy use was equal lowest in Victoria, New South Wales and Queensland. Only New South Wales had a lower proportion of methamphetamine users than Victoria. Males were more likely to have recently used any illicit drug than females across all states and territories. In Victoria, the estimates of 17.4% and 11.3% for males and females respectively were similar to the national Australian estimates. In all Australian jurisdictions, persons aged 20–29 were the most likely age group to use an illicit drug in the past 12 months. The proportion in Victoria (27.4%) was similar to the national average of 27.3%.

Males were more likely to have 'ever used' (i.e., lifetime) illicit drugs than females (46% and 38% respectively) and were more likely to have used an illicit drug in the previous 12 months (18.1% and 12.1% respectively). The

age groups most likely to have ever used any illicit drug were people aged 30-39 (57%) and 40-49 (52%). Recent illicit drug use was highest among people aged 20-29 (27%).

While older people (aged 50 or older) generally have the lowest rates of recent illicit drug use, in recent years this age group has shown the largest increase in illicit use of drugs. For instance, from 2010 to 2013 the percentage of adults aged 50 – 59 years reporting use of illicit drugs increased from 8.7% to 11.1%, while for those aged 60 and over the percentage reporting use of illicit drugs increased from 5.1% to 6.4%. This increase was mainly due to an increase in cannabis use. The mean age for first use of drugs has fluctuated between 18.6 years of age and 19.4 years of age since 1995.

In the period 2001 to 2013, the median age of drug use increased for most illicit drugs including cannabis (from 27 to 30); ecstasy (from 23 to 25); and meth/amphetamines (24 to 28), while the median age injecting drug increased from 26 years of age to 36 years of age – an effect that was strongly influenced by the cohort of heroin users. This trend appears to be the result of an ageing cohort of drug users rather than an increase in drug use in older age groups over time.

Cannabis and meth/amphetamine users were more likely to use the drug on a regular basis compared with other drugs, with 45% and 32% respectively using that drug at least once a month. Ecstasy users were more likely to be infrequent users, only using the drug once or twice a year (54% and 71% respectively). While there was no change in the frequency of cannabis or ecstasy use in 2013, there was a rise in the proportion of meth/amphetamine users taking the drug daily or weekly (from 9.3% to 15.5%), particularly among ice users with 25% using it at least weekly – comparable to 12.4% in 2010.

The opportunity to use drugs was highest for cannabis, with 20.6% of Australians stating that they had been offered or had the opportunity to use the drug in the last 12 months, compared to 7.2% for ecstasy and 5.8% for meth/amphetamines.

Specific details on the prevalence and trends in drug use and drug use patterns are summarised below for cannabis, ecstasy and meth/amphetamines.

3.2.1 Cannabis

- Males were more likely to use cannabis across the lifetime than females (38.7% v 30.9%), and most recently (12.8% v 7.6%).
- The age group most likely to have used cannabis was 30-39 years (51.6%) for lifetime use and 20-29 years (20.8%) within the previous 12 months.
- Cannabis users were more likely to try cannabis in their teens, with the age of first use being younger compared to other illicit drugs.
- Recent cannabis users (Median age = 30, 2013) were generally older than users of ecstasy (median age: 25 years) meth/amphetamines (median age: 28 years).
- Almost 20% of recent cannabis users used the drug weekly or more often and older people (aged 50 or older) were more likely than younger people to use cannabis regularly, with at least 40% using it as often as once a week or more.

Age and sex comparisons over time

Although cannabis use has remained relatively stable over the past decade, some significant changes occurred among different age groups. Recent cannabis use either increased or remained stable for the older age groups (40 or older) but decreased among the younger age groups (14-39). There appears to be an ageing cohort of cannabis users. The proportion of users aged over 50 was at its highest over the past decade with the proportion of people aged 50-59 and 60 and over increasing from 5.5% to 7.3% and from 0.5% to 1.2% respectively from 2010 to 2013. Although the proportion of cannabis users is highest among younger age groups (under 40), males aged 60 or older were twice as likely to use cannabis in 2013 compared to 2010 (increasing from 0.8% to 1.8%) whilst females aged 50-59 were 1.6 times more likely to use cannabis over this period (increasing from 3.2% to 5.2%).

3.2.2 Ecstasy

- 12.6% of males and 9.2% of females had used ecstasy over their lifetime, with 3.2% of males and 1.8% of females using ecstasy in the previous 12 months.
- Adults aged 30 - 39 years were most likely to have 'ever' used the drug (23.1%) and those aged 20 - 29 years were most likely to have used it in the last 12 months (8.6%).
- The majority of recent ecstasy users only took ecstasy once or twice a year (54%).
- The median age of recent ecstasy users was 25 years, and most people tried ecstasy at age 18.2 years.

Age and sex comparison over time

Before peaking in 2007, ecstasy use had been gradually increasing since 1995. It then declined in 2010 and again in 2013. There was an overall drop between 2010 and 2013 that was only significant for females (from 2.3% to 1.8%) and for people aged 30-39 (from 3.9% to 2.6%), particularly females in this age group (from 3% to 1.2%).

3.2.3 Meth/amphetamine

- Regarding lifetime use, 8.6% of males and 5.3% of females had ever used amphetamines/methamphetamines and 2.7% and 1.5% of males and females respectively had used the drug within the last 12 months.
- Adults aged 30 - 39 years were most likely to have used the drug in their lifetime (14.7%).
- Adults aged 20 - 29 year were most likely to have used the drug in the last 12 months (5.7%).
- Meth/amphetamine users are getting older; the average age of users was 24 in 2001, compared with 28 in 2013 and age of first use was also older, increasing from 17.9 in 2010 to 18.6 in 2013 among young people aged 14 - 24.

Age and sex comparisons over time

- Meth/amphetamine use remained stable at 2.1% between 2010 and 2013 following a peak at 3.7% in 1998.
- There were no significant changes in the proportion of people using meth/amphetamines among different age groups or sexes in the last 12 months.
- Since 2001, recent use among females has declined but it remained relatively stable in 2013 (1.7% in 2010 compared to 1.5% in 2013).
- Since 2001, recent use among males has declined, but remained stable between 2010 and 2013 at around 2.5%.
- Among people aged under 29 years of age, there was a substantial drop in recent use between 2004 and 2007 but little change since 2007.

The frequency and form of meth/amphetamine used changed in 2013 compared to earlier years. Ice replaced powder as the preferred form of the drug and, among recent users, powder decreased from 51% to 29% while the use of ice doubled from 22% in 2010 to 50% in 2013. This trend is based on both availability and also effects, with the 'high' experienced from using ice (crystal meth) and base (sticky paste) being much more intense than that following use of other forms of meth/amphetamine including powder and pills.

In addition:

- There was an increase in the proportion of people using meth/amphetamine daily or weekly (from 9.3% to 15.5%) in 2013.
- Meth/amphetamine users who were mostly ice users were much more likely to use ice on a regular basis with 25% using it at least weekly compared to only 2.2% of those who used mainly powder.

3.3 DRUG-DRIVING PREVALENCE AND TRENDS

The two main types of studies used to examine drug-driving prevalence are random roadside testing of oral fluid typically conducted by police, and self-report studies using interviews or surveys.

Twenty-six studies examined the prevalence of drug-driving; seven using large-scale random roadside studies of drug use in oral fluid within the general driving population, and 19 using self-report surveys of drivers from the general population and from a range of different drug user groups (See Table 3.1). The period within which prevalence was measured across all studies ranged from 2000 to 2015, with 73% carried out within the last ten years.

Of the seven roadside studies, two each were carried out in Victoria and Queensland and one each were carried out in New South Wales, South Australia and Western Australia. Of the 19 self-report studies, six focussed on the general driving population, including two from New South Wales, one each from South Australia and Queensland, and two Australia wide. A further six studies measured drug-driving prevalence in regular/dependent drug user groups (primarily drug users who inject) within Australia (n=3), Victoria (n=1), South Australia (n=1) and New South Wales (n=1). Convenience samples were used to measure drug-driving prevalence in university students in two studies from Queensland and one study from Western Australia, and two studies measured drug-driving prevalence in rave/night club attendees in Melbourne, Victoria. Lastly, single studies measured drug-driving prevalence in police detainees in Australia and in long-haul truck drivers in Queensland.

3.3.1 Drug prevalence in samples of oral fluid

The presence of THC, ecstasy and methamphetamine in oral fluid was measured in all seven roadside studies of the general driving population. The prevalence of any one of these drugs ranged between two percent of the screened population in New South Wales (Rowden et al., 2011) and five percent of the screened population in Western Australia (Woolley & Baldock, 2009). The Victorian study by Drummer et al (2007) found an overall detection rate of 2.4%. Thompson et al (2008) found an overall detection rate of 2.9% in South Australia, whilst in two studies in Queensland, Davey et al (2007) and Davey et al (2014) found overall detection rates of 3.8% and 2.7%, respectively. The differences in prevalence rates between states may reflect differences in the sample size and time period within which the studies were conducted, both of which make it difficult to make meaningful comparisons across studies.

Only two studies reported prevalence estimates for individual drugs. Davey et al (2009) found that 1.99% of their Queensland sample were positive for MDMA, whilst 1.73% and 0.86% were positive for THC and amphetamines, respectively. In Victoria, Drummer et al (2007) found a detection rate of 1.3% for MDMA, 0.66% for cannabis and 2.1% for methamphetamine. The combined use of THC and methamphetamine was found in 0.6% of drivers.

Four studies measured the breakdown of drug types detected within the proportion of drivers who tested positive for drugs (Davey et al., 2014; Chu et al., 2012; Thompson, 2008 and Rowden et al., 2007). Across all four studies, methamphetamine was the most commonly detected drug, followed by THC. In the two studies conducted more recently by Davey et al (2014) and Chu et al (2012), methamphetamine and THC taken together were the third most commonly detected drugs, whereas MDMA was the third most commonly detected drug in the earlier studies.

The influence of age, gender and road user group on drug-driving prevalence

Only a small proportion of studies examined whether drug-driving prevalence varied according to age, gender and road user group. In the studies measuring differences across gender, males were consistently more likely to be detected driving under the influence of THC, MDMA and methamphetamine, ranging between 80% and 86% of positive results (Drummer et al., 2007; Rowden et al., 2011 Davey et al., 2014). In the three studies measuring prevalence by road user group, drug-driving was more prevalent in car drivers compared to large or heavy vehicles (Davey et al., 2014; Drummer et al., 2007; Rowden et al., 2011). In the two studies measuring age differences across drug use, Davey et al (2014) and Rowden et al (2011) found that drivers detected with THC were more likely to be aged under 30 years, whilst drivers detected with methamphetamine were more likely to be slightly older.

Studies measuring drug use in oral fluid provide more objective estimates of the prevalence of drug-driving than those using self-report. However, a disadvantage of studies using oral fluid is that they capture drug-driving behaviour at a single point, and generally do not capture information regarding general patterns of drug-driving behaviour including drug-driving frequency. To an extent, these studies also reflect differences

in the length of time that drugs remain at detectable levels in saliva. As such, the higher proportions of methamphetamine detections found in roadside tests may not be reflective of usage, in terms of absolute numbers of users in the community, but rather the ability to better detect methamphetamine as compared to THC via saliva at the roadside. Consequently, some drivers may not be detected, particularly for THC, when driving with concentrations below the sensitivity of the cut off threshold for the roadside screening devices (Drummer et al., 2007).

The next section summarises the estimates of drug-driving prevalence in studies using self-report methods.

3.3.2 Drug prevalence in self-report studies

General driving population

All six studies of drug-driving within the general driving population measured the prevalence of THC, with estimates of having ever driven on THC ranging between 11% (Jones et al, 2003) and 12.3% (Mallick et al, 2007). In those studies which measured more than one drug, THC was the most commonly reported drug used prior to driving.

Methamphetamine was surveyed in two studies of the general driving population, with drug-driving prevalence estimated at 6.9% Australia wide (Mallick et al, 2007) and at 14% in South Australia (Donald et al., 2006). Ecstasy was surveyed in only one study in which 5.8% of drivers reported ever driving under the influence of this drug whilst driving (Mallick et al, 2007). There were no studies surveying the prevalence of driving under the influence of amphetamine within the general population.

There was evidence of higher rates of drug-driving among those who were frequent drug users. For example, Jones et al (2003) found that the prevalence of ever driving after cannabis use was 53% in those who reported frequent (weekly or more) drug use, whilst Mallick et al (2007) found that the frequency of ever driving under the influence of cannabis was 84% for weekly cannabis users compared to 32% for monthly cannabis users. Similarly, the prevalence of drug-driving was higher among those who reported more frequent use of amphetamine (93% for weekly users compared to 46% for monthly users) and more frequent use of ecstasy (82% for weekly users compared to 34% for monthly users) (Mallick et al., 2007).

The influence of age and gender on drug-driving prevalence

Only the study by Mallick et al (2007) examined whether drug-driving prevalence varied according to age and gender. Similar proportions of drivers across all age groups reported driving within three hours of cannabis use (about half of all drivers) except for those 60 years of age and older (10%). In contrast, ecstasy users aged 16 – 19 years of age and those aged 20 - 29 years most likely to report that they had driven a vehicle within three hours of using ecstasy. The prevalence of driving under the influence of methamphetamine across the different age groups was similar to that found for cannabis. With respect to gender, a significantly larger proportion of males than females reported driving under the influence of alcohol (18.6% v 10.8%); cannabis (61.8% v 41.5%) and ecstasy (42.7% v 32.6%), whilst driving under the influence of methamphetamine was similar across males and females (54.8% v 50.8%).

Regular (including injecting) drug users

The most recent estimates of driving under the influence of drugs come from the studies by Horyniak and Dietze (2015) who compared self-reports of drug-driving in Victoria with the rest of Australia in a sample of regular ecstasy users and a sample of regular injecting drug users. Among regular ecstasy users in Victoria in 2013, the most common drug types ever driven after in the six (6) months preceding interview were: methamphetamine (57%); cannabis (43%); ecstasy (34%); cocaine (6%); LSD (3%) and benzodiazepines (3%). Among regular injecting drug users in Victoria in 2013, the most common drug types ever driven after in the 6 months preceding interview were: heroin (58%), cannabis (45%), benzodiazepines (23%), and methamphetamine (13%). In the four studies measuring the prevalence of multiple drug use in Australia, heroin was the most prevalent drug used prior to driving, followed closely by cannabis.

Rave/night club attendees

Two studies surveying drug-driving prevalence in rave/night club attendees found that cannabis was the most commonly used drug, with 46% of users reporting they had ever driven under the influence of cannabis in the study by Duff and Rowland (2006) and 52% in the study by Degenhardt et al (2004). The prevalence of ever driving under the influence of ecstasy ranged from 33% to 43%. Cannabis was the most frequently reported drug in both studies, followed by ecstasy and then methamphetamines.

Truck drivers

An early study of drug use patterns among 35 long haul truck drivers (Davey et al (2004) found that the pattern of drug-driving prevalence was different to that found for drivers within the general population. All drivers interviewed had used amphetamines at some stage whilst driving, compared to 30% who had used cannabis. All drivers admitted to having been dependent on drugs at some stage in their lives.

3.3.3 Drug prevalence in oral fluid versus self-report studies

For all drugs examined within the general driving population, the prevalence of drug use in self-report studies was much higher than that reported in studies using oral fluid. This is not surprising since oral fluid studies provide only a snapshot in time of the drug-driving prevalence, whereas self-report studies can capture information about regular driving and drug use habits. Self-report studies consistently showed that THC was the most commonly used drug within the general driving population, whilst roadside studies of oral fluid found that methamphetamine was the most common, followed by THC. As noted above, it is possible that the higher prevalence of methamphetamine over THC in roadside surveys is an effect of the difference in time windows of detection for the two drugs using current roadside screening technology. Until more frequent and precise roadside drug screening becomes possible, the differences in prevalence estimates between oral fluid and self-report studies highlight the importance of using both types of studies to provide an estimate of drug-driving prevalence.

It is also important to bear in mind that only 12 studies on drug-driving prevalence within the general population have been published within Australia over the last 20 years, only a small proportion of which have been conducted within the last five years.

3.3.4 Drug prevalence in the general population versus other groups

Although the self-reported prevalence of drug use was relatively low among the general population of drivers, drug-use was consistently much higher in other samples of drivers including for instance regular and injecting drug users, rave/nightclub attendees and long-haul truck drivers. This was apparent for all drugs reviewed in the present study. For example, THC use in the general population ranged between 11-12% but between 26-57% in regular injecting drug users, and between 46-52% in rave/nightclub attendees. Similarly, methamphetamine use was much higher among regular injecting users, with estimates between 25% and 53% versus 7% and 14% in the general population. Ecstasy use was just under 6% in the general population but between 37% and 49% in regular drug users and between 33% and 43% in rave/nightclub attendees. In regular drug users, heroin was the most commonly used drug prior to driving, whilst THC was more commonly used among the general population and among young rave/nightclub attendees.

3.3.5 Trends in drug-driving prevalence – general population

Currently, neither the peer reviewed literature nor the grey literature captures information on trends in drug-driving prevalence using consistent data sources and collection methods within the general population of Australia.

While the NDSHS (described above in Section 4.2) provides regular information on drug use prevalence and trends within Australia, it does not focus on drug-driving.

3.3.6 Trends in drug-driving prevalence – regular drug users

The only regular surveys of drug-driving prevalence and patterns over time in Australia are focussed on sentinel samples of specific drug user groups. The Illicit Drug Reporting System (IDRS) is a national illicit drug monitoring system intended to serve as a strategic early warning system, identifying emerging trends of local and national concern in illicit drug markets. It comprises an annual survey of people who inject drugs (PWID) regularly. The Ecstasy and Related Drugs Reporting System (EDRS) is a national monitoring system for ecstasy and related drugs (ecstasy, methamphetamine, cocaine) associated with use in recreational settings like nightclubs dance parties) with essentially the same objectives as the IDRS. The EDRS is based on the IDRS methodology and consists of an annual survey of regular ecstasy and psychostimulant users (REU/RPU).

Among regular ecstasy users in Victoria (Dietze et al., 2015; Horyniak et al., 2015), there was a significant reduction between 2007 and 2013 in the prevalence of driving under the influence of ecstasy from 63% to 34% and cannabis from 63% to 43%.

Among regular injecting drug users in Australia (Dietze et al., 2015; Horyniak et al., 2015), the percentage of participants driving after heroin use across all years was highest in Victoria, most likely reflecting higher use

of heroin in general in Victoria. In Victoria there was a significant reduction in the prevalence of driving under the influence of methamphetamine (from 33% to 13%) between 2007 and 2013, while the percentage of participants who drove on benzodiazepines increased significantly from 16% to 23%. The percentage of participants driving under the influence of cannabis remained stable (from 53% to 45%).

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TABLE 3.1 PREVALENCE OF ILLICIT DRUGS IN DRIVERS IN AUSTRALIA

Roadside Surveys Using Oral Fluid		
Author, Year, Location	Method	Key Findings
Davey et al (2014) Queensland	Random roadside testing of oral fluid N=80,624 drivers, December 2007-June 2012	2.7% positive any drug (MA, MDMA, THC); test ratio: 1 in 38 drivers tested positive • MA: 40.8% • THC: 29.8% • MA + THC: 22.5% • MDMA + THC: 1.9% • MDMA: 1.7% • MA+MDMA: 1.7% • MA+MDMA+THC: 1.5% Demographics: 86% were male, mean age 33 years; 32.4% aged 30-39, 20.1% aged 40-49, 19.4% 25-29. Youngest drivers more likely to take THC, 25+ more likely to take MA. MDMA more common in drivers aged 30 and under Vehicle type: 82.9% car drivers, 12.4% heavy vehicles, 3.9% motorcycles, 0.7% watercraft, 0.1% bus. Heavy vehicles over-represented. Time of day: detection rate highest between 12pm - 5:59am (4.5%) followed by 6 pm -11:59 pm (3%)
Chu et al (2012) Victoria	Analysis of 853 drug positive samples in oral fluid June 2009-August 2010	• Methamphetamine (MA) (all): 77% • THC (all): 42% • MDMA (all): 17% • Cocaine: 8% *Combinations* • MA + THC: 20% • MA + MDMA: 15% • THC + MDMA: 0.7% • MA + MDMA + THC: 3.9% • MA + cocaine: 7.9% • MDMA + cocaine: 3.5% • THC + cocaine: 2.2%

Roadside Surveys Using Oral Fluid		
Author, Year, Location	Method	Key Findings
Davey et al (2009) QLD (Brisbane, Townsville, Gold Coast)	Roadside oral fluid testing and random self-report study N = 2,657 drivers (self-report) N = 101 (OFT) 2006-2007	3.8% tested positive for at least one illicit substance • MDMA: 1.99% • THC: 1.73% • Amphetamines: 0.86% • Cocaine 0.22% Driving after use (within 4 hours): • 4.4% reported doing so at least once week
Woolley & Baldock (2009) Western Australia	Random roadside testing of oral fluid October 2007-November 2008	5.3% positive any drug (MA, MDMA, THC) • MA: 42.5% • THC: 8.7% • MDMA: 2.9% • MA + MDMA: 7% • MA + THC: 22.7% • MDMA + THC: 1.2% • MA + MDMA + THC: 3.9%
Thompson (2008) South Australia	Random roadside testing of oral fluid July 2006 – June 2007	2.9% positive any drug (MA, MDMA, THC) (test ratio: 1:34 tested positive) • MA: 43% • THC: 26% • MDMA: 3% • Two or more (unspecified) of MA, THC and/or MDMA: 27%

Roadside Surveys Using Oral Fluid		
Author, Year, Location	Method	Key Findings
Drummer et al (2007) Victoria	Random roadside testing of oral fluid N=13,176 drivers Period: December 2004-December 2005	Positive to any drug (MA, MDMA, THC): 2.4% (ratio: 1:42 tested) • MA: 2.1% • MDMA: 1.3% • THC: 0.7% • THC + MA: 0.6% Vehicle type (% positive): Cars: 2.8%, for ratio of 1:36; Large vehicles: 1.4%, for ratio of 1:71 Demographics: 81% male, mean age 28 years; for heavy vehicle drivers: 38 years (mean)
Rowden et al (2007) New South Wales	Random roadside testing of oral fluid N=83,928 drivers Period: January 2007-December 2010	2.0% positive any drug (MA, MDMA, THC) • MA: 44% • THC: 41% • MDMA: 15% Vehicle type: 2.2% drivers and riders; 1.2% heavy vehicle drivers Demographics: 83% male, mean age 31 years; 32% aged 16-25, 29.8% aged 30-39 (heavy vehicles: 40 years) Heavy vehicles (of drug positive) • MA: 78% • THC: 14% • MDMA: 8% Light vehicles (of drug positive) • 40% MA: 40% (marginally older cf. THC and MDMA) • 44% THC: 44% (majority < 30 years) • 16% MDMA: 16% (driving more common among persons 16 – 25 years of age)

Self-Report Surveys of Different Drug User Groups		
General Population		
Author, Year, Location	Method	Key Findings
Freeman et al (2010) Queensland	Survey using snowball sampling approach N=899 drivers	Drug-driving behaviour: 19.2% (at least once) • Number occasions drug-driving: 1-2: 10%; 3-5: 2.9%; 6-10: 1.6%; >10: 4.7% Sample demographics: mean age 30 years; 52% male
Bryant et al (2008) New South Wales	Survey using snowball sampling approach N=501 drivers	3.6% admitted to drug-driving • 83% marijuana • 36% ecstasy • 23% cocaine Sample demographics: males (78%); aged 17-29 (47%) most likely to drug-drive
Roche et al (2008) Australia	Stratified sampling approach (National Drug Strategy Household Survey), N=14,851 aged 12+ in paid employment	Drug-driving behaviour: • 51% of methamphetamine users drove under the influence in the last 12 months • 22% drove after using other drugs (either steroids, cannabis, cocaine, acid, ecstasy, heroin and other drugs)

Self-Report Surveys of Different Drug User Groups		
General Population		
Author, Year, Location	Method	Key Findings
Mallick et al (2007) Australia	Internet survey N=6,801 drivers	Driver after use • Driven under influence drug other than alcohol: 29.9% of drivers • Driven under the influence of any illicit drugs (within 3-months, in last 12 months): 16.9% Prevalence of drug-driving (within last 12-months) • Alcohol (under influence of, BAC>0.05): 12.6% • Cannabis (within 3 hours of use): 12.3% • Methamphetamines (within 3 hours of use): 6.9% • Ecstasy (within 3 hours of use): 5.8% • Cocaine (within 3 hours of use): 3.1% • LSD/hallucinogens (within 3 hours of use): 0.8% • Ketamine (within 3 hours of use): 0.7% • GHB-type substances (within 3 hours of use): 0.5% • Heroin (within 3 hours of use): 0.5% • Benzodiazepines (within 3 hours of use): 4% • Analgesics (within 3 hours of use): 15.0% *Prevalence of polydrug use:* 9.1% of sample reported having used one of the combinations below *and driven within 3-hours of use*: • Alcohol and cannabis: 4.1% • Alcohol and ecstasy: 2.2% • Alcohol and methamphetamine: 1.9% • Alcohol and benzodiazepines: 0.9% *Proportion driving under the influence of [drug] by frequency of use* • Alcohol: 4.4% once a month or less, 18.5% weekly, 29.6% daily • Cannabis: 32.4% once a month or less, 84% weekly, 91% daily • Ecstasy: 34% once a month or less, 82% weekly, 40% daily • Methamphetamine: 46.6% once a month or less, 93% weekly, 90% daily • Benzodiazepines: 22.6% once a month or less, 47.4% weekly, 75% daily

Self-Report Surveys of Different Drug User Groups		
General Population		
Author, Year, Location	Method	Key Findings
Donald et al (2006) South Australia	Survey using snowball sampling approach, December 2004-April 2005 N=91 eligible drivers	Driving post drug use • Cannabis: 88% • Alcohol: 69% • Methamphetamine: 59% • Ecstasy: 30% Frequency of drug-driving • Cannabis: 34% reported weekly driving; 21% reported daily driving • Alcohol: 22% weekly • Methamphetamine: 14% at least weekly driving • Ecstasy (1% at least weekly driving)

Jones et al (2003)
North Coast New South Wales
	Telephone survey
	N=502, 18-29 years of age
		Driving post drug use (within 1 hour of use): Ever - 11.2%; Within last 12-months - 7.4%
		• Recent cannabis users
		  ○ Ever driven within hour of use: 43.1%
		  ○ Driven within previous 12-months: 28.5%
		• Frequent cannabis users (weekly or more)
		  ○ Ever driven within hour of use: 53.8%
		  ○ Driven within previous 12-months: 40.6%
		• Driven after combined cannabis and alcohol use: 1.8% (last 12-months)
		• Cannabis and alcohol used together: 1.8% [7% of THC users, 24.3% of those driven under influence cannabis last 12-months]

Self-Report Surveys of Different Drug User Groups		
Regular Drug Users		
Author, Year, Location	**Method**	**Key Findings**

Horyniak & Dietze (2015); Dietze et al. (2015)
All capital cities of Australian states and territories, 2007-2013
	Face to face interview (IDRS, injecting users)
	Victoria: N = 150 regular injecting drug users
	Rest Australia: N = 737
		Driven in last 6-months
		• Victorians: 79% of those that had driven (26% of Victorian sample, n=39)
		  ○ Common drugs used and having driven: heroin (58%), cannabis (45%), benzodiazepines (23%), and methamphetamine (13%)
		• Rest of Australia: 76% of those that had driven (34% of Rest Australia sample, n=252)
		  ○ Common drugs used and having driven: heroin (37%); methamphetamine (37%); cannabis (34%); benzodiazepines (9%); cocaine (2%) and ecstasy (2%)

Horyniak & Dietze (2015); Dietze et al. (2015)
All capital cities of Australian states and territories, 2007-2013
	Face to face interviews (EDRS, regular ecstasy users)
	Victoria: N = 100
	Rest Australia: N = 586
		Driven in last 6-months
		• Victorians: 54% of those that had driven (65% of Victorian sample, n=65)
		  ○ Common drugs used and having driven: methamphetamine (57%); cannabis (43%); ecstasy (34%); cocaine (6%); LSD (3%) and benzodiazepines (3%)
		• Rest of Australia: 57% of those that had driven (75% of Rest Australia sample, n=442)
		  ○ Common drugs used and having driven: cannabis (73%); ecstasy (46%); methamphetamine (18%); LSD (9%); cocaine (4%) and benzodiazepines (2%)

Stafford & Burns (2014) Australia	Regular injecting drug users in 2013 N = 887	Driven after use (median 30 minutes post-use): 77% (of those that had driven recently, 41.7%, n=370) • Number occasions driven: 18 times (median); range: 1 – 180 times • Drugs: heroin: 32%, cannabis: 26%, methamphetamine (25%)
Sutherland & Burns (2013) South Australia	Survey (IDRS, injecting users) (2006-2011) N = 597	Driven after consuming, within 6-months: • 2011: 24 occasions (mean), equates to once / week • 2007: 81 occasions (mean), equates to three times / week Common drugs prior to driving: heroin and cannabis most commonly used, then methamphetamines (% not given) and use of ecstasy was negligible

Self-Report Surveys of Different Drug User Groups		
Regular Drug Users		
Author, Year, Location	Method	Key Findings
Mallick et al (2007) Australia	Internet survey N = 6,801 drivers	Of users, *drove within 3-hours of consuming drug (% reported use)* • Alcohol: *13.8%* (91.6% of sample reported use) • Cannabis: *51.3%* (24% of sample reported use) • Methamphetamines: *52.7%* (13.2% of sample reported use) • Cocaine: *33.4%* (9.1% of sample reported use) • Ecstasy: *37.5%* (15.5% of sample reported use) • LSD/ hallucinogenic: *14.7%* (5.4% of sample reported use) • Ketamine: *19.4%* (3.8% of sample reported use) • Heroin: *52.3%* (1.0% of sample reported use) • GHB-type substances: *25.9%* (2.0% of sample reported use) • Prescription stimulants: *43%* (2.6% of sample reported use) • Benzodiazepines: *30.3%* (4.1% of sample reported use) • Analgesics (morphine, codeine): *44.8%* (16.1% of sample reported use)
Darke et al. (2004) Sydney	Survey using snowball sampling N = 300 regular injecting drug users (defined as injecting at least once within the last 6 months) [mean age: 31 years] April – November 2002	Drug-driving / drove after use (of known drivers) – no difference in proportions of male / females in drug-driving • 87% reported driving soon after taking drugs in last 12 months • 59% drove soon after taking drugs in the preceding month Drug-driving / drove after use, by drug (last 12-months) • Drove after cannabis use: 57% • Drove after heroin use: 56% • Drove after amphetamine use: 34% • Drove after cocaine use: 33% Drug-driven weekly (last 12-months): 22% • Drove after cannabis use: 21% • Drove after heroin use: 22% • Drove after amphetamine use: 9% • Drove after cocaine use: 9%

Self-Report Surveys of Different Drug User Groups		
Regular Drug Users		
Author, Year, Location	**Method**	**Key Findings**
Gascoigne et al. (2004) Australia	Survey N = 216 ecstasy users	49% consumed ecstasy prior to driving
Aitken et al (2000) Victoria	Survey using snowball sampling approach N = 160 injecting heroin drug users	Drug-driving behaviour • Of those who were current drivers, 67% reported having driven in the preceding week shortly after injecting drugs (opiates, stimulants and cannabis)
Rave or Night Club Attendees		
Author, Year, Location	**Method**	**Key Findings**

Duff & Rowland (2006)
Melbourne
	Cross-sectional 'Intercept' survey
	N = 455 recreational drug users (metropolitan and rural nightclub and rave attendees) aged between 15 and 30
		Drug-driving behaviour
		• 48% (n = 218) respondents drove within four hours of consumption of illicit drugs in the last month
		  ○ 46% had consumed cannabis
		  ○ 33% had consumed ecstasy
		  ○ 20% had consumed amphetamines
		  ○ 8% had consumed cocaine
		  ○ 10% consumed LSD and 2% consumed 'other drugs'

Degenhardt et al. (2004) Melbourne	Cross-sectional survey N = 273 recreational drug users (metropolitan nightclub attendees) aged 18-45	Drug-driving behaviour (after drug use) • Cannabis: 52% ever; 28% in past month; 7% on night of interview • Ecstasy: 43% ever; 19% in past month; 5% on night of interview • Methamphetamine powder (speed): 42% ever; 18% in past month; 5% on night of interview • Methamphetamine (ice): 26% ever; 7% in past month; 3% on night of interview • Cocaine: 28% ever; 8% in past month; 4% on night of interview • Heroin: 12% ever; 2% in past month; 2% on night of interview

Self-Report Surveys of Different Drug User Groups		
University Students		
Author, Year, Location	Method	Key Findings
Armstrong et al. (2005) Queensland	Survey N = 331 university students who used drugs for recreational purposes (27% male; mean age: 24 years)	Drug-driving behaviour • Ever: 25%; Within last 12-months: 8%; Within last 4-weeks: 5% Drug-driving behaviour, by drug • Cannabis: Ever: 21%; Within last 12-months: 8%; Within last 4-weeks: 4.5% • Amphetamines: Ever: 7.6%; Within last 12-months: 2.7%; Within last 4-weeks: 2.4% • Ecstasy: Ever: 8.8%; Within last 12-months: 5.4%; Within last 4-weeks: 2%
Davey et al. (2005) Queensland	Survey N = 275 university students (26% male; mean age: 24 years)	Drug-driving behaviour within 6 hours of drug use: 25% • Cannabis: Ever: 22%; Within last 12-months: 13% • Speed: Ever: 10%; Within last 12-months: 6%, • Ecstasy: Ever: 4%; Within last 12-months: 3% • Cocaine: Ever: 2%; Within last 12-months: 1% Drink-driving: 6% Drink and drug-driving: 8% Drug-driving by sex: Female – Ever: 25%; Within last 12-months: 13; Male – Ever: 36%; Within last 12-months: 20% Drug-driven in last 12 months, by age: 18-21 years: 13%; 22-36 years: 18%; 36+ years: 10%
Stevenson et al. (2001) Western Australia	Survey (convenience sample), 286 university students (49% male; mean age: 21 years)	"Drove while feeling effects of drug": 18%, and drug used: • Cannabis: 21% • Ecstasy: Ever: 21% • Speed: Ever: 29% "Drove while feeling effects of drug and alcohol": 14%

Self-Report Surveys of Different Drug User Groups		
Police Detainees		
Author, Year, Location	Method	Key Findings
Adams et al. (2011) Australia	Survey (based on the Drug Use Monitoring in Australia – DUMA Program) N = 1,215 police detainees who reported driving within the last 12 months	Driven following drug and/or alcohol use (last 12-months): 65% • Males driven following drug and/or alcohol use (last 12-months): 66% • Females driven following drug and/or alcohol use (last 12-months): 59% Reported having driven, by drug type • Alcohol: 31% • Cannabis: 40% • Amphetamine / methamphetamine: 30% • Cocaine: 4% • Drove after alcohol and any of the above drug types: 18% Frequency of drug-driving, by drug: once per week • Alcohol: 25% • Cannabis: 58% • Amphetamine/methamphetamine: 50% • Benzodiazepines: 32% • Cocaine: 15% • Alcohol and any of these drugs: 29%
Long-Haul Truck Drivers		
Author, Year, Location	Method	Key Findings
Davey et al. (2004) Queensland	Convenience sample using snowball sampling N = 35 long haul truck drivers (mean age: 40 years; truck driving experience: 18.7 years)	Drug use: ever at work: 57%, of which 70% report current use Drugs used: • Amphetamines (speed): Ever used - 100%; Current use: 55% • Amphetamine-based pharmaceutical drugs (illegally obtained): Ever used - 45%; Current use: 15% • Cannabis: Ever used - 30%; Current use: 20% Almost all past and present drug users at some stage in their career described what is consistent with being dependent on amphetamines (amphetamine dependency syndrome)

3.4 DRUG USE IN TRAFFIC CRASHES - PREVALENCE AND TRENDS

The prevalence of drugs in crash involvement is generally measured using biological samples (blood, saliva, urine) selected from official records held by police, hospitals, coroners, or insurance agencies. A small number of these studies collect information about crash involvement from the individual involved in the crash him/herself using surveys or interviews.

Twelve studies examined the prevalence of drug use in traffic crashes (See Table 3.2). Nine of these were large-scale studies using biological samples drawn from hospital or coroners' data, and three were smaller scale studies relying on self-report measures. The period within which prevalence was measured across the studies ranged from 1995 to 2012, with only 42% carried out within the last ten years.

Of the nine studies using biological measures of drug use, three were conducted in Victoria, two in New South Wales and one in South Australia. The other two were conducted in multiple states: Victoria, New South Wales and Queensland, and Victoria, New South Wales, Queensland, Western Australia and South Australia. Five studies measured the prevalence of drug use in serious injury crashes and four measured it in fatal crashes. Three self-report studies measured crash involvement for any level of severity: one in Queensland, one in Victoria and one in New South Wales.

The prevalence of THC in fatal crashes ranged from 10.5% (Drummer et al., 1995) to 13.5% (Drummer et al., 2003). The prevalence of stimulants in fatal crashes was fairly consistent across studies, ranging from 3.2% (Gerastomoulos et al., 2000) to 4.1% (Drummer et al., 2003). The definition of stimulants varied between the studies, with methamphetamine and amphetamine included together in some studies which makes it difficult to isolate the role of individual drugs in crash involvement. It should also be noted that Drummer's 2003 study provides the latest available estimate of the prevalence of drug use in oral fluid in Australian fatal crashes. As this study is now over 12 years old it is possible that the prevalence of THC and stimulants in fatal crashes would be different today.

In serious injury crashes, the prevalence of THC was more variable across studies than that found for fatal crashes, ranging from 7.6% (Ch'ng et al., 2007) to 36% (Gerastomoulos et al., 2002). The higher estimate in Gerastomoulos et al., (2002) most likely reflects the measurement of both active and inactive THC metabolites which would possibly overestimate the prevalence of THC compared to other studies that only measured active THC metabolites. The most recent study by Drummer et al (2012) estimates the prevalence of THC in serious injury crashes at 9.8%. This estimate is probably the most reliable given that the other studies are now at least eight years old.

The involvement of amphetamines in serious crashes ranged from 4.1% (Ch'ng et al., 2007) to 12% (Gerastomoulos et al., 2002). Methamphetamine and MDMA use were reported in only the one study by Drummer et al (2012), with an estimated prevalence of 3.1% and 0.8%, respectively. Cocaine use was also relatively low, ranging between 1.4% (Ch'ng et al., 2007) and 2% (Gerastomoulos et al., 2002).

Polydrug use was measured only in the study by Ch'ng et al (2007) who estimated the prevalence in serious injury crashes at 9.4%. Three other studies measured polydrug use combined with alcohol, with prevalence estimates of 12% in Drummer et al (2012) and 16% in Sugrue et al (1995). For fatal crashes, the prevalence of alcohol and polydrug use was fairly consistent over time and across studies although, as noted previously, these studies are now relatively old. Drummer et al reported estimates of 9% both in 1995 and 2003, and Gerastomoulos et al., (2000) reported an estimate of 10%.

3.4.1 Age, gender and road user group

The prevalence of drug-driving was compared in three studies across road user groups. Drummer et al (2003) examined drug use in the fatal crashes of car drivers, motorcyclists and truck drivers and found that the prevalence of THC was higher in motorcyclists, whilst stimulants had a larger prevalence in truck drivers. In serious crashes, Sugrue et al (1995) found a higher proportion of THC in drivers and pedestrians compared to cyclists. Griggs et al (2007) found that the prevalence of THC in serious crashes was highest in motorcyclists and cyclists (28% and 20% respectively), whilst similar proportions were evident in pedestrians and car drivers (around 16% each). Amphetamine use was highest in pedestrians and similar across drivers and motorcyclists.

In studies that compared prevalence across age and gender, drug involvement was consistently much higher in males across fatal (Tutt et al., 2001; Drummer et al., 2003) and serious injury crashes (Ch'ng et al., 2007; Sugrue et al., 1995; Drummer et al., 2012; Griggs et al., 2007). With respect to age, Ch'ng et al (2007) found that drug use, including THC, was most common in drivers aged under 45. Similarly, Drummer et al (2003)

found that THC was highest in young drivers and motorcyclists aged 22-30 whereas stimulants were highest in the same age group for truck drivers – and at a much higher rate to that reported in car drivers (44% v 5% respectively).

3.4.2 Trends in the prevalence of drug-driving

The lack of recent studies measuring the prevalence of drugs in traffic crashes precludes any meaningful assessment of trends in drug-driving over the past five years. This remains an urgent priority to address; however, the availability of time-series data is limited.

3.4.3 Methodological limitations

A number of methodological limitations may have influenced the estimates of prevalence in this review. Almost sixty percent (60%) of studies measuring drug involvement in fatal and serious crashes were conducted over ten years ago. As drug use and availability patterns have changed over the past decade then these estimates will not provide a reliable indication of the magnitude of the drug-driving problem today. There is clearly a need for more research on the prevalence of drugs in road trauma. In addition, some of the studies in this review were conducted in different years and over different periods of time, both of which make it difficult to make sensible comparisons between studies in relation to trends over time.

Although studies measuring drugs in samples of oral fluid provide the most objective estimates of prevalence, most studies of roadside drug screening are targeted at areas of suspected high use such as truck routes or rave party precincts. As these studies are not truly random the data provides only a weak indication of the prevalence of drug-driving in the general population. In addition, differences in prevalence estimates across some drug types may be a consequence of the difference in time windows of detection for the drugs using current roadside screening technology.

Some of the studies in this review used different types of biological samples to estimate the prevalence of drug-driving and drug-driving crashes. Those studies using urine samples (Griggs et al., 2007; Gerastomoulos et al., 2000) may lead to an overestimation of prevalence because drugs can be detected for a relatively long time after consumption and may not reflect recent use and/or impairment.

TABLE 3.2 PREVALENCE OF ILLICIT DRUGS IN CRASH-INVOLVED DRIVERS IN AUSTRALIA

Killed Road Users			
Author, Year, Location	Method	Key Findings	Limitations
Drummer (1995) Victoria, New South Wales, Western Australia	1,052 fatally injured drivers N = 1052 Period: January 1990 - December 1993	Alcohol: 36% Drugs present: 22% • THC: 10.5% • Stimulants (amphetamines, ephedrine): 3.3% • Benzodiazepines 3.2% Alcohol + Drugs: 9%	
Gerostamoulos et al (2000) Victoria, New South Wales, Western Australia, South Australia and Queensland	921 drivers killed in motor vehicle crashes N = 921 Period: January 1995-December 1996	Alcohol: 36% • Alcohol (>0.01%): 32% Drugs present: 27% • THC: 13% • Stimulants (amphetamines, ephedrine): 3.2% • Benzodiazepines 3.8% • Opioids: 4% Alcohol + Drugs: 9%	The prevalence estimates in South Australia and Queensland are highly skewed due to targeted or limited drug screening practices at the time of the study

Killed Road Users			
Author, Year, Location	Method	Key Findings	Limitations
Drummer et al. (2003) Victoria, New South Wales, Western Australia	Fatally injured road users in traffic crashes N = 3,398 • 2,609 car drivers • 650 motorcyclists • 139 truck drivers Period: 1990-1999	Alcohol and drugs detected • Drivers: ○ BAC ≥0.05: 30.3% ○ Drug and alcohol positive: 9.8% ○ Cannabis: 11.9% (22-30 years: 19.7%) ○ Stimulants (ephedrine, MA, MDMA): 3.4% (22-30 years: 5.4%) • Motorcyclists ○ BAC ≥0.05: 28.9% ○ Drug and alcohol positive: 10.5% ○ Cannabis: 22.2% (22-30 years: 44.4%) ○ Stimulants (ephedrine, MA, MDMA): 2.8% (22-30 years: 5.4%) • Truck drivers ○ BAC ≥0.05: 8.6% ○ Drug and alcohol positive: 2.9% ○ Cannabis: 6.5% (22-30 years: 44.4%) ○ Stimulants (ephedrine, MA, MDMA): 23% (22-30 years: 5.4%)	The exclusion of cases who survived for a time in hospital. Postmortem redistribution may have resulted in increases in blood concentration especially for methamphetamine. However, even allowing for possible post-mortem changes many of the cases had drugs detected at concentrations that reflect misuse of the drug
Drummer & Yap (2016) Victoria	Fatally injured drivers N = 2,368 Period: 2000 - 2013	• BAC ≥0.05: 24.8% ○ 2000-2007: 26%; 07-13: 23.6% • Drug and alcohol positive: 11.9% ○ 2000-2007: 11.7%; 07-13: 12.1% • THC: 11.9% ○ 2000-2007: 14.4%; 07-13: 14.4% • Stimulants (ephedrine, MA, MDMA): 7% ○ 2000-2007: 5%; 07-13: 8.4% • Benzodiazepines: 7.0% ○ 2000-2007: 5.7%; 07-13: 8.3% • Opiates: 6.6% ○ 2000-2007: 6.1%; 07-13: 7.2%	

Injured Road Users			
Author, Year, Location	Method	Key Findings	Limitations
Gerostamoulos et al (2002) Melbourne	Seriously injured drivers (time period not specified) N = 358	Drugs detected • Cannabis: 36% • Amphetamines: 12% • Cocaine: 2% • Benzodiazepines 14%	Cannabis contains mixed cases of the inactive and active form of THC Single trauma centre
Ch'ng et al. (2007) Melbourne	Divers seriously injured in crashes N = 436 Period: December 2000-April 2002 (70% male; 69% aged 15-44)	Drugs detected • THC: 7.6% (metabolites of cannabis: 46.7%) • Amphetamines (4.1%) • Cocaine (1.4%) • Benzodiazepines (15.6% • Opiates (11%) • Methadone (3%) • Polydrug use in 9.4% of sample	Not all injured drivers were sampled.
Drummer et al. (2012) Victoria	Drivers injured in crashes N = 1714 drivers Period: July-November 2009	Positive test: 35% (male: 66%, female: 34%) Drugs detected • THC: 9.8% • Methamphetamine: 3.1% • MDMA: 0.8% • One or more drugs: 12.5% • Alcohol plus drugs 12% Prescription drugs detected • Opioids: 9.4% • Anti-depressants: 9.2% • Benzodiazepines: 8.9% • Anti-psychotic drugs: 1.7%	Potential bias in that not all drivers injured had blood specimens collected

Injured Road Users			
Author, Year, Location	Method	Key Findings	Limitations
Sugrue et al. (1995) Sydney, New South Wales	164 drivers, 12 cyclists and 31 pedestrians non-fatally injured in traffic crashes, October 1992-October 1993	Drivers • Alcohol exceeding 0.08 g/Dl: 16.5% of drivers • Cannabinoids: 15.2% (84% were male, more likely to be < 20 years age) Cyclists • Cannabinoids: 8% Pedestrians • Cannabinoids: 13% Combined use of alcohol and other drugs in 16% of drivers	Urine samples do not provide reliable estimates of recent drug use despite the high cut off concentrations used in this study Small sample size
Griggs et al. (2007) South Australia	Admitted to hospital following any accident (including motor vehicle crashes) N = 2127 Period: August 2003-August 2004	Car drivers: 38.5% positive for alcohol and other drugs (of N = 539) • Alcohol: 22.6% • THC/THC acid: 17.4% • Benzodiazepines: 17.7% • Amphetamines: 6.9% • Opiates: 3.3% Motorcyclists: 43% positive for alcohol and other drugs (of N = 203) • Alcohol: 11.7% • THC/THC acid: 28% • Amphetamines: 7.4% • Benzodiazepines: 6.9% • Opiates: 5.3% Cyclists: 31.1% positive for alcohol and other drugs (of N = 74) • Alcohol: 20.2% • THC/THC acid: 20.2% • Other drugs (unspecified): 5% Pedestrians: 40.2% positive for alcohol and other drugs (of N = 102) • Alcohol: 40.2% • THC/THC acid: 16.7% • Amphetamines: 11.8%	Positive tests for cannabis may include both recent and non-recent use of drugs

Injured Road Users			
Author, Year, Location	Method	Key Findings	Limitations
Tutt et al. (2001) New South Wales Central Coast	Drivers aged under 45 killed in motor vehicle crashes N = 45 (92% male) Period: 1996-1999	• Exceed 0.05% BAC: 42%, (40% of these were THC positive) • Less than/equal 0.05 BAC: 58% (42% THC positive)	

Survey – Crash Involvement			
Author, Year, Location	Method	Key Findings	Limitations
Aitken et al. (2000) Victoria	Survey using snowball sampling approach 160 injecting heroin drug users	Crash-involvement: 50% • Reported: 192 crashes, including property damage only: 18 injury / ambulance attendance Information on 'last-crash' – reported by 51 respondents • 37.3% reported being stoned (drug affected) • 31% had recently had a hit (injected heroin within an average of 1.75 hours before driving) • 27.5% thought their heroin use had contributed to the crash Trip purpose: • Social trips / reasons: 36% • Work or shopping: 32% • Trips to buy drugs: 26%	
Armstrong et al. (2006) Queensland	Survey 331 university students who used drugs for recreational purposes (% male: 27%; mean age: 24)	Drug-related crash: 3% (equates to 10% of 182 that had drug-driven) *Drug type not specified	As recorded drug use tends to be higher in males, the over-representation of females in the study may underestimate the true prevalence of drug use in the sample

Survey – Crash Involvement			
Author, Year, Location	Method	Key Findings	Limitations
Darke et al. (2004) Sydney	Survey using snowball sampling approach 300 regular injecting drug users (defined as injecting at least once within the last 6 months) Period: April – November 2002	Drug-driving crash (all severity) • 32% (males: 36% had crash; female: 24%) • Drug-driving crash (injury crash: driver injured): 15% • Drug-driving crash (injury crash: another person injured): 8% • Drug-driving crash (injury crash: another person injured): 1% Recent drugs prior to most recent crash • Heroin: 53% • Cannabis: 46% • Alcohol: 42% Number drugs involved in the last driving crash was 2.1 • 2 or more: 66% • 3 or more: 28% • 4 or more: 12% Polydrug use • Heroin + Cannabis: 21% • Cannabis + Alcohol: 20% • Heroin + Alcohol: 18% • Heroin + Benzodiazepines: 12% • Cannabis + Benzodiazepines: 12%	

4 DRUG-DRIVING AND CRASH RISK

4.1 OVERVIEW

This section reviews epidemiological studies that have examined crash risk associated with driving under the influence of cannabis, ecstasy, amphetamines, and methamphetamines. The time period of studies included is 1995 – 2015 (see Method), with later meta-analysis also included.

Experimental and on-road studies have provided important information regarding the impairing effects of drugs on driving performance (e.g. Berghaus et al., 2011). However, it has been stated that these studies are limited to the extent that they can provide a meaningful representation of crash risk in real-world driving due ethical considerations that limit the dose of illicit drugs administered to participants (Gjerde et al., 2015). That these studies still demonstrate impairments in driving performance associated with illicit drugs is notable (see Shinar, 2017 for brief review).

The four types of epidemiological studies used to measure crash risk are: cohort and population studies; case-control studies; responsibility studies, and case-crossover studies. These are described below, along with their advantages and disadvantages. Table 4.1 (Section 4.7) provides a summary of the studies examined, while Appendix C provides a summary of each research paper discussed below in Table format.

4.1.1 Cohort and population studies

Cohort and population studies examine crash involvement between drug users compared to non-drug users. The key information collected is self-reported frequency of drug use and involvement in traffic crashes with and without the drug under investigation. The information is generally collected via telephone interviews or surveys. Some of the limitations associated with cohort and population studies include underreporting, recall bias, and social desirability bias. Advantages include the ability to control for a potentially large number of key variables that can impact on crash risk estimates such as personality or health.

4.1.2 Case-control studies

Case-control studies compare drug use among crash-involved and non-crash involved drivers. Case-control studies are used to examine the association between a defined exposure (drug use) and an outcome of active exposure (crash involvement) (Gjerde et al., 2015). Cases are drivers involved in traffic crashes and may be selected from official records held by police, insurance agencies, hospitals, coroners, or from the individual involved in the crash him/herself (self-reported crash involvement). Controls are drivers not involved in crashes and may be selected from random traffic, driver licensing databases, or self-reported non-involvement in traffic crashes.

Odds ratios are used to estimate the risk of involvement in a crash under the influence of drugs. The odds ratio is a ratio between the odds of having a crash among those who were positive for a given substance (exposed) and the odds of having a crash among those who were not positive for a given substance (non-exposed) (Hels et al., 2011). Thus, all other factors being equal, an odds ratio greater than one indicates how much of an increase in crash risk is attributable to driving while on drugs.

Drug exposure is measured by analysis of biological samples (blood, saliva, urine or sweat) or via self-reports. Blood samples are the best biological matrix for analysis because their concentration is correlated best with the degree of drug impairment and they are also more likely to reflect recent rather than past drug usage (Gjerde et al., 2015). Urine samples are not ideal because a positive drug specimen does not only indicate active drug exposure since drug/metabolites may be present some days after a blood sample when the driver is no longer impaired by the drug.

Blood, or otherwise the same biological specimen, should be collected from both cases and controls as there are differences in the average drug detection time between different types of bodily fluids and in the rate of drug metabolism. It is also critical that equivalent cut off concentrations for drugs are used within and between case and control samples. Since the concentration level of the drug is subject to change resulting from metabolism or, in fatal cases, post-mortem redistribution, blood samples need to be taken immediately after the crash. Toxicological analysis should also include a large number of drug types to eliminate cases with additive effects due to multi-drug use or combinations of alcohol or drugs. Failure to adhere to these conditions can result in an under or overestimation of real crash risk.

High refusal rates are common among control drivers particularly where blood samples are requested. In situations where refusal is due to the fear of detection and/or prosecution among drug users, a small sample size that includes only non-users of the drug would result in an overestimate of crash risk. Oral fluid (i.e., saliva) can be taken instead to avoid these potential threats to validity since both specimen types are positive for drugs for the same average length of time after intake of a single dose (Bogstrand et al., 2012).

Case-control studies are often regarded as the 'gold standard' in evaluation studies because an attempt is made to match cases and controls on key covariates that are known to influence crash involvement in addition to the drug itself. These covariates include age, sex, time of day, day of week, type of road or crash site, driving experience, physical and mental health, and other behavioural and personality factors (Elvik, 2013). The matching process is carried out by ensuring that cases and controls are randomly selected from the same population (i.e., controls should be selected in an unbiased manner from those individuals who would have been included in the case series had they been involved in a crash) (Gjerde et al., 2015; Walsh et al., 2004). However, as pointed out by Gjerde et al (2015) and Walsh et al (2004), it is not possible to control for all confounding variables, particularly those that may be outside the researchers' control and/or influenced by budgetary, practical or other constraints. Thus, the outcome of the study will generally reflect not only the risk of crashing due the drug itself but also to other factors that co-vary with drug use and crash risk.

4.1.3 Responsibility studies

Responsibility studies are case-case studies that examine crash involved drivers only. Drivers are classified according to their degree of responsibility for the crash and then a comparison of drug use is made between those deemed culpable for the crash (the 'cases') and those not deemed so (the 'controls') (Bates & Blakely, 1999). If greater use of a drug is evident in culpable drivers, then that drug is linked to a greater crash risk (Baldock et al., 2008). Judgements about crash responsibility are made by examining the circumstances leading up to the crash, typically by experts who are blinded to information pertaining to driver characteristics such as drug and alcohol use, previous crash involvement and infringement records (Robertson & Drummer, 2004).

There are several limitations associated with responsibility studies that may render crash risk estimates unreliable. Studies in which the assessment of responsibility relies to some extent on the judgement of police may be biased by the greater likelihood of police attributing culpability to an impaired driver. This would result in drugs being more likely to be associated with crash culpability (Keall & Frith, 2004), leading to an overestimation of crash risk. In other cases, drivers classified as non-culpable may have in fact contributed to the crash in some way and thus would not be representative of a control group for this type of study. This would make it less likely that a responsibility study would find an association between use of this drug and crash culpability, leading to an underestimation of crash risk. As with case-control studies, blood samples should ideally be used for all categories of crash responsibility and the samples should be taken immediately after the crash (Gjerde et al., 2015; Walsh et al., 2004). The blood analysis ought also to include a large number of drug types to eliminate cases with additive effects due to multi-drug use or combinations of alcohol or drugs.

It is also important to note that the culpability ratio presented in responsibility studies are not technically odds ratios as they are calculated differently. This is important when making comparisons with case-control derived odds ratios and crash risk, and those derived from responsibility analysis.

4.1.4 Case-crossover studies

Like responsibility studies, case-crossover studies examine crash involved drivers only. Case-crossover studies make comparisons between the numbers of crashes for each driver during periods of drug use with periods without drug use. As each person in the study is both a case and his/her own matched control, the design eliminates the need to control for confounding factors (Gjerde et al., 215). The main limitation associated with case-cross over studies is that any untreated illness during periods of non-drug use may underestimate the true risk associated with driving under the influence of drugs.

4.2 ESTIMATES OF CRASH RISK

4.2.1 Cannabis (CNS depressant)

The crash risk associated with driving under the influence of cannabis was measured in 40 studies (see Appendix C for detail; Table 4.1 for summary). Of these, 19 were case-control studies in which 16 used biological samples for measuring drug use, two relied on self-report measures, and one used a combination of both. Ten studies were responsibility studies, 11 were cohort/population studies, and two were case-cross over studies (both of which used a combination of biological and self-report measures).

With respect to crash severity, 13 studies examined the risk for involvement in fatal crashes; 13 examined serious injury crash risk; nine examined crash risk for any level of injury severity (these were mostly cohort/population studies using self-report data), and four examined both fatal and serious injury crash risk (two of which combined fatal and serious injury crashes in the one risk estimate). In one study the definition of *crash* was not given.

Of the studies included in this review, half (n=20) reported a significant statistically significant increase in crash risk associated with cannabis. The Odds Ratios were generally in the range of 1-4, with the OR being within the 1.5 – 2.0 range most common.

The remaining 20 studies found no statistically significant increase in crash risk, noting however that the statistically significant association between cannabis and crash risk in four studies was eliminated once co-variates were included in the statistical models.

While the 40 studies provide inconsistent results, there are a host of methodological differences, including how the presence of cannabis use was assessed and over what timeframe, between the studies. These include a host of 'quality issues' that impact on the validity and reliability of reported findings. The implications of this point for policy makers is clear: with such inconsistent results (that it must be said are driven by methodological challenges), what is the appropriate course of action in relation to road safety? This is particularly pertinent in relation to public policy debates concerning the legalisation of cannabis use.

With researchers recognising these points, a number of meta-analysis studies have been conducted. With a rule-based quality assessment process, and a pooling of data across studies, a robust estimate of the association between cannabis use and crash risk can be derived. This is presented and discussed below.

For the sake of completeness, it is noted here that a large number of studies have examined the effects of acute cannabis intoxication on driving performance within the confines of driving simulators and closed tracks. These studies consistently report reduced performance in tasks associated with safe driving, including among study participants described as regular users (see Shinar, 2017 for a brief overview).

Notwithstanding the points above, it is still of value to report key findings from the studies reviewed.

Crash risk and road user group

Most of the 40 studies examined drivers only. One study reported motorcyclists separately in the analysis, another examined cyclists only, and further two examined truck drivers only. Eighty percent of the sample by Woratanarat et al (2009) comprised motorcyclists, however the authors did not examine crash risks separately for motorcyclists and drivers.

In most population studies, road user type was not explicitly stated, though it is assumed that the majority of respondents in these studies were drivers. Since there were too few studies on road users besides drivers, it is not possible to make comparisons between road user groups in terms of their risk of crash involvement.

Cannabis use and the impact of age and gender on crash risk

Few studies examined whether crash risk associated with cannabis use varied according to age and gender. In most cases this was due to the small number of cases and controls within each stratified sample and drug type.

In a major study, Hels et al (2013) found that for male drivers the risk of being involved in a serious injury crash was about 65% that of female drivers. In contrast, Li et al (2013) found that only male drivers were at significantly increased risk of fatal crash involvement, although their analysis combined a number of different drugs including cannabis.

With respect to age, Hels et al (2013) found that the risk of serious injury crash was about three times as high for the young drivers (18-24) than for the drivers aged 50 and over. Risk decreased with increasing age and, for drivers aged 35-49, the risk was not significantly different from that of the drivers aged 50 and over. Li et

al (2013) found that **drivers** aged 21 to 34 years or 65 years and over were at significantly increased risk of fatal crash involvement.

Evidence for a dose-response relationship between cannabis and crash risk

A small number of studies examined whether crash risk increases with drug use in a dose response manner. This type of analysis is only possible in studies that have used biological measures of drug use with equivalent cut-off concentrations across cases and controls.

Drummer et al (2004), Gadegbeku et al (2011) and Laumon et al (2005) reported an increasing risk of attributed responsibility for fatal crashes with increasing cannabis levels.

Specifically, Drummer et al (2004) found that THC positive drivers had a significantly higher likelihood of being 'culpable' for a crash than drug-free drivers (OR 2.7, 95% CI 1.02-7.0); for drivers with THC concentrations of 5 ng/mL or higher the odds ratio was 6.6 (95% CI 1.5-28.0).

Similarly, Gadegbeku et al. (2011) reported that the odds of being responsible for a fatal crash was 2.8 in drivers with THC levels between 3-5 ng/ml compared to 1.53 in drivers with THC levels between 1-3 ng/ml.

In study by Laumon et al. (2005), the risk of fatal crash increased from 2.18 with THC levels at less than 1 ng/ml to 4.72 with THC levels greater than or equal to 5 ng/ml. Finally, Kuypers et al (2012) found that the risk of serious injury crash involvement in their case-control study was four times higher at THC levels between 2-4.99 ng/ml than at THC levels between 1-1.99 ng/ml.

Cannabis use in combination with other drugs

There is good evidence that the crash risk associated with cannabis (and other drugs) increases when cannabis is combined with other drugs and/or alcohol.

In two case studies by Gjerde et al (2011) and Gjerde et al (2013), a non-statistically significant increase in crash risk was associated with the use of cannabis alone, but a statistically significant increase in crash risk was found when cannabis was used in combination with other (unspecified) drugs.

Similarly, the case-control study by Brault et al (2004) found a higher odds ratio for involvement in fatal crashes for cannabis use combined with other substances (unspecified) (OR 4.5, CI 3.3-6.0) than for cannabis use alone (OR 1.6, CI 1.1-2.4).

In his responsibility studies, Drummer et al (2004) reported that the odds of being culpable for a crash was 2.9 times greater for drivers who were both THC positive and had a BAC>0.05 compared to BAC>0.05 positive drivers.

Note, the reader is referred to Section 4.7 for crash-risk estimates for cannabis use derived using meta-analysis.

4.2.2 Amphetamines (CNS stimulant)

Ten studies examined the association between amphetamine use and crash involvement, eight of which were published in the last ten years (see Appendix C). Eight of the ten studies found a significant increase in crash risk associated with the use of amphetamines. The crash risk estimates ranged from 8.9 to 54.8; these risk estimates are much higher and more consistent than those reported for cannabis.

The elevated crash risk associated with amphetamine use is well accepted and not contentious.

It is relevant to note that studies did not distinguish between amphetamines and their derivatives (i.e., methamphetamines, MDMA; refer Chapter 2.4). This is due to the processes of chemical breakdown of substances and test protocols. While these substances are of the same chemical family and share generic physiological and psychological effects, there are differences in that methamphetamine is associated with particularly severe effects. Similarly, MDMA has added 'trance-like effects', as well as hallucinogenic effects among some users.

Details of the 10 studies:

- Study types: Nine studies were case-control studies using biological samples and one was a responsibility study.
- Crash severity: Five studies examined the risk for involvement in fatal crashes; four examined serious injury crash risk; and one study combined fatal and serious injury crash risk in the one estimate.

Crash risk and road user group

All of the studies examined crash risk associated with drivers only. As with cannabis, the failure to examine or report amphetamine use in road user groups besides drivers precludes an assessment of whether crash risk associated with this drug varies across road user groups.

Amphetamine use and the impact of age and gender on crash risk

Few studies examined whether crash risk associated with amphetamine use varied according to age and gender and other key variables including time of day, geographic region and crash type.

Hels et al (2013) found that female drivers were at higher risk for involvement in serious injury crashes associated with amphetamine than males. With respect to age, Hels et al (2013) found that the risk of severe injury crash was about three times as high for the young drivers (18-24) than for the drivers aged 50 and over, with this risk decreasing with increasing age. Similarly, Bernhoft et al (2012) found that young drivers aged 18-25 years had the highest risk for fatal and serious injury crashes. Gjerde et al (2011) found that the risk for involvement in fatal crashes for drivers aged under 45 was five times higher than that for drivers aged over 45 years although the results for amphetamines were not reported separately. Gjerde et al (2013) (2011) found higher odds ratios for single vehicle fatal crashes compared to multiple vehicle fatal crashes.

Evidence for a dose-response relationship between amphetamine use and crash risk

None of the studies examined whether crash risk increases with increasing dose.

Amphetamine use in combination with other drugs

In the case control study by Gjerde et al (2013), a much higher risk for fatal crash was found for the use of amphetamines combined with other substances (OR 76.9, CI 38.7-152.9) compared to the use of amphetamines alone (OR 42.0, CI 12.2-145.1).

The risk of fatal crash following the combined use of amphetamines and benzodiazepines was also very high (OR 98.2, CI 24.9-386.9). In a similar case-control study, Gjerde et al (2011) found a significantly higher risk associated with methamphetamine or amphetamine combined with other substances (OR 57.1, CI 27.3-119.5 compared to methamphetamine or amphetamine alone (OR 20.9, CI 7.3-60).

4.2.3 Stimulants (CNS stimulant)

Six studies, (three responsibility studies and three case-control studies) examined the link between a combination of different stimulants and crash risk (see Appendix C). Four of these studies found significant increases in crash risk or risk of responsibility for a crash associated with stimulants. However, as crash risk estimates were not given separately for the stimulant drugs of interest in this review (i.e. amphetamines, methamphetamines and cocaine) the results of these studies are not discussed further.

4.3 FREQUENCY OF DRUG USE AND CRASH RISK

The studies reviewed in the previous sections examined the effect of drug use and/or impairment on crash risk where the interval between drug taking and driving is generally short.

Little is known about any isolated effects on crash risk of drug use frequency (i.e. occasional versus regular versus dependent/addict) and whether habitual drug use influences crash risk in ways that are different from, or interact with, the effects of recent drug impairment on driving.

A small number of studies examined crash risk associated with a diagnosis of drug use disorder/s. Callaghan et al (2013) calculated age, sex and race adjusted standardised mortality rates for deaths due to motor vehicle crashes in relation to the general population in California. They found that mortality ratios were higher across all drug cohorts including alcohol (n=1,747) (4.5, 95% CI, 4.1-4.9), methamphetamine (n=172) (2.6, 95% CI 2-3.1), polydrug use (n=1,077) (2.6, 95% CI 2.4-2.9) and cannabis (n=64) (2.3, 95% CI 1.5-3.2). However, their study was not able to determine crash culpability and, for most drug categories, less than half of all fatalities were identified as drivers (methamphetamine: 44%, polydrug: 49%; alcohol: 53%, cannabis: 62%).

In a study of 453 individuals convicted of repeat driving under the influence of alcohol offences, C'de Baca et al (2009) examined differences in the rates of crashes between individuals reporting a lifetime drug use disorder diagnosis and individuals without a lifetime drug use disorder diagnosis. The drug types examined were depressants (opiates, sedatives), stimulants (cocaine, prescription and non-prescription amphetamines) and cannabis. Individuals diagnosed with a drug use disorder involving CNS depressants experienced a 47% increase in traffic crashes compared with those diagnosed with an alcohol use disorder alone (1.47, 95% CI

1.06-2.03). Stimulant or cannabis use disorders were not associated with increased crash involvement compared to those diagnosed with an alcohol use disorder alone.

Chipman, MacDonald and Mann (2002) compared crash risks between 'at fault' and all crashes in a sample of clients undergoing treatment for drug abuse. Approximately 90 clients were examined in each of seven treatment groups: alcohol, cannabis, cocaine and all possible combinations of these substances. The control group comprised 518 matched drivers randomly selected from the state's driver records database. Prior to commencing treatment, cocaine and cannabis users involved in all crashes (i.e. crashes in which no differentiation was made on who was responsible) had a significantly higher crash risk compared to control drivers (cocaine: 1.79, CI 95% 1.42-2.25; cannabis: 1.49, CI 95% 1.17-1.89; cannabis and cocaine: 1.52, CI 95% 1.16-1.98). The risks were 10-15% higher for at fault crashes compared to all crashes. In the post-treatment period, only being male and being younger, not the substance that had been abused were associated with higher crash risk.

A handful of studies have examined the effect of habitual drug use on crash risk in mostly non-dependent drug user populations. Pulido et al (2011) found a significant association between daily cannabis use in the last 12 months and non-fatal crash risk for drivers (OR 2.5, CI .12-5.1) but no significant association for less frequent use. Similarly, a significant association was found between weekly cocaine use and involvement in non-fatal crashes (OR 2.8, CI 1.1-7.1) but not for less frequent use. Mann et al (2007) found the risk of crash involvement was higher among those who had in their lifetime used cannabis compared to those who had not (OR 1.47, CI 1.08 – 1.99) and between those who had used cannabis more than once a week compared to those who had used it once per week or less in the last 12 months (OR 2.76, CI 1.50-5.08). They also reported a significant association between cannabis dependence in the last 12 months and crash involvement (OR 1.72, 1-2.96). Using a similar methodology, Mann et al (2010) found that lifetime cannabis use was not associated with increased crash risk compared to having never used cannabis, nor was there any association between cannabis use and crash involvement in last 12 months compared to never having used cannabis during this period.

In a birth cohort of 907 persons aged 18-21 years, Fergusson and Horwood (2001) examined the association between drug use and crash risk for different levels of cannabis use: 1-10 times, 11-50 times and 51 or more times. They found a significant relationship between cannabis use more than 50 times per year and self-reported crash rate (OR 1.6, CI: 1.2-2.0) for crash in which driver behaviour contributed to the crash; however, this effect was eliminated once confounding variables were controlled. In a later study on the same birth cohort four years later, Fergusson et al (2008) found a significant relationship between frequency of cannabis use (more than 20 times per year) and self-reported accident rate (OR 2.25, CI:1.65-3.07) that was also eliminated once confounding variables were controlled.

Unfortunately, none of these studies collected toxicological or self-report data on drug use prior to driving so it is not possible to determine whether any increase in crash risk was associated with acute or long-term drug use (or both).

In order to examine the potential contribution of acute versus long term effects of drug use on crash risk, both of these factors need to be examined in isolation while holding constant the effects of the other factor. Only one study in this review followed this method. Blows et al (2005) examined the relationship between acute cannabis use (within three hours of the crash), habitual cannabis use (once per week or more in the past 12 months) and car crash injury using a population-based case control study with 1,159 participants. Whilst no effect on crash risk of acute cannabis use was found, there was a strong significant association between habitual use and car crash injury after adjusting for acute use prior to driving and a number of other important confounding factors (OR 9.5, 95% CI 2.8 – 32.3).

The mechanism by which habitual drug use increases the risk of car crash injury is not known (Blows et al (2005). A possible explanation is that habitual users engage in other risk-taking behaviour that increases their crash risk. For example, Fergusson and Horwood (2001) found that habitual cannabis users were more likely to report risky/illegal driving behaviours and attitudes which were associated with increased risk of car crashes. Blows et al (2005) included the risky driving variables speed, non-use of seat belts, sleepiness and high blood alcohol level in their analysis but found that this did not remove the significant effect of habitual cannabis use. They note that heavy users may be more likely to engage in other risky driving behaviours associated with car crashes that were not controlled for in their analysis. Alternatively, it is possible that long term drug use induces mental impairment such as memory, concentration or coordination difficulties that in turn affects driving ability (e.g., Ryb, Dischinger, Kufera & Read, 2006). Although there is some evidence that habitual cannabis use can cause long term effects on brain functioning (e.g., Block 1996; Hall & Solowij, 1997), to date there have been no studies of the long-term effects of drug use on crash risk. Blows et al (2005) also

suggest that their study findings may reflect an ongoing acute effect of habitual drug use brought about a build-up of high levels of the drug over time.

4.4 METHODOLOGICAL LIMITATIONS

Previous *Reviews* have already identified the methodological limitations and challenges for studies measuring the association between crash risk and driving under the influence of drugs (Gjerde et al., 2015; Elvik et al., 2013; Houwing et al., 2013; Asbridge et al., 2012; Houwing et al., 2012; Sewell et al, 2009; Lenguerrand et al., 2008; Baldock et al., 2008; Walsh et al, 2004; Bates & Blakely, 1999; Moscowitz, 2005; Ramaekers, 2003). These challenges are also discussed in Shinar (2017). It is notable that discussion of the methodological limitations surrounds research on cannabis and crash risk, and so the discussion below needs to be considered with this in mind. These study design issues are however relevant for all research studies on drug use and crash risk, irrespective of the drug being examined.

As Gjerde et al (2015) have pointed out, the calculated odds for involvement in a crash will not only be related to risks posed by the drug per se, but also to the study design, participation rate, confounding factors that are not adjusted for during matching and/or data analysis, and often an uncertainty introduced because of using different biological fluids from cases and controls. The inconsistent crash risk estimates in this review are likely to reflect these limitations and challenges as outlined in the section below.

A key challenge is confounding effects due to other drug use, and as such it has been stated that a full drug screen is necessary to ensure that a significant increase in one substance is not due to combinations with other substances (Bogstrand et al. 2012; Gjerde et al., 2011; 2015; Elvik et al., 2013). Importantly, just over 25% of studies failed to control for other drug use, and three failed to account for the presence of alcohol in the analysis conducted (Asbridge et al., 2005; Fergusson & Horwood, 2001; 2008; Laumon et al., 2005; Wadsworth et al., 2006; Richer & Bergeron, 2009; Soderstrom et al., 2005; Marquet et al., 1998; Mann et al., 2007; 2010).

Studies relying on self-report data have particular limitations, and deriving odds ratios based on data obtained from case drivers with full toxicological screens compared against 'control' drivers using self-report is especially problematic. This would have the effect of over-stating the degree of the association between drug use and crash risk.

While the use of formal toxicological analysis is critical, the number of drugs measured and recorded was also seen to differ (Dubois et al., 2015; Romano et al. 2014; Li et al. 2013; Gates et al., 2013). Some studies reported that 'other drug use' was examined, failing though to state the number or types of drugs (Movig et al., 2004; Pulido et al., 2010).

In the assessment of crash risk associated with drug-driving, Elvik et al (2013) argued that the following confounding variables besides alcohol and other drug use should be controlled for: age, gender, kilometres driven, drug use history, dose of drug, health status (co-morbidity), and place of residency.

None of the studies identified in this review controlled for all of these factors.

All except two studies (Asbridge et al., 2014a; Asbridge et al., 2014b) controlled for age and sex, and only a quarter of studies measured place of residence. The epidemiological study design does not easily allow for adjusting for factors such as driving experience, drug use history, health status and driver risk-taking behaviour and style, factors which are more easily obtained in studies utilising self-report data. However, while 80% of self-report studies examined driving exposure, two (Dubois et al., 2015; Pulido et al., 2011) measured prior drug use history; two measured driver risk-taking propensity and only one (Wadsworth et al., 2006) measured health status. Outside self-report studies, drug use history was only examined in the study by Movig et al (2004), and no studies measured health status or driving exposure. No studies identified (nor controlled for) the purpose for which drugs were taken (i.e. therapeutic or recreational) even though recreational drug users may be more predisposed to driving behaviours that increase crash risk.

Studies using biological samples are superior to those relying on self-report due to being able to objectively confirm and quantify the full range of available substances. However, in a quarter of all case-control studies utilising biological samples, only a dichotomous marker of drug use was used and reported (Duboios et al., 2015; Li et al., 2013; Romano et al., 2014). Where drug concentrations were used, the cut off concentrations in half of these case control studies were not equivalent across cases and controls (Assum et al., 2005; Beirness et al., 2013; Mathijssen & Houwig, 2005; Movig et al., 2004), leading to difficulties in comparing the groups.

It is evident then that the most reliable method for detecting drug use is to collect the same specimen (preferably blood) from both cases and controls or, where this is not possible, to collect saliva samples in

controls and blood samples in cases. Only Kuypers et al (2012) compared blood samples across cases and controls and, in the studies by Li et al. (2013), Matthijsen & Houwig (2005) and Romano et al., (2013), either urine or blood was collected in controls and compared to blood samples in cases.

In six studies urine, or a combination of urine, blood or sweat, was collected across both cases and controls. In studies measuring urine only, the crash risk is likely to be underestimated. This is because a positive drug specimen does not only indicate active drug exposure since drug metabolites may still be present days after a blood sample when the driver is no longer impaired by the drug; this is especially problematic in relation to cannabis due to the relatively long half-life and its metabolites.

Given the above, studies such as these are only able to measure an association between crash involvement and drug use at some time in the past rather than between crash involvement and recent impairment due to drug use. In studies comparing blood samples in cases and urine and/or blood samples in controls, the crash risk estimates are likely to be compromised since the comparisons were between recent drug use in cases and past drug use in controls.

It is also likely that some studies over or underestimated crash risk as a result of high refusal rates in the cases or controls or differences in participation rates between cases and controls using different biological samples. Kuypers et al (2012) found a high refusal rate of 52% among controls when blood sampling was requested. If control drivers positive for drugs were more likely to refuse participation in the roadside survey than others this would lead to an overestimation of risk. In Movig et al (2005) the proportion giving urine samples was significantly higher in controls than cases thus underestimating the calculated risk estimates. Asbridge et al (2014a) and Asbridge et al (2014b) found no significant association between drug use and crash involvement when using only self-report measures for cases and controls. However, a significant association was found between the two when using biological samples only. If under reporting was restricted to cases, then the estimates of association between cannabis use and crash risk would be conservative. If under reporting occurred in 'control drivers' then the association would be over-estimated.

4.5 QUALITY ASSESSMENT OF CRASH RISK ESTIMATES

Two major barriers to assessing the impact of drug use on driving crash risk are firstly that many of the studies suffer from important methodological limitations, and secondly that the variables used to measure crash risk across studies vary considerably. Both of these issues were highlighted in the previous section of this report.

With regard to methodological limitations, it extremely difficult, if not impossible, to avoid all potential study limitations when assessing the association between illicit drug use and driving crash risk (even in well-funded, large scale epidemiological studies).

However, studies that avoid more of these limitations are likely to provide the best estimates of crash risk. With regard to variability of study methods, the lack of standardisation across key variables limits the extent to which meaningful comparisons across studies can be made. This is particularly problematic when the study outcomes are mixed. In the present review, the evidence for the increased crash risk associated with stimulants including amphetamines was consistent and strong. For cannabis, however, half of all studies showed an increase in crash risk while the other half found no such increase. It is likely that limitations in study design as well as a lack of standardisation across studies account, at least in part, for these variable outcomes.

One approach to resolving inconsistent research findings is to assess the outcomes of the research on the basis of the quality of the data. Estimates of crash risk derived from carefully designed studies are likely to be more reliable than those that are based on poorly designed and/or poorly controlled studies. As noted by Elvik 2008; 2011), assessing study quality is not an exact science. However, it is widely regarded in research studies where the outcomes of different studies disagree.

In a recent meta-analysis of 66 epidemiological studies on drug use and driving crash risk, Elvik et al (2013) developed a numerical index of study quality using the following criteria:

- Measurement of drug use: A distinction was made between five methods of determining drug use. Listed in order from the most reliable to the least reliable, these were: (a) Laboratory analysis of blood samples (5 points); (b) Laboratory analysis of saliva samples or a mixture of blood and saliva (4 points); (c) Laboratory analysis of urine samples or a mixture of urine and other body fluids (3 points); (d) Self-reported drug use (1 point). Maximum possible score = 5 (25% of total score).
- How crash severity was specified. A distinction was made between three levels (fatal, injury, property damage only), and a study was rated as best if it included estimates of risk for all levels of crash severity.

Studies that measured at least two levels of crash or injury severity within the one study scored 2 points; studies that measured crash at a specific level of injury severity (fatal, injury, property damage) scored 1 point; and studies that included a mix of injury crashes and property damage crashes scored zero points. Maximum possible score = 2 (10% of total score).

- Control for confounding factors including age; gender; kilometres driven; use of other drugs; use of alcohol; drug use history; dose of drug; health status (co-morbidity), and place of residence. A study was rated best (scored nine points) if it controlled for all nine confounding variables. Two additional points were given if multiple other potentially confounding factors were controlled for, and one additional point was given if one other potentially confounding factors was controlled for. Maximum possible score = 9 (55% of total score).
- Test of dose-response. Studies that tested and found a dose-response relationship (2 points) were rated more highly than studies that tested for and found no such relationship (1 point) or studies that did not test for such an association (zero points).

On the basis of these criteria, Elvik (2013) reported a tendency — albeit inconsistent — for the estimated effects of drug use on crash risk to be smaller in well controlled studies than in poorly controlled studies.

However, Elivk's (2013) review did not include the more recent European studies from the Driving Under the Influence of Drugs (DRUID) Project (Hels et al., 2011; 2013; Kuypers et al., 2012) in which an attempt was made to improve the quality of research design and data collection processes on previous studies measuring drug use and driving crash risk.

To address this gap, Section 4.7 provides an examination recent meta-analysis where the association between drug-use and crash risk was considered.

4.6 SUMMARY OF RESEARCH LITERATURE ON DRUG-DRIVING AND CRASH RISK

Table 4.1 presents a summary of studies that examined crash risk and driving under the influence of cannabis, amphetamines, and stimulants (unspecified). The review did not identify studies specific to the crash risk associated with driving under the influence of ecstasy or methamphetamines alone, noting these were included under the category of stimulants (unspecified).

Cannabis was the most commonly used drug prior to driving, however the association with crash risk was inconsistent, although all four studies examining a dose-response relationship demonstrated an increased crash risk outcome. In contrast, amphetamines and stimulants (not all specified) were consistently associated with a very high crash risk.

Where documented, crash risk was higher when multiple substances were used than when used in isolation. There is consistent evidence that alcohol-use combined with illicit drug use is associated with particularly high crash risk odds ratios.

The few studies that examined the effect of age and gender on crash risk found a higher crash risk among males and younger road users. There was limited available information on whether crash risk varies according to road user type.

Little is known about any isolated effects on crash risk of drug use frequency (i.e. occasional versus regular versus dependent/addict) and whether habitual drug use influences crash risk in ways that are different from, or interact with, the effects of recent drug impairment on driving. The one well designed study on this topic, which focused only on cannabis use, found that whilst no effect on crash risk of acute cannabis use was found, there was a strong significant association between habitual use and car crash injury after adjusting for acute use prior to driving and a number of other confounding factors. This finding suggests other, broader risk factors that interact with habitual use drives this increase in crash risk.

TABLE 4.1 STUDIES ON DRIVING UNDER THE INFLUENCE OF DRUGS AND CRASH RISK

Study Information	Cannabis	Amphetamines	Stimulants - unspecified
No. studies published 1995 – 2015 included in review	40	10	6
Published last 10 years (%)	75%	80%	66.7%
No. case-control	19	9	3
No. cohort	9		
No. responsibility	10	1	3
No. case-crossover	2	0	0
% studies increase risk	50%	80%	66.7%
Risk estimate range (odds ratio)	**1-4**	**8.9-54.8**	**2.27-8.83**
% studies no difference in crash risk	50%	20%	33.3%
No. studies assessing dose-response relationship	4	0	0
% studies dose-response relationship found	100%	N/A	N/A
No. studies assessing polydrug use	2	2	0
% studies increased risk for polydrug use	100%	100%	N/A
Studies using biological specimens	25 (62.5%)	9 (90%)	6 (100%)
Controlled for other drug use	21 (84%)	8 (88.9%)	3 (50%)
Controlled for all key confounding variables besides other drug use	0	0	0
Controlled for age and gender	25 (100%)	9 (100%)	6 (100%)
Using equivalent drug cut off concentrations	13 (52%)	5 (55.6%)	1 (16.7%)
Measuring blood in cases & controls	8 (32%)	2 (22.2%)	2 (33.3%)
Measuring blood in cases & oral fluid in controls	8 (32%)	5 (55.6%)	1(16.7%)
Measuring urine in cases & controls	4 (16%)	1 (11.1%)	0
Measuring mixed specimens in cases (blood or sweat or urine) & oral fluid in controls	4 (16%)	1 (11.1%)	3 (50%)
Measured drug use after crash (4 hours maximum)	6 (24%)	5 (55.5%)	1 (16.7%)

As discussed, the estimates of crash risk reported in this review need to be considered within the context of a number of methodological limitations, which may result in an over-estimate or under-estimate of crash risk. These issues are discussed in detail by Elvik (2018).

To summarise, key methodological issues include: failing to control for drug and/or alcohol use besides the drug/s under investigation; use of different biological samples across cases and controls (particularly urine which provides a measure of past as well as recent drug use); a failure to measure drug use concentrations (relying instead on a dichotomous marker of drug use or use of non-equivalent cut off concentrations in cases and controls); high refusal rates among cases and controls; and a failure to control for key confounding variables including age, gender, kilometres driven, drug use history, dose of drug, health status (co-morbidity), and place of residency.

Due to the complexity in measuring crash risk associated with driving under the influence of drugs, it is arguably impossible to avoid all of these methodological limitations, even in well designed, large-scale epidemiological studies.

However, one approach to assessing the reliability of crash risk estimates in different studies is to assess the outcomes of the research on the basis of the quality of the data, and then subjecting these studies to a meta-analysis process. This has the advantage of obtaining estimates of crash risk not only from carefully designed studies but takes advantage of pooling the individual samples to create a very large sample size, with the resultant odds ratios being known as 'pooled estimates'. This is discussed in the next Section.

4.7 ESTIMATES OF THE ASSOCIATION BETWEEN DRUG USE AND CRASH-RISK DERIVED VIA META-ANALYSIS

Meta-analysis offers an important approach to understanding, in this case, the association with drug use and crash risk. By taking advantage of the findings of multiple studies, it is possible to create a 'pooled estimate' of the association of interest.

An important step in conducting a meta-analysis is the choice of research studies for inclusion. With consideration given the methodological limitations of the published literature, the establishment of a-priori quality criteria is critical. Authors of important and influential meta-analysis papers, such as Elvik (2013), Rogeberg (2019), Asbridge and colleagues (2012), explicitly state inclusion criteria and the quality assessment process. Nonetheless, differences of opinion can emerge in how particular studies are assessed, as well as the statistical procedures for analysis.

As stated above, the crash risk estimates derived for amphetamines and stimulants are well accepted. This is likely to be due to research studies reporting consistently high odds ratios.

In contrast, the inconsistent results in relation to the crash risk associated with cannabis has resulted in considerable debate (see paper by While, 2018 for example). Shinar (2017) discusses this, stating that 'we still lack sufficient data on the levels of cannabinoids that compromise driving, or how to measure them in a dose-response manner' (p.673) and further, 'to conclude that the relationship is causal requires a leap of faith' (p.674), and 'proof of association is not proof of causality' (p.674). Shinar (2017) points a need for better quality research, a statement that mirrors that of Elvik (2013).

Below we present the results of three key meta-analysis on drugs and crash risk, referring only to cannabis and amphetamines and related substances; the reader is referred to the individual papers for a detailed discussion of methods used.

4.7.1 Meta-analysis by Elvik (2013)

Elvik (2013) included 66 studies in his meta-analysis, performing detailed quality assessments in arriving at summary estimates of crash risk associated with the use of 11 illicit and prescription drugs.

TABLE 4.2 ESTIMATES OF RELATIVE RISK OF CRASH INVOLVEMENT DERIVED BY ELVIK (2013)

Drug	Crash Severity	Best Estimate of Odds Ratio (95% CI)	Best Estimate, Adjusted for Publication Bias
Amphetamine	Fatal	5.61 (2.74-11.49)†	5.17 (2.56-10.42)†
	Injury	6.19 (3.46-11.06)†	6.19 (3.46-11.06)†
	Property damage	8.67 (3.23-23.32)†	8.67 (3.23-23.32)†
Cannabis	Fatal	1.31 (0.91-1.88)	1.26 (0.88-1.81)
	Injury	1.26 (0.99-1.60)	1.10 (0.88-1.39)
	Property damage	1.48 (1.28-1.72)†	1.26 (1.10-1.44)

*Source: Elvik (2013), Table 6.
† $p < 0.05$

As seen in Table 4.2, the odds ratio for amphetamines and crash risk is in excess of five. Elvik (2013) notes that summary estimates based on fewer than five studies must be regarded as 'uncertain'. With respect to the odds ratio for amphetamines, impacts the odds ratio for injury crashes (2 studies) and property damage crashes (1 study), whereas the odds ratio for fatality crashes was based on eight studies.

With respect to cannabis, estimates were based on 42 studies overall (fatality crashes: 10; injury: 15; property damage: 17). In reporting his results, Elvik (2013: 262) states that '…the summary odds ratio indicates that the

risk of becoming involved in an accident at any level of severity increases moderately (by about 25–50%) when using cannabis', and further, that adjusting for publication bias lowered all summary estimates of risk'.

Elvik (2013) also conducted a quality assessment on each of the included studies, noting that 'in many cases (there is) a tendency for estimates of risk to be higher in poorer quality studies' (p.264). While this was true for amphetamines the reverse was the case for cannabis (see Table 4.3). Elvik (2013) did not provide any indication of the number of studies meeting the quality criteria in such a way to describe here, nor were assessments of statistical significance provided. It is nonetheless of interest to note that in better controlled studies (0.5), the elevated risk associated with cannabis use and crash involvement was at 36% higher for injury crashes, 58% for fatality crashes and 247% higher for property damage crashes (or 3.47 times greater than non-use). Notably, estimates of crash risk associated with cannabis were higher when derived from studies with a quality score of 0.8, though again, it is not noted how many studies reached this score.

TABLE 4.3 ESTIMATES OF RELATIVE RISK OF CRASH INVOLVEMENT ACCORDING TO STUDY QUALITY SCORE, DERIVED BY ELVIK (2013)

Drug	Crash Severity	Summary of Estimate of Risk for All Studies	Fitted Estimate of Risk for Quality Score of 0.2	Fitted Estimate of Risk for Quality Score of 0.5	Fitted Estimate of Risk for Quality Score of 0.8
Amphetamine	Fatal	5.61	7.02	4.71	3.16
Cannabis	Fatal	1.31	2.26	1.58	7.03
	Injury	1.26	1.04	1.36	1.55
	Property damage	1.48	1.46	3.47	12.08

*Source: Elvik (2013), Table 8.
† $p < 0.05$

4.7.2 Meta-analysis by Asbridge et al. (2012) on cannabis and crash risk

Asbridge et al (2012) conducted a meta-analysis using nine studies to assess the association between cannabis and crash risk. The key finding was a point estimate odds ratio of 1.92 (95% CI: 1.35-2.73), indicating a near doubling of crash risk (Figure 4.1).

Asbridge et al. also reported crash risk odds ratios for case-control and culpability studies, high and medium quality rated studies and studies that examined fatal and non-fatal collisions (Figure 4.2). With the exception of non-fatal collisions, the increased odds ratio (indicating increased crash risk) was statistically significant.

This meta-analysis is reported here due to its prominence; however, this work has been criticised recently for combining crash odds ratios with culpability ratios (see Rogeburg, 2019). Of note though is that odds ratios are presented in Figure 4.2 for case-control studies and culpability studies separately, both of which demonstrate a statistically significant association between cannabis use and crash risk (and being culpable for the crash).

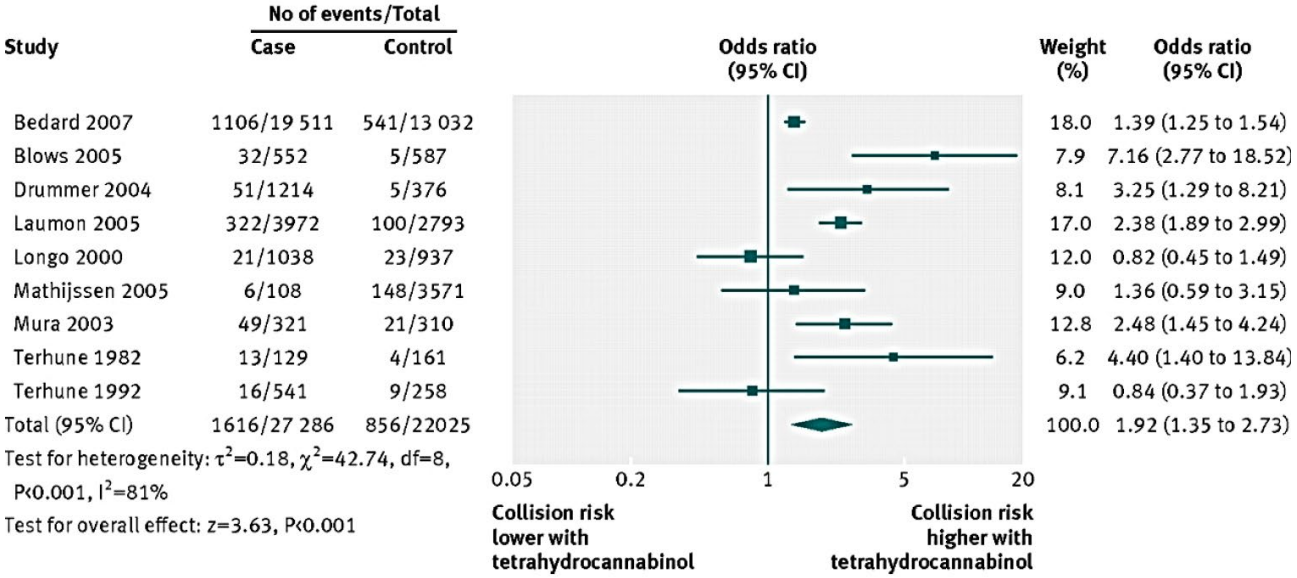

FIGURE 4.1 META-ANALYSIS OF OBSERVATIONAL STUDIES INVESTIGATING THE ASSOCIATION BETWEEN ACUTE CANNABIS CONSUMPTION AND MOTOR VEHICLE CRASHES (FROM ASBRIDGE ET AL., 2012, FIGURE 2)

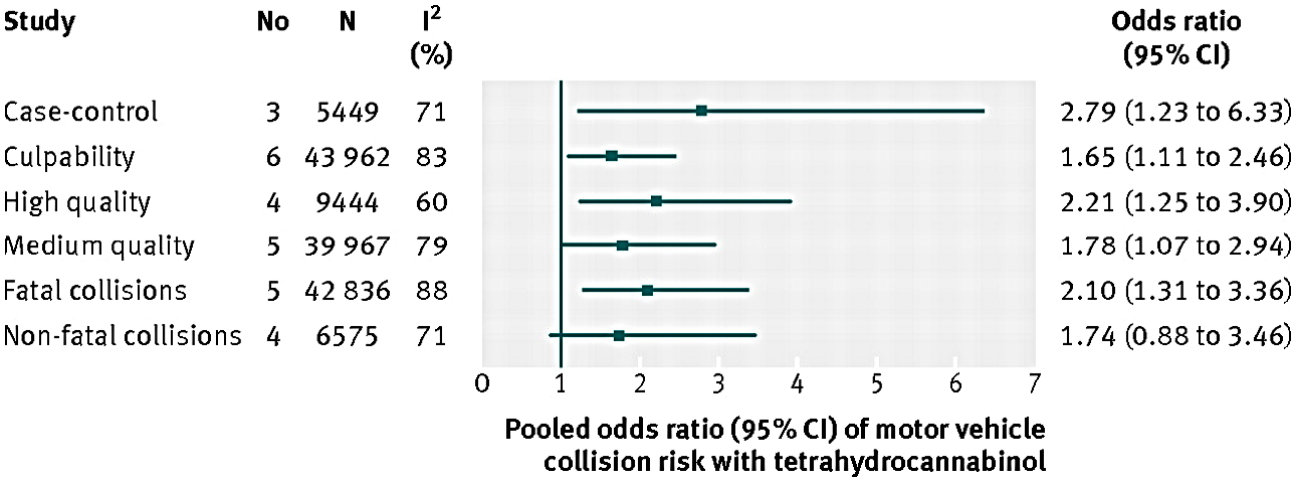

FIGURE 4.2 POOLED ODDS RATIO (95% CI) OF MOTOR VEHICLE COLLISION RISK WITH THC FOR SUB-GROUPS OF STUDIES

4.7.3 Meta-analysis by Rogeberg et al. (2016a, 2018) on cannabis and crash risk

In 2016 Rogeberg and Elvik published a meta-analysis on cannabis and crash risk (Rogeberg & Elvik, 2016a). In doing so, they highlighted a range of methodological issues and interpretation errors in previous meta-analysis research. In their meta-analysis, they used advanced statistical methods and employed rigorous controls.

These findings were updated in Rogeberg et al (2018) following a number of identified issues with included studies, including controlling for alcohol and overlapping data from one study; in addition, three studies were included in the update from the DRUID program.

The analysis presented by Rogeberg et al (2018) reports a combined odds ratio of 1.32 (95% CI: 1.09-1.59), indicating that the odds of crash involvement associated with cannabis intoxication is estimated to be 32% higher than no cannabis being present; this increased risk could be as low at 9% higher to 59% higher (Table 4.4). Notably, the crash risk estimate associated with cannabis use was higher when the included studies were assessed to be of 'high quality' (OR: 1.53, 95% CI: 1.11-2.09), whilst those studies assessed to be of medium or low quality were associated with a lower – albeit non-statistically significant — increase in crash risk. It is also notable that the case-control point estimate is 1.82 (95% CI: 1.19 – 2.79), which is comparable to the point estimate reported by Asbridge et al. (2012) of 1.92 (95% CI: 1.35-2.73).

In closing, Rogeberg et al (2018) described the results as being '…consistent with low-to-moderate risk increases across all subgroups of studies' (p.968).

TABLE 4.4 ESTIMATES OF ODDS RATIOS OF CRASH RISK AND CANNABIS (MIXED EFFECTS MODEL)

Drug	Number of Studies	OR	95% Confidence Intervals
All	**26**	**1.32†**	**(1.09, 1.59)**
Study design			
Case–control	15	1.82†	(1.19, 2.79)
Culpability	11	1.12†	(1.05, 1.2)
Quality assessment of study			
High quality	8	1.53†	(1.11, 2.09)
Medium quality	14	1.26	(0.88, 1.81)
Low quality	4	1.20	(0.7, 2.06)
Adjustment for confounding			
Limited or no confounder adjustment	16	1.62	(0.98, 2.67)
High confounder adjustment	10	1.20†	(1.05, 1.37)
Use data (drug)			
Low-quality use data	6	1.12	(0.93, 1.35)
Medium-quality use data	9	2.35†	(1.1, 5)
High-quality use data	11	1.26†	(0.97, 1.64)
Controlled for alcohol presence			
Alcohol controlled	24	1.31†	(1.07, 1.6)
Alcohol not controlled	2	1.50†	(1.05, 2.16)
Severity			
Fatalities involved	13	1.30†	(1.04, 1.61)
Fatalities not involved	13	1.52	(0.99, 2.34)

*Source: Rogeberg et al (2018), Table 1.
† $p < 0.05$

4.7.3 Meta-analysis by Rogeberg (2019) on cannabis and crash culpability

In an expansion of previous research, Rogeberg (2019) used Bayesian models to examine the association between cannabis use and culpability status. This relied on 13 published studies that specifically examined culpability, noting these are different data to those included in Rogeberg (2018) which used 26 studies.

In conducting this analysis, Rogeberg (2019) noted the legalisation of recreational cannabis in the US and Canada, and with this, the fact that increased attention is being paid to previously published research on crash risk.

The analysis by Rogeberg includes a new study by Romano et al (2017) that reported an odds ratio of 1.89 for cannabis use (and zero BAC) and being at fault in a fatality crash (compared to zero BAC and no cannabis). This OR increased for drivers positive for alcohol but with a BAC < 0.05 and with cannabis present (OR: 3.42, 1.28-2.46).

Rogeberg (2019) conducted a meta-analysis using data from the studies shown in Table 4.5. Using the data to assess crash risk, the pooled odds ratio was 1.28 (95% CI: 1.16-1.40), while the pooled odds ratio for crash culpability was 1.42 (95% CI: 1.11-1.17).

Interestingly, Rogeberg suggests that the culpability ratios exaggerate risk increases when they are interpreted as total crash odds ratios. This statement warrants further exploration; indeed, such a statement might be considered anomalous as it could be expected that culpability would indeed be higher given the increased crash involvement effect seen with cannabis use with these drivers more likely to be assessed as at fault for a crash. Whether this difference is more likely to highlight the underlying intention of the culpability ratio to isolate fault status compared to the crash risk (involvement) ratio needs to be examined.

TABLE 4.5 BAYESIAN META-ANALYSIS OF CANNABIS-CRASH CULPABILITY STUDIES

Drug	Crash relative risk	Culpability relative risk
Terhune (1982) (N = 259)	1.18 (0.91-1.56)	1.48 (0.78-2.46)
Williams et al. (1985) (N = 97)	1.15 (0.74-1.59)	1.23 (0.61-1.92)
Terhune et al. (1992) (N = 818)	1.13 (0.73-1.58)	1.2 (0.6-1.87)
Longo et al. (2000) (N = 1931)	1.08 (0.82-1.36)	1.15 (0.66-1.69)
Lowenstein Kozial-Mclain (2001) (N = 250)	1.14 (0.83-1.51)	1.3 (0.65-2.06)
Drummer et al. (2004) (N = 1646)	1.62 (1.12-2.56)†	1.82 (1.15-3.04)†
Laumon et al. (2005) (N = 8421)	1.49 (1.3-1.72)†	1.89 (1.54-2.31)†
Soderstrom et al. (2005) (N = 1705)	1.18 (0.96-1.43)	1.28 (0.94-1.67)
Bédard et al. (2007) (N = 32,543)	1.23 (1.15-1.32)†	1.39 (1.25-1.55)†
Poulsen et al. (2014) (N = 623)	1.33 (0.96-1.8)	1.44 (0.94-2.07)
Li et al (2017) (N = 23,884)	1.28 (1.21-1.35)†	1.65 (1.49-1.82)†
Martin et al (2017) (N = 3262)	1.54 (1.25-1.95)†	1.98 (1.46-2.74)†
Romano et al (2017) (N = 2584)	1.22 (0.99-1.5)	1.39 (0.98-1.89)

*Source: Rogeberg (2019), Table 3.
† $p < 0.05$

4.8 CONCLUSION

This chapter set out to document and review the published epidemiological studies that have examined the association between crash risk and driving under the influence of illicit drugs, namely, cannabis, ecstasy, amphetamines, and methamphetamines.

In the ten-year period, 1995 to mid-2015, 40 studies that examined the association between cannabis and crash risk were identified, 10 studies examined amphetamines, and six studies examined 'stimulants' as a generic group. The results from each of these studies was described in detail as were the methods. Studies examining cannabis were a mix of self-report (15) and confirmed use through assessment of biological samples (i.e., blood, urine, saliva), whereas all described studies of amphetamines and stimulants used biological samples for confirmation of use.

4.8.1 Amphetamines (including derivatives) and crash risk

The research evidence points to a large increased crash risk associated with amphetamine use, with odds ratios being larger than five. This increased risk is well accepted. Studies that have examined stimulants as a generic, or combined group, similarly report high odds ratio for use and crash risk, as well as culpability where assessed. While it could be expected to be the case, whether the crash risk associated with 'ice', or methamphetamine, is even higher warrants investigation.

4.8.2 Cannabis and crash risk

The findings in relation to cannabis use and crash risk, as well as culpability, are more inconsistent, despite being heavily studied. Estimates of the association between cannabis and crash risk in the studies reviewed range from 1.0 to approximately 4. In examining this literature, Shinar (2017: 674) recently stated that '…multiple individual studies have converged on an odds ratio of approximately 2.0 or less…to put it in perspective, an odds ratio of 2 is equivalent to a BAC=0.05 ….' (p.674).

Challenges in establishing the association between cannabis and crash risk

However, a significant issue with the drug-driving literature is that there is little uniformity in study design, assessments of study quality differ and are controversial at times, as well as a lack of a standardised, internationally accepted study protocol. This state of affairs has important public policy implications, particularly in light of the legalisation of recreational cannabis in some parts of the United States and Canada, and present debates in Victoria.

Meta-analysis and overcoming the cannabis crash risk debate

To address this, researchers have used meta-analysis methods to arrive at pooled estimates of crash risk. This relies on combining multiple studies, each assessed for quality, and statistically adjusting for confounding variables such as age, sex, and the presence of alcohol and/or other drugs. Given the number of studies included, these studies have the advantage of considerably larger sample sizes, therefore permitting a range of sub-group analysis while making appropriate statistical adjustments for other factors that might influence crash risk.

In this chapter, we highlighted meta-analyses conducted by Elvik (2013), Asbridge et al. (2012), and a very recent series led by Rogeberg (2016a, 2016b, 2018, 2019). The meta-analysis on the association between cannabis use and crash risk, as well as culpability, led by Rogeberg is arguably the best science presently available on this matter, notwithstanding commentary from Gjerde & Mørland (2016) (see below for discussion on THC levels and acute intoxication).

As noted above, Rogeburg, Elvik and White report a combined odds ratio of 1.32 (1.09-1.59) for cannabis crash risk, indicating that the odds of crash involvement associated with cannabis intoxication is estimated to be 32% higher than no cannabis being present; interpreting the 95% confidence intervals shows that this increased risk could be as low at 9% higher but as high as 59%. It can also be seen that the point estimate derived from case-control studies is 1.82 (95% CI: 1.19 – 2.79); importantly, it can also be seen that the OR was 1.53 (95% CI: 1.11-2.09) when limiting the analysis to studies classified as being 'high quality' whilst those studies assessed to be of medium or low quality were associated with a lower – albeit non-statistically significant — increase in crash risk. A more recent examination of 13 culpability studies demonstrated an odds ratio of 1.42 (95% CI: 1.11-1.17), indicating that drivers known to have used cannabis had 42% increased odds of being classed as culpable for the crash. This increase in crash risk and also culpability was described as being 'low-to-moderate' in magnitude by the authors.

A comment on labelling the magnitude of observed crash risk, reference to alcohol-related crash risk, and implications for public policy

Commentary of the magnitude of the association is important, as in the policy context and community discussions statistics are, in the authors of this report view, reduced to 'descriptors' of risk, rather than actual values. Elvik (2013) had previously described the increased risk as being '…in most cases fairly modest; a majority of estimates indicate that the increase in crash risk is less than 100% (i.e., less than doubling)' (p.265). From a public policy perspective, it is worth noting that a doubling of the increase in crash risk due to speed is seen to be of key importance.

A further point of comparison of the magnitude of the odds ratio for cannabis is made with respect to the crash risk associated with alcohol. This is an important point, with Rogeberg (2016a) stating that the '…the average effect of 1.2–1.4 found for cannabis is comparable to the increased risk for any traffic crash found for a blood alcohol content (BAC) of 0.04–0.05' (p.1356). Recent research by Lacey et al. (2016) provides useful updates of the BAC-crash risk relationship, which were originally estimated in the Long Beach / Grand Rapids studies (see Blomberg et al., 2009; Borkenstein et al., 1964, 1974).

There are some key points to be made in this context. Alcohol intoxication is seen to be associated with increases in risk driving behaviour, including speeding. In contrast, and as noted by Shinar (2017) and Rogeberg and Elvik (2016a), cannabis users tend to be aware of their impairment, even if self-perceived to be low, they reportedly compensate for this and drive more cautiously. Shinar (2017) makes an important observation: '…perhaps the most striking effect of marijuana [cannabis]…is that (unlike alcohol), people who have smoked…are much more aware of their potential limitations, consider their performance to be poorer than those impaired by alcohol, and exert much more effort to compensate for it…it is therefore surprising that most regular marijuana users and many occasional user report driving after using…' (p.667).

Rogeberg and Elvik (2016a, 2016b) suggest that given this compensatory strategy and choice to drive, crash risk estimates may be an under-estimate of the risk of 'currently non-driving users'; the implication is: any shift of this non-driving user group who are acutely intoxicated would result in an increased average risk, were they to drive, as this group 'could have a substantially higher risk of causing a crash if they altered their behaviour (2016b, p: 1498). They also suggest that those that choose to drive, even with knowledge of impairment, might be predisposed to more risky driving, hence, have a higher crash risk.

This direct reference and contrast to alcohol is interesting, particularly from a motivational perspective to drive (see Chapter 5). Whether driving after use is related to defiance, or the perception that cannabis does not impair performance (as much as legally available alcohol), or to a belief they are 'safe' as they take steps to compensate, remains to be tested. With many drivers suggesting that cannabis has no negative effects on their driving, there is a clear need from a road safety perspective to address this view.

Finally, on the comparison of crash risk associated with cannabis and alcohol and the equivalence to a BAC of 0.05, in jurisdictions that are actively searching for ways to reach zero road deaths and serious injuries, such a description, whilst arguably correct (and notwithstanding the odds ratio as a 'average risk', see below), is anomalous to the broader road safety goal. Indeed, in jurisdictions such as Victoria, having drivers operating at the limit, or even 'at' or slightly above a BAC of 0.05 is a concern for road safety. It must also be acknowledged that many drivers are subject to 0.00 BAC licence requirements and best practice suggests a shift downwards from 0.05 to 0.02 BAC for fully licenced drivers (WHO, 2013; GRSP 2015).

4.8.3 Odds ratios as 'average risk'

Studies of crash risk and culpability report odds ratios. It is important to note that the point estimates for odds ratios are indicative of average crash risk. Using cannabis as an example, Rogeberg and Elvik (2016a) highlight the range of sub-group estimates, which was updated to be 1.12 to 2.35, depending on the sub-group analysis (see Rogeberg et al., 2018). Further, the point estimate where alcohol is controlled for is 1.32 and 1.50 when not, noting alcohol and cannabis are commonly used together. These estimates can provide a range of crash risk estimates, but they are depending on the characteristics of drivers captured by the individual research studies.

With reference to 'average crash risk', it can be expected then that 'for any single individual, impairment would be expected to rise with higher THC levels' (Rogeberg and Elvik, 2016b: 1499). Issues of THC concentration, frequency of use and perceived impairment would all be factors influencing observed crash risk. Similarly, drivers with co-morbid physical and mental health conditions, as well as illicit drug use, may have an even higher than average crash risk, however this has not been examined in the available literature.

4.8.4 A debate on cannabis blood levels, acute intoxication and odds ratios

Despite its importance, few studies have examined the impact of increasing illicit drug levels on crash risk, otherwise known as the *dose-response effect*. Indeed, only four studies examined the dose-response effect of cannabis on crash risk, with each reporting incrementally higher crash risks with increased cannabis concentration levels in the body.

In their response to the work of Rogeburg, Gjerde and Mørland (2016) highlighted the importance of differentiating concentration levels of drugs in the body, and what can be defined as acute intoxication. While this point was made in the context of cannabis, the principle applies to other drugs and its relationship to the degree of impairment.

For cannabis, Gjerde and Mørland (2016) note that the legal limit for the presence of cannabis while driving is 1.3 ng/mL and in Norway driving with a THC concentration of 3 ng/mL (i.e., acute intoxication seen within the first few hours of smoking 30 mg THC) in a blood sample from a driver will result in the same court sentence as a BAC of 0.5 g/L.

Gjerde and Mørland (2016) note that studies that have assessed the relationship between acute cannabis intoxication and crash risk where THC concentration exceeded 5 ng/mL exceeded an odds ratio of 2.2 (95% CI: 1.32-3.38) (Drummer et al., 2004; Kuypers et al., 2012; Laumon et al., 2005), and that a culpability study of acute cannabis intoxication had an odds ratio of 2, or a doubling of the odds of being deemed culpable (Gadegbeku et al., 2011).

While Gjerde and Mørland (2016) highlight these as they are higher than the odds ratios reported by Rogeberg and colleagues, it is important to note that drug concentration levels have been adopted in Norway for 20 substances, including cannabis, stimulants and a number of prescription medications with respect to driving while impaired. Excluding the amphetamine family, LSD, buprenorphine and methadone where impairment limits apply, graded penalties exist for THC, GHB, morphine and benzodiazepines at concentration levels based on comparable impairment to a BAC of 0.05 and BAC of 0.12 (see Vindenes et al., 2011 for detailed discussion).

4.8.5 Concluding comment: Application to policy

The complexity associated with deriving crash and culpability estimates associated with drug use is clear from this review. Nonetheless, it can be stated that a statistically robust relationship exists between drug use and crash risk.

While the high magnitude of the association for amphetamines and like substances is well accepted, debate has surrounded the size of the association between cannabis and crash risk, which has been described and low-to-medium, and alternatively as 'modest'. There is no debate however that such a relationship between cannabis and crash involvement or being culpable for a crash exists. Based on the evidence presented here, the best estimate given the presence of cannabis in the body is a minimum 32% increased crash risk (and +53%, 95% CI: +11% to +109% if considering only high-quality studies) and 42% increased odds of being deemed culpable. Sub-group analysis suggests this risk can be close to doubling, while studies of acute cannabis intoxication based on blood concentration levels exceed an odds ratio of 2.0.

Comparisons of the observed crash risk from meta-analysis and other studies examining cannabis have been made with alcohol. On this Rogeberg (2019) specifically states,

> *'Combining the prevalence estimates of cannabis-positive driving and the low (but likely positive) risks, cannabis impaired driving as a whole is estimated to have a minor impact on the* ***total number of crashes*** *[MUARC author emphasis]– with the mean attributable risk fraction in the majority of study samples well below 1% and most likely below 2.5%. While this indicates that the overall public health impact of cannabis impaired driving is minor relative to that of alcohol-impaired driving, it does not imply that cannabis impaired driving is safe, and the low average is consistent with the presence of a smaller group of high-dose drivers with more substantially raised risks' (p.78).*

On this statement we note the importance of use rates of cannabis in the community and how this can influence the total number of crashes – including fatality, hospitalisation, and property-damage – that can be attributed to cannabis use. Noting that such a statement does not consider dose-response effects of cannabis use on crash risk, whether the impact remains *minor relative to alcohol* depends on use rates of both substances in the community and pattern of use.

The point of comparison between BAC and cannabis use and crash risk is useful, particularly in the context of public communication of risk. Indeed, there value in making such a contextual reference given the long history and highly negative impacts of drug-driving. Accepting the reference to alcohol, and the similar *average* crash risk of cannabis use and having a BAC of 0.05, further weight of this elevated risk when one considered 0.00 BAC requirements for some driver / rider groups and a view that the legal BAC ought to be reduced to 0.02, such as the case in Sweden.

From a road safety policy perspective, it can be suggested that any factor associated with an increase in crash risk is cause for concern. This is particularly pertinent in the context of road safety strategies action plans, such as Victoria's Towards Zero, that have at their core the stated goal of eliminating fatality and serious injury crashes.

On the impact of illicit drug use on the broader road trauma problem, it can be stated that a key factor in the impact of drug-use on road crashes at a population level is a product of the observed crash risk relationship and the prevalence of drug use in the community. Hence, any change in the policy settings that could see an increase in use would likely result in an increase in drug-related crashes.

This has particular relevance in Victoria where amphetamine use has increased – but is a fraction of the number of cannabis users; however, combined with the much higher crash risk (as well as increased in purity), there has been a large increase in amphetamine-related crashes (see Baseline Report 2).

It is pertinent here then to note observed increases in crashes associated with the legalisation of recreational cannabis in the United States (see for instance: HLDI, 2018; IIHS, 2018; Rocky Mountain High Drug Trafficking Area (HIDTA) Strategic Intelligence Unit, 2017). These findings run counter to a) the notion drivers would switch from alcohol consumption that has a high crash risk to cannabis consumption which has a lower crash risk and purportedly used more at home than not, and hence, less driving exposure (Rogeberg & Elvik, 2016a), and b) that observation that given the crash risk associated with cannabis (and prevalence estimates), cannabis impaired driving would have a minor impact on the total number of traffic crashes (Rogeburg, 2019). That the contrary has occurred could be a consequence of an increase in the number of cannabis users and with this an increase in the number of new users who elect to drive, an increase in the frequency of use, an increase in the available concentration level and/or the propensity of existing users to drive after use. With these US jurisdictions not having implemented a random roadside oral fluid test to detect drug-driving, the lessons for other jurisdictions are clear.

It is also relevant to note here the legalisation medicinal cannabis in some jurisdictions, including Victoria. With the area of medicinal cannabis and driving being very new, research in managing this potential risk is urgently required. It is imperative that these research findings inform guidelines on medical fitness to drive. Whilst it could be expected that the condition(s) for which medicinal cannabis is being used to treat is (are) already covered by fitness-to-drive guidelines, the use of prescribed medicinal cannabis for such conditions ought to be considered.

Finally, it is the case for all drugs, including illicit substances and prescription medications, that there is a need for an improved understanding of the dose-response relationship between blood concentration and crash risk. This has implications for roadside tests, the identification of drivers at particularly high risk, and the setting of threshold levels as is done in Norway were such a policy to be pursued. Irrespective of this, the current body of drug-driving research clearly points to an increased crash and crash culpability associated with the use of both amphetamine-class drugs and cannabis.

5 ATTITUDES, MOTIVATIONS AND PERCEPTIONS ASSOCIATED WITH DRIVING UNDER THE INFLUENCE OF DRUGS

5.1 BACKGROUND AND SCOPE

Drug-driving is complex as it sits within the broader context of illicit drug-use. This is important to understand, particularly as it relates to binge-use and dependency. This has considerable implications for drug-driving, and following Chapter 4, the road safety risk is clear.

Research across many areas of risky behaviours has consistently shown that attitudes and perceptions of risk are strong predictors of behaviour. Consequently, these factors can play a role in motivating behaviour change, and ought to play a central role in developing drug-driving countermeasures (Davey et al., 2007; Mallick et al, 2004).

This chapter seeks to addresses the question 'What are the attitudes, motivations and perceptions associated with drug-driving among those who take drugs and drive?' This can be divided into four key questions:

1. Why do people drug-drive? (motivations for drug-driving)
2. What are the attitudes and perceptions associated with drug-driving?
3. What factors are predictive of drug-driving?
4. What are the most important predictors of drug-driving?

To address these questions, a review of the research literature published since 1995 was conducted (see Appendix B and C for detail of each study). The focus of the review was driving under the influence of cannabis and amphetamine-substances, including ecstasy (MDMA) and methamphetamines. The findings of this review will then form the basis for understanding which countermeasures could be effective in reducing drug-driving behaviour.

5.2 MOTIVATIONS AND REASONS FOR DRUG-DRIVING

Self-reported reasons for drug-driving were examined in 13 studies (see Appendix D, Table D.1). Most studies (n=10) were conducted in Australia (Melbourne, Sydney or Brisbane), with two in Scotland and one in Pakistan.

In the majority of studies, participants were mostly young (aged 18-30) recreational drug users who drug drove occasionally and mostly under the influence of cannabis (Barrie et al., 2011; Donald et al., 2006; Duff & Rowland, 2006; Gavin et al., 2008; Hawkins et al., 2004; Neale, 2001; Townsend et al., 1998).

In three studies the focus was on commercial drivers with an average age of 40; these participants reported frequently drug-driving under the influence of stimulants (Davey et al., 2007; Kayani et al., 2013; Mabbott & Hartley, 1999). Two studies addressed regular injecting or dependent drug users, with these having infrequent and irregular drug-driving patterns (mean age: approximately 30 years; Darke et al., 2004; McIntosh et al., 2008).

In most studies drug-driving was primarily undertaken for functional reasons, meaning that driving was seen as part of the everyday or normal activity. It was rare that drug-driving occurred for the sole purpose of enjoyment and/or thrill seeking. In studies of dependent drug users, drug-driving was most commonly undertaken for the purposes of obtaining or dealing drugs, and in this context the car was typically perceived to be a safe and comfortable place for to do so.

Convenience and a lack of reliable or alternative transport options were the main reasons cited in studies of recreational drug-driving. This was particularly common among night club or rave party attendees at night and on weekends (Barrie et al., 2011; Donald et al., 2006; Duff & Rowland, 2006). For this group, drug-driving was seen as a relatively normal activity, with some respondents reporting the overall reduced costs of drug-driving compared to drink-driving. Associated with this thinking was the relatively lower perceived likelihood of getting caught by police and the relatively lower perceived impact of drugs on driving performance). Other reasons for nightclub or rave party attendees to decide to drug-drive was not wanting to leave the car to collect at another time or having been assigned to be the designed driver among a group of friends.

In four studies of recreational drug users, one of main reasons for drug-driving was a perception that there is nothing wrong with drug-driving and/or that drugs do not negatively impact driving ability.

In the studies of drug use in commercial truck, bus and taxi drivers, combatting fatigue was a key reason to use drugs and then drive. Drug-driving was also stated to be a natural consequence of addiction problems, for socialisation, and to fit into the trucking stereotype (Davey et al., 2007; Kayani et al., 2013; Mabbott & Hartley, 1999). Relaxation and to 'feel good' were also noted to be reasons for using drugs.

In short, drug-driving most commonly occurred as part of everyday activity, including for work, general transport and for social purposes. This pattern was evident across both recreational and dependent drug users. Among dependent drug users, however, one of the primary reasons for drug-driving within the context of everyday activity was to 'score' (purchase) or deal drugs.

5.3 ATTITUDES AND PERCEPTIONS ASSOCIATED WITH DRUG-DRIVING

This section summarises the literature on the attitudes and perceptions associated with drug-driving among those who had driven under the influence of cannabis or amphetamines, including related drugs ecstasy and methamphetamine. The literature was divided into the following key areas:

1. Perceptions of drug use on driving skills/abilities.
2. Perceptions of drug use on driving impairment.
3. Perceptions of danger associated with drug-driving.
4. Perceptions of crash involvement and drug-driving.
5. Perceptions of the risk of being detected by police for drug-driving.
6. Self-reported strategies to reduce risk associated with drug-driving.
7. Perceptions of deterrents to drug-driving.

A critical review of the literature identified that a small proportion of studies did not measure the perceptions of drug users, while others combined the perceptions of drug users who had and had not driven under the influence of drugs. Whilst all of these studies have been included in Table format (see Appendix D), this section summarises only those studies in which separate measures of the attitudes and perceptions of drug-drivers were provided.

Studies that examined cannabis, or ecstasy or meth/amphetamine were the focus of this review, although in a number of studies attitudes and perceptions were not reported separately for the different drug types. Unless otherwise specified it should be assumed that the study has combined results for a number of different drug types if a specific drug type is not stated.

5.3.1 Perceptions of drug use on driving skills / abilities

The perceived impact of drug use on driving ability or skill was examined in 20 studies (refer Appendix D, Table D.2).

Most (n = 11, 55%) studies were conducted within Australia, four (20%) were conducted in Canada, two (10%) were conducted in each of Europe and the UK, and one (5%) was conducted in New Zealand. The perceived impact of drugs on driving ability among those who had taken drugs and driven was examined in 12 studies (60%) (Adams et al., 2015; Bergeron et al., 2014; Donald et al., 2006; Gavin et al., 2008; Hammond et al; 2009; Hawkins et al., 2004; Lenné et al., 2001; Mallick et al., 2007; MacDonald et al., 2008; Forward et al., 2010; Neale et al., 2001; Payne et al., 2013).

Cannabis

The perceived impact of cannabis on driving ability was examined in ten studies. In six studies, respondents indicating that cannabis had no impact or made no difference to their driving ability formed a large proportion of respondents (Adams et al., 2008; Donald et al., 2006; Hammond et al., 2009; Mallick et al., 2007; Neale et al., 2001; Payne et al., 2013; Townsend, 1998).

In two studies, respondents were more likely to indicate that the drug had a negative effect on their driving ability (Adams et al., 2008; Lenné et al., 2001), whilst in one study the majority of participants reported that cannabis had a positive effect of cannabis on driving ability (MacDonald et al., 2008). The view that cannabis improved driving ability is pervasive, even if it was not a majority-held view, with 7.5% to 43% of participants in seven studies stating that their driving ability was improved.

With many drivers suggesting that cannabis has no negative effects on their driving, or indeed improves their driving ability, there is a clear need from a road safety perspective to address this view.

Meth/amphetamine

The perceived impact of drugs on driving ability was examined in five studies for meth/amphetamine (Adams et al., 2008; Donald et al., 2006; Hammond et al., 2009; Mallick et al., 2007; Neale et al., 2001) and in three studies for ecstasy (Donald et al., 2006; Hammond et al., 2009; Mallick et al., 2007).

Across all meth/amphetamine studies, participants were generally more likely to indicate that the drug had no effect on their driving ability compared to an improved or an adverse effect. Participants were more likely to indicate that ecstasy had no improvement or a slightly worse impact on driving ability (in about similar proportions) than either an improved or an adverse effect. Like cannabis, a substantial proportion of drug-drivers perceived that each of these drugs had a positive effect on their driving ability (ranging between 22%-41% for meth/amphetamine and between 10%-14% for ecstasy).

What do drivers state about how drugs improve their driving ability?

In three studies, respondents described the perceived positive effects of cannabis on their driving ability. Cannabis was thought to encourage slower and more cautious driving and improve concentration and alertness (Donald et al., 2006; Lenné et al., 2001; MacDonald et al (2008).

Donald et al. (2006) also examined the perceived positive effects of methamphetamine and ecstasy. Drivers under the influence of ecstasy argued that the drug made them feel more alert and aware of their surroundings and improved their reflexes and concentration.

Fewer reported on how methamphetamine could improve their driving, with those doing so stating that the drug increased alertness and awareness and made them more considerate of others. Many reported caveats to these perceptions of improvement when coming down and feeling tired or if they had consumed large amounts of the drug in question.

Comparisons between different drugs

Four studies compared perceptions of drug use on driving ability for different drug types (Adams et al., 2008; Donald et al., 2006; Hammond et al., 2009; Mallick et al., 2007). Across all studies, drivers were more likely to perceive that amphetamine/methamphetamine improved their driving ability compared to cannabis and ecstasy, and in three studies (Adams et al., 2008; Hammond et al., 2009; Mallick et al., 2007) cannabis was more likely than other drugs to be perceived as having no impact on driving ability, followed by meth/amphetamine and then ecstasy.

Comparisons between drug users who had and had not driven under the influence

The perceived impact of drugs on driving ability was compared in three studies between drug users who had and had not driven under the influence of drugs (Gavin et al., 2008; Hawkins et al., 2004; Neale et al., 2001).

In all studies, drug-drivers were more likely to believe that the drugs they took did not diminish their driving ability, although separate estimates were not given for each of the drug types examined (namely, cannabis, ecstasy, cocaine, speed, LSD and heroin).

Frequency of drug use

The impact of frequency of cannabis use on drug-driving perceptions was examined in the studies by Bergeron et al (2014) and Plancherel et al (2005). Both studies found that the more frequently participants consumed cannabis, the lower was their perceived risk when driving under the influence of cannabis.

Gender

Three studies examined gender differences in drug-driving perceptions. Donald et al. (2006) and Lenné et al found that males were more likely than females to believe that cannabis could improve their driving ability. Similarly, Donald et al (2006) found that males were more likely to believe that methamphetamine could improve their driving than females. Among dance club samples (Neale et al (2001), male clubbers were more likely than female clubbers to believe drug-driving did not improve their driving skills.

Key findings on perceptions of the impact of drug use on driving skills / abilities

- The perceived impact of drug use on driving ability was most commonly studied for cannabis.
- Most respondents perceived that cannabis had no impact or made no difference to their driving ability.
- The majority of respondents stated that they perceived cannabis as having a negative effect on driving skill as opposed to having a positive impact. Nonetheless, across the various studies a proportion (7% to 43%) of drug-drivers perceived that cannabis had a positive effect on driving skill.
- Respondents were generally more likely to indicate that meth/amphetamine and ecstasy had no effect on their driving ability than having a negative effect.
- Respondents were more likely to perceive that amphetamine/methamphetamine improved their driving ability than cannabis and ecstasy.
- Cannabis was more likely than other drugs to be perceived as having no impact on driving ability
- Drug users who drove under the influence of drugs were more likely to believe that the drugs they took did not diminish their driving ability compared to drug users who did not drive under the influence of drugs.
- The more frequently participants consumed cannabis, the lower was their perceived risk when driving under the influence of cannabis.
- Males were generally more likely than females to believe that drug use improved their driving ability.

5.3.2 Perceptions of drug use on driving impairment

The perceived impact of drug use on driving impairment was examined in 11 studies (see Appendix D, Table D.3). Five of these studies were conducted in Australia, three in Canada, two in the UK and one in the US.

In eight studies drivers were asked to rate their perceived level of impairment when driving under the influence of drugs. In four studies respondents were more likely to perceive that use of drugs impaired their driving to some extent (Fischer et al., 2006; Matthews et al., 2009; Nguyen et al., 2012; Terry & Wright, 2005). In the remaining four studies (Arora & Burns, 2011; Davey et al., 2005; Fischer et al 2014; Sutherland & Burns, 2011) respondents were more likely to perceive that use of drugs had no impairing effect on their driving ability. It is notable that in all studies, a small proportion of respondents perceived that use of drugs improved their driving performance, ranging between 6% and 24%.

Comparisons between different drugs

Two studies compared perceptions of driving impairment across different drug types. Matthews et al (2009) found no difference in perceptions of driving impairment due to ecstasy, cannabis, or methamphetamine. Sutherland and Burns (2011) found that those who used methamphetamine prior to their most recent drug-driving episode were more likely to think the drug had improved their driving ability. In contrast, those who used cannabis were less likely to think that it had no impact upon their ability to drive.

In the three studies in which drug-driving was compared to drink-driving, the impairing effects of alcohol were consistently deemed to be much higher than those of other drug types, and even higher when used in combination with other drugs (Albery et al., 2000; Fischer et al., 2006; Matthews et al., 2009).

Self vs. other perceptions

The Fischer et al (2006; 2014) studies also found that drivers under the influence of cannabis were more likely to ascribe higher levels of impairment to others than to themselves. Most of these respondents believed they had ways to compensate for at least some of the potentially impairing effects of the drug.

Frequency of drug use

Frequency of drug use and perceptions of driving impairment were examined in three studies (Albery et al., 2000; Davey et al., 2005; Fischer et al., 2014). All studies found that high frequency cannabis users were more likely than low frequency cannabis users to perceive their own driving ability as not being impaired by cannabis use. This was especially the case for dependent drug users. Moreover, Davey et al (2005) found that dependent drug users never considered implementing any of the types of 'compensatory' behaviours implemented by recreational drug users, including waiting for the effects of the drugs to wear off and driving more slowly and/or carefully.

Key findings on perceptions of drug use and driving impairment

- Findings were mixed on whether drugs impaired driving performance, with half of the studies reporting that the majority believed drugs impaired their driving *at least* to some extent, while others reported no effects on driving.
- In all studies, a small proportion of respondents perceived that use of drugs improved their driving performance (between 6% and 24%).
- The impairing effects of alcohol were consistently deemed to be much higher than those of other drug types and even higher when used in combination with other drugs.
- High frequency cannabis users were more likely than low frequency cannabis users to perceive their own driving ability not to be impaired by cannabis use.

5.3.3 Perceptions of danger associated with drug-driving

The perceived level of danger associated with drug use and driving was examined in 10 studies (see Appendix D, Table D.4). Seventy percent of these studies were conducted within Australia and one (10%) was conducted in each of New Zealand, Canada and Germany.

Comparisons between different drugs

Three studies compared mean ratings of the perceived level of danger associated with driving under the influence across different drug types (Darke et al., 2004; Hammond et al., 2009; Lobmann & Krueger, 2000). Ratings were generally made on Likert scales between 1 to 5, with scores of 1 being safe or not very dangerous and scores of 5 being very dangerous. Alcohol was generally rated as the most dangerous drug, ranging between 3.83 and 4.5, while cannabis was generally rated as the least dangerous drug, ranging between 2.3 and 3.5.

The ratings of perceived danger associated with ecstasy were mixed in the two studies in which this drug was examined. Methamphetamine was rated in three studies and was generally perceived to be neither safe nor dangerous, but typically safer than ecstasy.

Three studies compared the proportions of respondents who rated different drugs at various levels of perceived danger (Darke et al., 2004; Donald et al., 2006; Mallick et al., 2007). Across all studies, the proportion of respondents rating substances in the very dangerous category was highest for alcohol and lowest for cannabis. Compared to methamphetamine, a larger proportion of respondents rated ecstasy as very dangerous, but both of these substances fell in between the ratings given for alcohol and cannabis. The proportion of respondents rating substances in the 'not at all dangerous' category was highest for cannabis (ranging between 14% and 58%) and methamphetamine (ranging between 18% and 40%) and lowest for ecstasy (ranging between 5% and 8%).

Comparisons between drug users who had and had not driven under the influence

Five studies compared the perception of danger associated with drug-driving among drug users who had and had not driven under the influence of drugs.

In all studies in which cannabis (Darke et al., 2004; Hammond et al., 2009; Mallick et al., 2007), ecstasy (Hammond et al., 2009; Mallick et al., 2007) and methamphetamine (Hammond et al., 2009; Mallick et al., 2007) were examined, respondents who *had not* driven under the influence of drugs (or had not driven under the influence of drugs recently) perceived driving under the influence of these substances as more dangerous than drivers *who had* driven under the influence of these substances.

The studies by Lobmann & Kreuger (2000) and McIntyre et al (2011) did not examine perceptions for specific drug types but found the same pattern of results; that is, non-users were perceived drug-driving as more dangerous than those that had previously used drugs and driven.

Gender

Donald et al (2006) examined gender differences in perceptions of danger associated with drug-driving. Males were more likely to believe it was *not at all* dangerous to drive following cannabis use compared to females. In relation to ecstasy, females were more likely to believe it was *not at all* dangerous to drive after ecstasy use. More females than males considered it would be very dangerous to drive following use of methamphetamine.

Key findings on perceptions of danger associated with drug-driving

- Alcohol was consistently rated as being 'very dangerous' by the majority of respondents across most studies.
- Cannabis was rated as the least dangerous drug in most studies, with the majority of respondents perceiving it to be 'not very dangerous'.
- Respondents who had not driven under the influence of drugs (or had not driven under the influence of drugs recently) perceived drug-driving as more dangerous than respondents who had driven under the influence of drugs.
- Differences between males and females on which drugs would be considered dangerous to drive after use.

5.3.4 Perceptions of crash involvement and drug-driving

The perceived risks of being involved in a crash when driving under the influence of drugs were examined in eight studies (see Appendix D, Table D.5). Most (n=6) studies were conducted within Australia; one was conducted in the UK and the other in Canada.

Comparisons between different drugs

Matthews et al (2009) found that a substantial proportion of respondents who had recently driven under the influence of drugs perceived the risk of crash involvement to be 'very unlikely' or 'unlikely' for alcohol (just under one quarter of respondents), cannabis, ecstasy, and methamphetamine (between 51-56% of respondents).

Albery et al (2000) found that alcohol was perceived as being more likely to cause a crash than cannabis, stimulants or heroin, and Porath-Waller (2008) found that perceptions of crash risk were higher for driving under the influence of cannabis in combination with alcohol than for driving under the influence of cannabis alone.

Jones et al (2006) examined the impact of providing factual information about drug use and crash risk on willingness to drug-drive among participants who had driven within one hour of cannabis use and who believed that driving under the influence of cannabis on its own either reduced or did not affect their risk of being involved in a crash. They reported that very few participants (less than ten percent) would be unlikely to drive following the intervention.

Comparisons between drug users who had and had not driven under the influence

The perceived risk of having a crash while drug-driving was compared in two studies between drug users who drove under the influence of drugs and those who did not.

Matthews et al (2009) found that a significantly greater proportion of those who had not driven under the influence of either cannabis, ecstasy or methamphetamine perceived that having a crash was 'likely' or 'very likely' compared to those who had recently driven under the influence of these substances.

Similarly, cannabis dependent participants in the study by Swift et al (2010) were half as likely as their non-dependent peers to believe their personal risk of having a crash while driving under the influence of cannabis was increased.

Comparisons of perceived crash risk over time

The perceived risk of having a crash when drug-driving was compared at different time points in the study by Matthews et al (2014). Matthews et al (2014) reported a significant increase between 2007 and 2011 in the proportion of regular ecstasy users who believed it was 'likely' or 'very likely' that they would have a crash if driving under the influence of ecstasy and methamphetamine, however no change in such perceptions were evident over this period for cannabis or alcohol.

Key findings on perceptions of crash-involvement and drug-driving

- Over half of respondents perceived the risk of crash involvement to be 'very unlikely' or 'unlikely' for cannabis, ecstasy, and methamphetamine.
- A quarter of respondents perceived the risk of crash involvement to be 'very unlikely' or 'unlikely' for alcohol.
- Respondents who had not driven under the influence of drugs were more likely to perceive that having an accident was 'likely' or 'very likely' compared to those who had (or had recently) driven under the influence of drugs.
- Perceptions of the risk of crash involvement increased among regular ecstasy users between 2007 and 2011 for driving under the influence of ecstasy and methamphetamine but no change in perceptions were evident over this period for cannabis or alcohol.

5.3.5 Perceptions of the risk of being detected by police for drug-driving

Sixteen studies examined perceptions of the risk of being caught by police for drug-driving (See Appendix D, Table D.6). Only Australian studies published since the introduction of random roadside drug testing were included in the review. This included three studies from all (or most) Australian capital cities combined, five from New South Wales, three from Queensland, two from the ACT and one each from Victoria and South Australia.

Comparisons between different drugs

Perceptions of the likelihood of being apprehended by police for drug-driving were examined in four studies. Across all studies, only a small proportion of respondents perceived that being caught was 'likely', with estimates ranging between 19% in Hawkins et al., (2004) and 35% in Darke et al. (2004). Donald et al (2006) found that most participants were not particularly concerned about the possibility of being caught by police the last time they drove within an hour or two of using an illicit substance, with 46% reporting being 'not at all concerned'. In regular ecstasy users who had driven in the last six months Dietze et al (2015) found that the median number of people out of 100 who participants believed would be caught while driving after taking drugs was only five.

Three studies compared perceptions of the likelihood of apprehension for different drug types (Matthews et al., 2014; 2009; Ross et al., 2007). In all of these studies, the largest proportion of respondents perceived that the risk of being caught for drink-driving was 'likely' or 'very likely', ranging between 68% and 80%. In contrast, the largest proportion of respondents perceived that the risk of apprehension for drug-driving was 'very unlikely' or 'unlikely'. Ross et al (2006) found that around 50% of participants perceived that it was 'unlikely' or 'very unlikely' that they would be caught for driving under the influence of methamphetamine, ecstasy or cannabis, while Matthews et al (2009) found that higher proportions of respondents perceived it 'very unlikely' or 'unlikely' that they would be apprehended while driving under the influence of ecstasy (67%) and methamphetamine (69%) than cannabis (60%). Matthews et al (2014) found little difference in the proportion of respondents who perceived it 'very unlikely' or 'unlikely' that they would be caught under the influence of ecstasy, methamphetamine and cannabis (around 40% for each drug).

Comparisons between drug users who had and had not driven under the influence

The perceived risk of being caught for drug-driving was compared in three studies between drug users who drove under the influence of drugs and those who did not (Darke et al., 2004; Hawkins et al., 2004; Matthews et al., 2009). All studies found that a higher proportion of those who had not driven under the influence of drugs perceived that being caught by police was 'likely' or 'very likely' compared to those who had driven under the influence of drugs.

Comparisons of perceived risk of apprehension over time

The perceived risk of apprehension by police for drug-driving across different time points was examined in three studies (Gavin et al. 2008; Matthews et al., 2014; Wilson et al 2010). In all studies perceptions of the likelihood of being apprehended for drug-driving had increased in recent years for some drug types. Matthews et al (2014) found that the perceived risk of apprehension increased for ecstasy and methamphetamine, but not for cannabis or alcohol.

Dietze et al (2015) asked participants whether they had changed their behaviour since the introduction of roadside drug testing and found that 43% of Victorians had done so compared to 52% of drivers in all other Australian jurisdictions. The most commonly reported changes in behaviour among those who reported that roadside testing had changed their behaviour were not driving after using drugs, waiting longer before driving, taking a taxi, and arranging an alternative driver.

Key findings on perceptions of being detected by police drug-driving

- Most respondents perceived that the risk of being caught for drink-driving was 'likely' or 'very likely', ranging between 68% and 80%.
- Most respondents perceived that the risk of being caught for drug-driving was 'very unlikely' or 'unlikely'.
- There was little difference in the proportion of respondents who perceived the risk of being apprehended by police for driving under the influence of cannabis, ecstasy and methamphetamine was 'very unlikely' or 'unlikely'.
- Those who had not driven under the influence of drugs were much more likely to believe that the risk of being apprehended by police for drug-driving was 'likely' or 'very likely' compared to those who had driven under the influence of drugs.
- Perceptions of the likelihood of being apprehended for drug-driving increased between 2007 and 2011 for ecstasy and methamphetamine, but not for cannabis or alcohol.

5.3.6 Self-reported strategies to reduce risk associated with drug-driving

Self-reported strategies to reduce risk associated with drug-driving were examined in three studies (Duff & Rowland, 2006; Swift et al., 2010; Wilson et al., 2010).

Across all studies, implementing strategies to reduce drug-driving were generally not common (cited by less 50% of drivers). Strategies comprised the following:

- Those that involved avoiding drug-driving altogether (including using alternative transport; asking a non-intoxicated friend to drive; leaving the car at home/work).
- The use of potentially unreliable and likely unsafe strategies (including eating or drinking; driving more slowly; concentrating more; taking the back streets; limiting the amount / quantity of drug(s) taken or waiting for effects to disappear/decrease before driving).

Of concern was that overall drivers were less likely to report using strategies that involved avoiding drug-driving altogether.

The association between use of strategies and other factors was examined in the study by Swift et al (2010). Cannabis dependent participants were less likely than their non-dependent peers to limit the amount of cannabis smoked; ask a non-intoxicated friend to drive; leave the car at home, or to wait before driving. Males were less likely to wait before driving compared to females who drove under the influence of cannabis, and those who drove greater distances were more likely to limit consumption and to get alternative transport.

Key findings on strategies to reduce risk whilst drug-driving

- Strategies to reduce drug-driving were cited as being used by less 50% of drivers.
- Drivers were less likely to report using strategies that involved avoiding drug-driving altogether.
- Drivers were more likely to implement a range of potentially unreliable/unproven and unsafe methods including eating or drinking; driving more slowly; concentrating more; taking the back streets; limiting the amount / quantity of drug(s) taken or waiting for effects to disappear/decrease before driving.
- Males, dependent drug users and those who drove shorter distances were less likely to implement strategies that they believed reduced the risks associated with drug-driving.

5.3.7 Perceptions of deterrents to drug-driving

Four studies examined what factors, if any, would deter drug users from driving under the influence of illegal drugs (Hawkins et al., 2004; McIntosh et al., 2008; Swift et al., 2010; Terry & Wright, 2005).

Overall, most drug-drivers perceived that *nothing* would deter them from drug-driving. However, when asked to indicate the extent to which a number of listed factors would affect their decision, most perceived that the risk of being apprehended by police would be the biggest deterrent.

Hawkins et al (2004) compared deterrents to drug-driving in those who reported drug-driving and those who used drugs but did not drive under the influence. The largest proportion of non-drug-drivers reported that drug-driving was 'simply the wrong thing to do,' and they were much more likely to report a fear of crashing or killing or injuring someone else than a fear of being apprehended by police. Conversely, the largest proportion of drug-drivers reported that nothing would deter them from drug-driving, and they were much more likely to be deterred by legal compared to crash risks.

Key findings on perceptions of deterrents to drug-driving

- Most drug-drivers stated that nothing would deter them from drug-driving.
- When asked to suggest the extent to which a number of factors would affect their decision, most drug-drivers perceived that the risk of being apprehended by police was the largest deterrent.
- For dependent drug users for whom the car was primarily used to obtain and sometimes use drugs, the need for the drug was perceived to take precedence over the risk of being apprehended by police for driving impaired.
- A fear of crashing or injuring someone else was the largest perceived deterrent for drug users who did not drive under the influence of drugs.

5.4 KNOWLEDGE OF DRUG USE AND DRIVING

Self-reported knowledge about driving under the influence of drugs was examined in six studies (see Appendix D, Table D.7).

In the studies by Hammond et al. (2009) and Mallick et al (2007), participants were asked 'How much do you know about the following drugs in relation to their effect on driving ability?' for a number of different substances including alcohol, cannabis, meth-/amphetamine, and ecstasy. With the exception of alcohol, knowledge of drug effects was poor. Alcohol was the only substance for which the majority stated that they knew 'a lot' or 'quite a lot' about its effects on driving ability. Relative to other drugs, somewhat more was known about cannabis. Respondents knew 'some' or 'very little' about amphetamines/methamphetamines, and most knew 'very little' about ecstasy.

In three studies (Hammond et al., 2009; Mallick et al., 2007; Porath-Waller, 2008), respondents were asked to indicate how long after consuming enough to feel under the influence of a number of different drugs it would be safe to drive. Most respondents said they did not know what timeframe is appropriate for most drugs. Alcohol was the only substance for which most reported knowing how long they should wait, with most nominating waiting 10 or more hours. The most common response for cannabis, ecstasy and meth/amphetamine was 'don't know', particularly for the latter two drugs.

Porath-Waller et al (2008) examined knowledge of drug-driving according to patterns of drug use and found that as past-year frequency of using marijuana increased, respondents' perceptions of how long marijuana affects their driving decreased. When differences in the perceived length of time that driving is affected following the use of either marijuana or alcohol were examined according to respondents' past-year frequency of alcohol use, non-drinkers were found to perceive significantly longer periods of time as compared to infrequent and regular drinkers.

Hawkins et al (2004) examined the impact of knowledge about the impairing effects of drugs on drug-driving behaviour in three clusters of drug-drivers (low risk, high risk and low knowledge). They found that 'Low knowledge' drug-drivers were more likely than other group members to either believe that the higher risk drugs (such as speed and ecstasy) were safe for driving or to say that they did not know whether they were safe.

In a sample of long and short haul operations truck drivers, Mabbott & Hartley (1999) examined whether knowledge of stimulants and their side effects differs according to trip length and number of known peers who use stimulants. The found that intrastate drivers were more likely to report that they did not know the side effects of stimulant drugs compared to interstate drivers. Those who knew no drivers using stimulants were less likely to report knowing the side effects of stimulants than those who knew more than 10 drivers who use stimulants.

Key findings on perceptions of knowledge of drug use and effects on driving

- Overall, knowledge of drug use and its effects on driving performance was poor.
- Alcohol was the only substance for which the majority self-reported that they knew 'a lot' or 'quite a lot' about its effects on driving ability.
- Relative to other drugs (excluding alcohol), somewhat more was known about cannabis.
- Respondents knew 'some' or 'very little' about amphetamines/methamphetamines, and most knew 'very little' about ecstasy.
- Perceptions of the length of time cannabis impaired driving performance was shorter as the frequency of cannabis use increased.
- Intrastate truck drivers were more likely to report that they did not know the side effects of stimulant drugs compared to interstate drivers.

5.5 FACTORS PREDICTIVE OF DRUG-DRIVING

Thirty-six studies investigated whether there was a statistical relationship between drug-driving and other factors that could usefully be targeted as part of drug-driving intervention programs. These factors included the following (see Appendix D, Table D.8):

- Attitudinal factors including the perceived impact of legal risk perceptions; crash involvement; danger or impairment, and social sanctions.
- Behavioural factors including drug use frequency; drug use dependency; polydrug use; place of drug use; use of drugs within peer/social networks; sensation-seeking; risk-taking; health and well-being.
- Demographics including age and gender.

5.5.1 Attitudes and perceptions

Perception of detection (legal risk)

Deterrence is the mechanism by which traffic enforcement measures aim to improve compliance with traffic safety laws. It is based on the theory that the perceived consequences of engaging in illegal behaviour will dissuade the illegal behaviour (Homel, 1998; Zimring & Hawkins, 1973). Specifically, it has been proposed that when an individual perceives the certainty of apprehension as high, the punishment as severe, and the administration of punishment as swift then the likelihood of illegal behaviour will be deterred.

Although the cornerstone of deterrence theory is the experiencing of legal punishment, the theory has been critiqued for overlooking the influence of punishment avoidance, and further, that it fails to account for the effect of vicarious experiences on an individual's perceptions. Consequently, Stafford and Warr (1993) proposed a reconceptualization of deterrence theory to account for its purported limitations. This theory includes both the direct and vicarious effects of punishment as well as punishment avoidance. According to Stafford and Warr (1993), specific deterrence needs to be considered as the direct effects of punishment and punishment avoidance on an individual, with general deterrence being the vicarious experiencing of punishment and punishment avoidance.

With this background in mind, we note that a number of studies have examined the perceived deterrence effect associated with random roadside oral fluid testing conducted by police; the outcomes have included actual drug-driving behaviour or intentions to drug-drive in future (Davey et al., 2008; Freeman et al., 2010; Armstrong et al., 2005; Armstrong et al., 2014; Watling et al., 2010; Matthews et al (2009); Matthews et al., (2014); Swift et al., 2010; Watling and Freeman, 2010). These studies have reported mixed results.

Davey et al. (2008) and Freeman et al. (2010) found that perceptions regarding the severity and swiftness of sanctions did not contribute to the prediction of intentions to drug-drive in the future. However, certainty of apprehension was a significant predictor in both studies, with those reporting lower perceptions of apprehension more likely to report their intention to offend in the future. Thus, those who reported a low perceived certainty of apprehension were more likely to drug-drive than those who perceived the probability of being caught for drug-driving to be high. Watling and Freeman (2010) found that neither the certainty, severity, nor swiftness were significantly predictive of intentions to drug-drive.

Armstrong et al (2005; 2014) and Watling et al (2010) applied Stafford and Warr's (1993) reconceptualised deterrence theory to examine its impact on reported intentions to drug-drive in future. All studies found partial support for Stafford and Warr's (1993) theory. Specifically, direct punishment avoidance (i.e., having avoided apprehension) and vicarious punishment avoidance (i.e., knowing of others that have avoided apprehension) were found to be significant predictors of reported intentions of drug-driving in future. Certainty of apprehension, severity and swiftness of sanctions were not predictive of future intentions to drug-drive. Armstrong et al (2005) found that vicarious punishment avoidance and direct punishment avoidance were more strongly associated with drug-driving behaviour than either vicarious exposure to punishment or perceived risk of apprehension. Together these findings suggest that drug-drivers held stronger perceptions about the lack of potential punishments and the ease with which punishments or detection could be avoided than they did about the likelihood of getting punished.

Matthews et al (2014) and Matthews et al (2009) however, examined legal risk perceptions associated with driving under the influence of each of alcohol, cannabis, ecstasy and methamphetamine. Lower legal risk perceptions were associated with increased risk of driving under the influence of methamphetamine in Matthews et al (2009) and with ecstasy in both studies. However, no association was evident for the other drug

types in either study. Swift et al. (2010) found no independent effect of beliefs about the likelihood of being apprehended by police for driving under the influence of cannabis.

Crash risk perceptions

The relationship between perceived risk of crash involvement and driving under the influence of drugs was examined in four studies. Matthews et al (2014) and Matthews et al (2009) found that lower crash risk perceptions were associated with engagement in driving under the influence of cannabis, ecstasy and methamphetamine in the last six months. Matthews et al (2014) also found that driving under the influence of alcohol in the last six months was associated with lower perceptions of the likelihood of having an accident. In both studies a higher perception of risk was associated with a lower likelihood of driving under the influence of each substance. Similarly, in the studies by Jones et al (2007) and Swift et al (2010) driving under the influence of cannabis was predicted by believing that cannabis use does not increase accident risk (versus believing driving under the influence of cannabis had no impact or decreased accident risk). Believing that cannabis increases crash risk was associated with a lower likelihood of driving under the influence of the drug.

Perceptions of danger

Three studies examined the relationship between driving under the influence of drugs and the perceived level of danger associated with drug-driving. Fischer et al (2014) found that high (i.e., > 12 times) (compared to low i.e., < 12 times) frequency cannabis use and driving was associated with perception of own ability to drive not being impaired by cannabis use, while Duff & Rowland (2006) found that permissive attitudes towards driving under the influence of either cannabis, ecstasy, speed, LSD, cocaine or heroin significantly predicted drug-driving.

The less concerned participants were about the effects of drug use on driving, the more likely they were to drive under the influence of an illicit drug. The Thomas Dols et al (2010) study showed that the lower the awareness of the dangers of cannabis, the higher the likelihood of driving after consuming drugs.

Perceptions of social sanctions

Five studies examined the relationship between driving under the influence of illicit substances (including cannabis, ecstasy, amphetamines) and peer group perceptions of drug-driving.

Davey et al., (2005) and Lobmann & Krueger, (2000) found that drug-driving was predicted by a permissive attitude within the social/peer network, with those whose friends perceived drug-driving to be favourable being more likely to drive under the influence of drugs. McCarthy et al (2007) found that greater perceived peer acceptance was associated with both increased likelihood and increased frequency of driving after use of cannabis, while Arteberry et al (2013 found that perceived peer disapproval of driving under the influence of cannabis did not reduce risk for engagement in this behaviour. Armstrong et al., (2005) and Freeman et al., (2010) found that perceived social sanctions arising from a drug-driving apprehension (i.e., concern over losing friends' respect) were associated with a lower likelihood of future drug-driving behaviour.

Key findings on attitudinal and knowledge factors and drug-driving behaviour

- Only a handful of studies examined the extent to which perceptions and attitudes were predictive of self-reported drug-driving behaviour including the perceived impact of apprehension by police; crash involvement; danger or impairment, and social sanctions (such as concern over losing friends' respect).
- Most studies found that neither the perceived certainty, severity or swiftness of sanctions were predictive of self-reported drug-driving behaviour or intentions to drug-drive in future.
- Direct punishment avoidance (i.e., having avoided apprehension) and vicarious punishment avoidance (i.e., knowing of others that have avoided apprehension) were more consistently found to be significant predictors of reported intentions of drug-driving in future.
- A higher perception of crash risk associated with drug use and driving was consistently found to be associated with a lower likelihood of driving under the influence of drugs.
- In general, the less concerned respondents were about the effects of drug use on driving, the more likely they were to drive under the influence of an illicit drug.
- Drug-driving was predicted by a permissive attitude within the social / peer network, with those whose friends perceived drug-driving to be favourable being more likely to drive under the influence of drugs.

5.5.2 Behavioural factors and drug-driving

Drug use frequency, drug use dependency, and polydrug use

Seventeen studies examined the association between frequency of drug use and self-reported drug-driving behaviour.

All studies found that drug use frequency was a significant predictor of drug-driving behaviour with drug-driving occurring more frequently as levels of drug usage increased (Agic et al., 2013; Bergeron & Paquette, 2014; Calaft et al; 2009; Darke et al., 2004; Davey et al., 2008; Davey, Davey & Obst, 2005; Dietze et al., 2015; Duff & Rowland, 2006; Fischer et al., 2006; Fischer et al., 2014; Freeman et al., 2010; Jones et al., 2007; Lobmann & Krueger, 2000; Matthews et al., 2009; Matthews et al., 2014; Sutherland and Burns; 2011; Watling and Freeman, 2010).

Of the 17 studies examining the association between frequency of drug use and self-reported drug-driving behaviour, eight examined the association between frequency of use of a particular drug and driving under the influence of that drug – all of which examined cannabis; three of which examined alcohol; three of which examined ecstasy; and two of which examined methamphetamines. In the nine remaining studies, the relationship between frequency of drug use and drug-driving was not specified for individual drug types but most studies included combinations of drug types that included cannabis, meth/amphetamine and ecstasy.

Six studies examined the association between drug use dependency and drug-driving. In all of these studies, drug-driving was significantly more likely to occur in those who were dependent drug users compared to those who were not dependent drug users (Adams et al., 2008; Begg et al., 2003; Darke et al., 2004; Jones et al., 2007; Lasebikan, 2010; Swift et al., 2010). Four of these studies examined the association between cannabis use dependency and driving under the influence of cannabis (Begg et al., 2003; Jones et al., 2007; Lasebikan, 2010; Swift et al., 2010). In the remaining two studies, cannabis and methamphetamines were included among other drug types, but the relationship between dependency on a particular drug type and driving under the influence of that drug was not examined or reported.

The association between polydrug use and drug-driving was examined by Darke et al. (2004) for cannabis, heroin, amphetamines and cocaine, and Dietze et al. (2015) for ecstasy, alcohol, cannabis, methamphetamine, cocaine and LSD. Both of these studies found that polydrug use predicted driving under the influence of drugs, with drug-drivers being more likely to use multiple drugs than drug users who did not drive under the influence.

Place of drug use

Duff & Rowland (2006) found that the propensity to use cannabis and ecstasy in rave and party settings significantly predicted drug-driving: rave and party goers were more likely to drug-drive than those who took drugs at their own or a friend's house or at club or pubs. Calaft et al (2009) found that driving under the influence of cannabis, ecstasy, or cocaine was predicted by 'usual choice of transport mode' to get to night life settings with those using a private vehicle to travel being over five times at greater risk of drug-driving than those who used public transport.

Peer group drug use

The relationship between drug-driving and drug use in one's peer group was examined in four studies. Duff & Rowland (2006) found that the less common it was for a respondent's friends to drive under the influence of an illicit drug, the less likely it was for the respondent to drive under the influence of an illicit drug (in this case, cannabis, ecstasy, speed, LSD, cocaine or heroin).

Likewise, Kohn et al (2014) found that driving under the influence of cannabis, stimulants, hallucinogens or alcohol was significantly more likely among those reporting that their best friends drove under the influence of drugs. Lobmann & Krueger (2000) found the same relationship among respondents who had driven under the influence of cannabis, ecstasy, amphetamines, cocaine, hallucinogens or opiates. Jones et al (2007) however found no relationship between peer drug-driving and driving under the influence of cannabis.

Sensation-seeking and risk-taking

Four studies examined the association between drug-driving and sensation-seeking (Armstrong et al., 2005; Bergeron & Paquette, 2014; Lobmann & Krueger, 2000; Richer & Bergeron, 2009).

Across all studies, those who scored high on the measure of sensation-seeking were significantly more likely to report driving under the influence of drugs than those who scored low on the measure of sensation-seeking. Two of these studies examined the relationship between cannabis use and sensation-seeking (Bergeron & Paquette, 2014; Richer & Bergeron, 2009) while in the studies by Armstrong et al (2005) and Lobmann & Krueger, (2000), cannabis use was examined in addition to amphetamine and ecstasy use.

Risk-taking and driving under the influence of cannabis was examined in four studies. Among males, Begg et al (2003) found that low constraint at age 18, a non-traffic police conviction before age 18, and a traffic conviction before age 21 predicted persistent driving after using cannabis. Bergeron & Paquette (2014) found that driving under the influence of cannabis was related to maximum speed in a driving simulator and with an increased risk of traffic tickets (e.g., for excessive speed or omitting to stop) and self-reported risky behaviours in the real world. Bergeron et al (2014) found that the more users of cannabis reported or showed risky driving behaviours in the simulator, the greater the likelihood that they were susceptible to driving after smoking cannabis or after drinking alcohol. Richer & Bergeron (2009) found that driving under the influence of cannabis was significantly and positively linked to risky driving, negative emotional driving, and dangerous driving.

Compared to non-drug-drivers, Scott-Parker et al (2014) found that drug-drivers were significantly more likely to speed, commit driving errors, engage in general risky driving behaviours, carry passengers in risky situations, drink-drive, and report stronger risky driving intentions and to report having had an offence detected. The specific drug types used by drivers were not specified in this study.

Employment and related factors

Employment status was not found to be associated with driving under the influence of cannabis (Duff & Rowland, 2006; Dietze et al., 2015; Jones et al., 2007); ecstasy (Dietze et al., 2015; Duff & Rowland, 2006); or methamphetamine (Dietze et al., 2015).

Police contact and employment

However, Adams et al. (2008) found that police detainees who drove under the influence of cannabis or meth/amphetamine were more likely to be unemployed than those who did not drive under the influence of these substances.

Mental health and related factors

Agic et al (2013) found that those reporting alcohol and cannabis use and driving showed more evidence of mental health problems than those who did not report driving after use of these substances. Those who drove under the influence of cannabis plus alcohol demonstrated the highest levels of psychological distress and were more likely to report fair or poor mental health.

The analysis of mental health measures and anti-social behaviour conducted by Begg et al (2003) showed that low constraint at age 18 predicted driving under the influence of cannabis. Sutherland and Burns (2011) found that those who reported suffering from drug induced psychosis within the past 12 months were significantly less likely to have driven after consuming heroin, cannabis or methamphetamine. In contrast, Darke et al (2004) found no difference in psychopathology between drug users who had and had not driven under the influence of cannabis, heroin, amphetamines or cocaine. Thomas Dols et al (2010) found that cannabis use associated with driving during a night out was associated with having a worse family relationship than in those who did not drive under the influence of cannabis.

Key findings on behavioural factors and drug-driving behaviour

- A small number of studies examined the extent to which behavioural factors were predictive of self-reported drug-driving including drug use frequency, drug use dependency, polydrug use; place of drug use; use of drugs within peer/social networks; sensation-seeking; risk-taking; and health and wellbeing.
- Drug use frequency was consistently found to be a significant predictor of drug-driving behaviour, with drug-driving occurring more frequently as levels of drug usage increased.
- Drug use dependency was consistently found to be a significant predictor of drug-driving behaviour, with drug-driving occurring more frequently as the level of drug dependency increased.
- Polydrug use was consistently found to be a significant predictor of drug-driving behaviour, with drug-driving occurring more frequently as the number of drugs used increased.
- Place of use of drugs was found to be predictive of drug-driving, with rave and party goers being more likely to drug-drive than those who took drugs at their own or a friend's house or at club or pubs.
- Drug-driving and drug use in one's peer group were significantly related, with drug-driving being more likely among those reporting that their best friends drove under the influence of drugs.
- Sensation-seeking was consistently shown to be predictive of drug-driving. Those who scored high on the measure of sensation-seeking were significantly more likely to report driving under the influence of drugs than those who scored low on the measure of sensation-seeking.
- Risk-taking was consistently found to predict drug-driving although it was measured differently across the studies. In general, compared to non-drug-drivers, drug-drivers were significantly more likely to speed, commit driving errors, engage in general risky driving behaviours, carry passengers in risky situations, drink-drive, report stronger risky driving intentions, and report having had an offence detected.
- Employment status was generally not found to be associated with driving under the influence of drugs.
- In general, there was a significant relationship between measures of health and wellbeing and drug-driving behaviour, although this was measured in different ways across the studies. Those who drove under the influence of drugs showed more evidence of mental health problems than those who did not report driving after drug use. However, those who reported suffering from drug induced psychosis were significantly less likely to drug-drive.

5.5.3 Demographics

Age

The association between age and driving under the influence of drugs was examined in 16 studies. Age was not a significant predictor of driving under the influence of cannabis in most studies where it was examined (Bergeron & Paquette (2014; Calaft et al., 2009; Darke et al., 2004; Davey et al 2008; Dietze et al., 2015; Fischer et al., 2014; Kohn et al., 2014; Matthews et al., 2009; Matthews et al., 2014; Richer & Bergeron, 2009; Swift et al., 2010). However, younger age predicted driving under the influence of cannabis in the studies by Armstrong et al (2014); Agic et al (2013); Lasebikan, (2010) and Payne et al., (2013).

For meth/amphetamine use, age was not a significant predictor of driving post-use in most studies where this was examined (Darke et al., 2004; Davey et al., 2008; Dietze et al., 2015; Matthews et al., 2009; Matthews et al., 2014) nor was age a significant predictor of driving under the influence of ecstasy (Calaft et al., 2009; 2004; Dietze et al., 2015; Matthews et al., 2009; Matthews et al., 2014).

In contrast, being of younger age predicted driving under the influence of ecstasy and meth/amphetamine (Armstrong et al., 2014) whilst driving under the influence of cannabis, speed, or ecstasy was predicted by older age in Davey et al (2005). Scott-Parker et al., (2014) found no association between age and driving under the influence of any (unspecified) illegal drug.

Gender

The association between gender and driving under the influence of drugs was examined in 11 studies. In most studies there was no independent effect of gender on driving under the influence of cannabis (Calaft et al., 2009; Darke et al., 2004; Davey et al., 2005; Fischer et al., 2014; Matthews et al., 2009; Matthews et al., 2014; Swift et al., 2010) or ecstasy (Matthews et al., 2014; Calaft et al., 2009). Matthews et al (2009; 2014); and Darke et al., (2004) found no association between gender and driving under the influence of meth/amphetamine.

In six studies, being male was associated with more frequent driving under the influence of drugs for cannabis (Agic et al., 2013; Armstrong et al., 2014; Dietze et al., 2015; Thomas Dols et al., 2010; Jones et al., 2007; Kohn et al., 2014); ecstasy (Armstrong et al., 2014; Dietze et al., 2015; Matthews et al., 2009); and meth/amphetamines (Armstrong et al., 2014; Dietze et al., 2015).

Key findings on behavioural factors and drug-driving behaviour

- The association between age and gender and drug-driving was examined in a relatively large number of studies.
- Age was generally not a significant predictor of driving under the influence of drugs.
- The association between gender and driving under the influence of drugs was generally mixed, with about half of all studies showing that being male was associated with a greater likelihood of driving under the influence of drugs.

5.5.4 Comparing the relative importance of drug-driving predictors

The relative importance of potential predictors of drug-driving was compared in a small number of studies. This type of comparison is important for helping to prioritise countermeasures for preventing drug-driving. For example, as research continually suggests that past drug-driving behaviour remains a strong predictor of future drug-driving behaviour (e.g., Agic et al., 2013; Bergeron & Paquette, 2014; Calaft et al; 2009; Darke et al., 2004; Davey et al., 2008; Davey, Davey & Obst, 2005; Dietze et al., 2015; Duff & Rowland, 2006; Fischer et al., 2006; Fischer et al., 2014; Freeman et al., 2010; Jones et al., 2007; Lobmann & Krueger, 2000; Matthews et al., 2009; Matthews et al., 2014; Sutherland and Burns; 2011; Watling and Freeman, 2010), it is important to explore whether other factors, particularly perceived deterrence of drug-driving enforcement (the primary drug-driving countermeasure in Victoria), can counteract the negative effect of drug consumption and past offending behaviour.

Davey et al (2008) compared the relative impact of current or past drug use behaviour and perceptions of both legal and non-legal sanctions on drug-driving behaviour. They found that that low perceptions of apprehension certainty were predictive of greater intentions to drug-drive in future, but that non-legal sanctions (i.e. social stigma as a result of informal sanctions i.e. peer disapproval/ losing their friends' respect, feeling guilty or ashamed about drug-driving from internalisation of norms; risk of physical loss i.e. an accident or damaging

one's vehicle) were not. However, Davey et al. (2005) report that current drug consumption levels were the largest predictor of drug-driving behaviour. Specifically, among those who reported using drugs frequently were over three times as likely to drug-drive in the next 6 months, whilst those who reported drug-driving in the previous 6 months were more than twice as likely to report intentions to offend.

Similarly, Freeman et al (2010) found that those with low apprehension certainty were significantly more likely to report future intentions of drug-driving. This was the same for individuals who were least concerned about the possible social sanctions associated with the behaviour. However, these two factors were less influential predictors than the behavioural variables of having drug-driven in the last six months or overall drug consumption.

Davey et al (2005) found that actual drug use was the strongest predictor of drug-driving behaviour, with those using drugs recently being more likely to drug-drive than others. The greater and the more frequent the drug taking behaviour, the more likely participants were to have drug-driven. The attitudes most strongly linked to drug-driving behaviour were those relating to what the participant's peers thought about drug-driving ('Most of my friends thin its ok to take drugs and drive), and the perceived harms, or risks (it's OK to drive if you're not too high). Perceptions regarding the likelihood of apprehension ('It's OK to drive as long as you don't get caught') did not emerge as strong predictors of drug-driving. However, this study was conducted in Queensland prior to the introduction of random roadside drug testing and, as such, these attitudes may not be reflective of those in relation to current drug-driving enforcement practices; given this is the case though, a replication of this study in Queensland would be quite revealing as to the possible impact of their roadside drug-testing enforcement regime.

Watling and Freeman (2010) compared perceptions of deterrence, deviance and defiance on intentions to drug-drive within the next six months. While the deterrence theory variables of certainty, severity, and swiftness of sanctions were not significantly predictive of intentions to drug-drive, defiance and deviance were. With respect to defiance, decreases in both reported feelings of shame and in the legitimacy of the sanctioning authority resulted in an increased likelihood of drug-driving. In terms of deviance, those showing a lower moral attachment to the norm were significantly more likely to report intending to drug-drive in future. However, overall drug consumption patterns emerged as the strongest predictor – the more drug use the individual reported, the more likely they were to report intending to drug-drive.

Matthews et al (2014) found that a higher perception of crash risk was associated with a lower likelihood of driving under the influence of alcohol, cannabis, ecstasy, and methamphetamine in the last six months. Perceptions of the likelihood of being appended by police for drug-driving were only related to driving under the influence of ecstasy, with those reporting lower risk perceptions being more likely to have driven under the influence. This difference suggests that crash risk perceptions may be more important than legal risk perceptions. The relatively low perception of the risk of police apprehension for methamphetamine and cannabis may account for the lower strength of this relationship. The frequency of drug use was associated with driving under the influence of drugs for all substances examined (alcohol, cannabis, ecstasy, and methamphetamine) and this relationship was stronger than that found for both crash and legal risk perceptions and drug-driving.

Matthews et al (2009) found that frequency of drug use was the most significant predictor of driving under the influence of cannabis, methamphetamine and alcohol compared to crash and legal risk perceptions. However, driving under the influence of ecstasy was most significantly predicted by crash risk perceptions compared to drug use frequency and legal risk perceptions.

In Fischer et al (2014) the variables that showed the strongest differentiation between high versus low frequency of driving under the influence of cannabis were weekly cannabis use and high future expectation of engaging in driving under the influence of cannabis. These variables were more important than other significant predictors of drug-driving including having been checked by police for impaired driving and perception of own driving ability to drive not being impaired by cannabis use.

Kohn et al (2014) compared the importance of a range of potential predictors of drug-driving in young students (demographics, housing arrangements, study habits, beliefs about drug use). These authors reported that use of drugs in high school and regular use of drugs in one's peer group had the strongest associations with drug-driving.

Key findings on the relative importance of drug-driving predictors

- The relative importance of potential predictors of drug-driving was compared in a small number of studies. This type of comparison is important for helping to prioritise countermeasures for preventing drug-driving.
- Frequency of drug use consistently emerged as the strongest predictor of drug-driving in the small number of studies examining perceptions of legal and non-legal sanctions on drug-driving behaviour.
- Comparisons of the relative importance of legal and non-legal sanctions generally showed mixed results. In some studies, perceptions of the likelihood of being apprehended by police for drug-driving were stronger predictors of drug-driving than what one's peers thought about drug-driving. In other studies, the reverse was true.

5.6 DISCUSSION AND IMPLICATIONS FOR COUNTERMEASURES

The purpose of this chapter was to examine the attitudes, motivations and perceptions associated with drug-driving among those who have driven under the influence of drugs.

Understanding the context in which drug-driving occurs is important for two reasons; first, drug-driving behaviour is a subset of drug use behaviour, and second, research in many areas has shown that attitudes and perceptions, in particular perceptions of risk, are strong predictors of behaviour. Accordingly, understanding these factors is central to the development of drug-driving countermeasures to achieve behavioural change. The four key questions addressed in the chapter were:

- Why do people drug-drive? (motivations for drug-driving)
- What are the attitudes and perceptions associated with drug-driving?
- What factors are predictive of drug-driving?
- What are the most important predictors of drug-driving?

5.6.1 Motivations for drug-driving

Drug-driving was primarily undertaken for functional reasons where it was seen as part of the driver's every-day or normal activity, and rarely occurred for the sole purpose of enjoyment or thrill seeking. This finding was evident in both recreational/infrequent drug users as well as dependent drug users.

In studies of dependent drug users, however, drug-driving was most commonly undertaken for the purposes of obtaining or dealing drugs and in many cases the car was also considered to be a safe and comfortable place to use drugs following a deal. Convenience and a lack of reliable or alternative transport options were the main reasons cited in studies of recreational drug-driving, particularly among night club or rave party attendees travelling at night and on weekends (Barrie et al., 2011; Donald et al., 2006; Duff & Rowland, 2006).

Dependent drug users were more likely than others to believe that nothing would deter them from driving under the influence of drugs. Although detection by police was considered to be their biggest deterrent, most were prepared to run the risk of driving under the influence of drugs (McIntosh et al., 2008). The overwhelming view was that getting caught by police would have little behavioural change impact given that they are already performing an illegal behaviour and most had a history of other offences. Moreover, the 'need' for the drug takes precedence over the risk of getting caught (McIntosh et al., 2008). Most dependent users considered educational campaigns to be ineffective in preventing drug-driving, as the demands of their drug addiction negate concerns about the potential legal and crash ramifications of drug-driving.

For a substantial proportion of recreational drug users, however, a lack of convenient and reliable public transport options was perceived to be an important barrier to preventing drug-driving. Unsurprisingly Calaft et al (2009) found that drug-driving was related to 'usual choice of transport mode' to get to nightlife settings; those that normally use a private vehicle to travel to events were over five times more likely to drug-drive than those who used public transport.

Recreational drug users were also motivated by the overall perception of lower financial costs when drug – driving compared to drink-driving, the relatively lower perceived likelihood of getting caught by police, and the low perceived impact of drugs on driving performance than alcohol.

Taken together, these findings point to the requirement for different prevention strategies to address the drug-driving problem. For dependent drug users, it is likely that prevention strategies need to be considered within the context of the overriding drug addiction problem. As such, education and enforcement-based countermeasures are unlikely to be effective in isolation. For recreational drug users for whom drug-driving was not so integral to their lifestyle, enforcement and educational measures are likely to be more effective. Improved transport options, including public transport, for those leaving clubs at night would seem to be a fundamental requirement to reduce the incidence of drug-driving in young recreational drug users.

Relatively few studies examined motivations for driving under the influence of illicit drugs in different road user groups such as young and older drivers, motorcyclists or commercial drivers. Early research examining drug use in commercial truck drivers (Mabbott & Hartley, 1999) found that drug-driving was primarily undertaken as a means for combating fatigue. However, more recent research (Davey et al., 2007; Kayani et al., 2013) with this group identified that factors other than fatigue were important motives for driving whilst impaired, including peer pressure, wanting to fit the trucking 'image', socialisation, relaxation and addiction. The findings suggest that in addition to modifying the workplace culture to reduce fatigue related problems, other strategies are required to address the more entrenched motives associated with addiction and anxiety that precipitate drug-driving.

5.6.2 Perceptions of the impact of drugs on driving skill and impairment

The largest proportion of drug-drivers perceived that cannabis (Adams et al., 2008; Donald et al., 2006; Hammond et al., 2009; Mallick et al., 2007; Neale et al., 2001; Payne et al., 2013; Townsend, 1998) ecstasy (Donald et al., 2006; Hammond et al., 2009; Mallick et al., 2007), and methamphetamine (Adams et al., 2008; Donald et al., 2006; Hammond et al., 2009; Mallick et al., 2007; Neale et al., 2001) had no effect on their driving ability, a finding that was more commonly identified for cannabis compared to other drugs.

Although drug-drivers were generally less likely to perceive a positive impact of drugs on their driving performance, such an effect was consistently reported by a small proportion of drug-drivers in most of the studies in which it was examined (e.g., Adams et al., 2008; Barrie et al., 2011; Davey et al., 2005; Donald et al., 2006; Hammond et al., 2009; Lenné et al., 2001; Mallick et al., 2007; Terry and Wright, 2008). This finding was more commonly reported for meth/amphetamine compared to cannabis and ecstasy.

The perceived positive effects of cannabis on driving ability included slower and more cautious driving and improved concentration and alertness (Donald et al., 2006; Lenné et al., 2001; MacDonald et al (2008). Drivers under the influence of ecstasy or methamphetamine argued that the drug made them feel more alert and aware of their surroundings and improved their reflexes and concentration (Donald et al., 2006). Cannabis was rated as the least dangerous drug, with the majority of respondents perceiving it to be 'not very dangerous'.

The perceptions associated with drug use and driving impairment are at odds with the evidence provided in the literature that drugs negatively impact driving ability (e.g. see Berghaus et al., 2011; Chapter 4, this report). This apparent lack of awareness reflects the need for education on the effects of drugs on driving and the ineffectiveness of compensatory behaviours. Of note was that most respondents perceived that ecstasy and methamphetamine had no effect on their driving ability, and studies examining knowledge of the effects of drugs on driving performance show that most knew only 'some' or 'very little' about the impact of these drugs on driving performance (Hammond et al., 2009; Mallick et al., 2007). Indeed, Barrie et al (2011) found that young recreational drug-drivers felt that there was no information available about how drugs impair driving skills, and thus personal experience played a large role in forming their current beliefs. For example, previous experiences of having avoided detection or knowing of others who had seemed to form the basis of a perception that the risks associated with drug-driving were low. Given this, cannabis should be targeted as a potential priority since it was more likely to be perceived as having no impact on driving ability compared to other drugs. Drug-drivers also reported being knowledgeable about the effect of cannabis on driving ability relative to other drugs (Mallick et al., 2007), highlighting a level of misinformation which should be targeted as a priority in future countermeasures.

A small number of studies examined the extent to which perceptions of driving impairment significantly predicted drug-driving. These studies consistently found that the less concerned respondents were about the impairing effects of drug use on driving, the more likely they were to drive under the influence of an illicit drug (Thomas Dols et al., 2010; Duff & Rowland, 2006; Fischer et al., 2014). This suggests that modifying currently held perceptions about the effects of drugs on driving impairment could be important in reducing drug-driving behaviour. However, while there may be some benefit to increasing awareness of the risks, previous research using hypothetical scenarios has shown that providing factual information about crash risks would be unlikely to impact drug-driving rates among current cannabis users (see Jones et al., 2006). However, this research

was conducted almost ten years ago and so it is possible that attitudes towards drug-driving and drug-driving education campaigns have changed in this time, particularly since police enforcement of both drug-driving and drink-driving is now more widespread.

5.6.3 Perceptions of the risk of being detected by police for drug-driving

Studies examining the perceived risk of apprehension by police for drug-driving were limited to those conducted in Australia since the introduction of random roadside drug testing. The studies consistently demonstrated that the risk of being caught for driving under the influence of drugs (cannabis, methamphetamines or ecstasy) was perceived to 'very unlikely' or 'unlikely' by the majority of drug-drivers.

Consistent with this finding, most studies found that the perceived certainty, severity or swiftness of sanctions were not significant predictors of self-reported drug-driving behaviour or intentions to drug-drive in future (Armstrong et al., 2005; 2014; Davey et al., 2008; Freeman et al., 2010; Watling & Freeman, 2010; Watling et al., 2010). However, direct punishment avoidance (i.e., having avoided apprehension) and vicarious punishment avoidance (i.e., knowing of others that have avoided apprehension) were more consistently found to be significant predictors of reported intentions of drug-driving in future (Armstrong et al., 2005; 2014; Watling et al., 2010). These findings suggest that drug-drivers held stronger perceptions about the lack of potential punishments and the ease with which punishments or detection could be avoided than they did about the likelihood of getting punished.

These findings are of concern, particularly given that random roadside drug testing is the primary drug-driving countermeasure in Australia. However, most of the studies on legal risk perceptions were conducted too soon after the implementation of roadside drug testing within the respective Australian jurisdictions so it is possible that more recent research may present a different picture. For obvious reasons, this research needs to be replicated.

Matthews et al (2014)'s study is one of the few to examine changes in driving under the influence of drugs and the role of risk perceptions associated with impaired driving over time (2007-2011). Matthews et al (2014) found that there was a decrease in driving under the influence of most types of illicit drugs, and that this pattern was accompanied by a significant increase in the proportion who reported experience of recent random roadside testing. These findings may suggest that the observed reductions in driving under the influence of some illicit drugs and the increase in the experience of saliva testing is related to the continued implementation and/or expansion of roadside drug testing in Australia since the 2007 survey was completed. The reduction in driving under the influence of ecstasy and methamphetamine was accompanied by changes in attitudes towards the risk of police apprehension for these drugs such that a greater proportion of the 2011 sample indicated that there was a higher likelihood of being apprehended when compared to the 2007 sample. These findings highlight the key role that attitude change has in achieving behaviour change.

Attitudes towards driving under the influence of cannabis had not changed despite the introduction of roadside saliva testing. This suggests that cannabis users still perceive the probability of being drug tested while driving is relatively low. Given that cannabis has been commonly used for a longer time than ecstasy and methamphetamine it may be that attitudes have become more entrenched and resistant to change (Matthews et al., 2014). This presents a significant challenge for drug-driving countermeasures. Increasing perceptions of the certainty of apprehension, increased testing frequency, and increased awareness of roadside drug testing enforcement could potentially lead to reductions in drug-driving. However, with random roadside drug testing now being well established in Australia, there is an opportunity to research to identify current perceptions of drug-driving enforcement. Tracking changes in perceptions over time and unpacking why this occurs is a priority as the findings would be invaluable in selecting and optimising road safety drug-driving countermeasures.

5.6.4 The impact of behaviour and perceived 'non-legal' sanctions on drug-driving

A number of studies examined the extent to which factors other than perceptions associated with impairment, crash risk or apprehension by police were influential in predicting driving under the influence of drugs. This being said, only a handful of studies compared the relative importance of these factors in predicting drug-driving.

Understanding the impact of these factors and how they relate to perceptions of current drug-driving countermeasures is important in shaping the development of countermeasures beyond education and enforcement which currently address the bulk of the drug-driving problem.

Drug use patterns

Drug use patterns emerged as the most consistent predictors of drug-driving, with those who used drugs more frequently, those who had greater drug dependency issues, and those who used multiple drugs being more likely to drive whilst impaired than drug users without these patterns of use. Moreover, drug use patterns emerged as more important predictors of drug-driving than other factors such as perceptions of enforcement, perceptions of impairment and social sanctions (what one's peers think about drug-driving) (Davey et al., 2005; 2008; Fischer et al., 2014; Freeman et al., 2010; Kohn et al., 2014; Matthews et al., 2009; 2014; Watling & Freeman, 2010).

These findings present a serious challenge for drug-driving enforcement as they suggest that it is drug use patterns and behaviours relating to drug use that negate the deterrent impact designed to prevent drug-driving; this relates to punishment avoidance (Davey et al., 2008). Drug-driving appears to be an embedded behaviour for some heavy drug users, and this being the case may be resistant to change. This finding is entirely consistent with the attitudes and perceptions among dependent drug users that their drug use overrides any rational based concerns over being apprehended by police or injuring or killing themselves or someone else (e.g., McIntosh et al., 2008). However, it is important to point out that these concerns apply to a smaller group of dependent drug users for whom tackling the underlying drug use problem through targeted intervention programs, including those that address the underlying addiction issues, is likely to be the most effective approach to reducing drug-driving.

Peer group perceptions and behaviour

Drug-driving was shown to be predicted by a permissive attitude within the social/peer network, with those whose friends perceived drug-driving to be favourable being more likely to drive under the influence of drugs (Armstrong et al., 2005; Davey et al., 2005; Freeman et al., 2010; Lobmann & Krueger, 2000; McCarthy et al., 2007). Drug-driving and drug use in one's peer group were also significantly related, with drug-driving being more likely among those reporting that their best friends drove under the influence of drugs (Duff & Rowland, 2006; Kohn et al., 2014; Lobmann & Krueger, 2000).

Comparisons of the relative importance of legal and non-legal sanctions generally showed mixed results. In some studies, perceptions of the likelihood of being apprehended by police for drug-driving were stronger predictors of drug-driving than what one's peers thought about drug-driving. In other studies, the reverse was true. The inconsistency of these findings will be an important avenue for further research in this area.

These results suggest that drug-driving interventions need to consider peer group influences on attitudes which are strongly linked to drug-driving behaviour. The interventions should be targeted towards the young driver population since all of the studies on peer influences were in young, generally recreational drug-drivers from university or college populations. It is not known what effect peer group or social norms have on older drug users as this group has received little attention in the research literature. This should also be a focus for future research in this area.

Risk-taking, sensation-seeking and well-being

Risk-taking and sensation-seeking should be considered as targets for drug-driving interventions as both were shown to consistently predict drug-driving. Those who scored high on the measure of sensation-seeking were significantly more likely to report driving under the influence of drugs than those who scored low on the measure of sensation-seeking (Armstrong et al., 2005; Bergeron & Paquette, 2014; Lobmann & Krueger, 2000; Richer & Bergeron, 2009). Risk-taking was consistently found to predict drug-driving with those exhibiting risk-taking behaviours including speeding, committing driving errors, carrying passengers in risky situations, drink-driving, reporting stronger risky driving intentions and having had an offence detected being more likely to drug-drive (Begg et al., 2003; Bergeron & Paquette, 2014; Richer & Bergeron, 2009' Scott-Parker et al., 2014). Whether behavioural interventions focussed on impulsivity, sensation-seeking and the concept of 'behavioural urgency' (see for e.g., Cyders et al., 2008; Billieux et al., 2010; Smith and Cyders, 2016) are effective in ultimately addressing drug-driving behaviour needs to be determined.

5.6.5 Attitudes towards drug-driving versus attitudes towards drink-driving

Not surprisingly, the attitudes and perceptions associated with driving under the influence of alcohol were considerably different to those associated with driving under the influence of drugs. Compared to drug-driving, driving under the influence of alcohol was consistently perceived to be more dangerous and impairing (Albery et al., 2000; Darke et al., 2004; Fischer et al., 2006; Hammond et al., 2009; Lobmann & Krueger, 2000; Matthews et al., 2009), more likely to increase the risk of a crash (Albery et al., 2000; Matthews et al., 2009; Porath-Waller, 2008), and more likely to result in apprehension by police (Matthews et al., 2014; 2009; Ross et al., 2007).

Evidence also suggests that, compared to drink-drivers, drug-drivers tend to rely more on their own perceived knowledge to validate their behaviour. For example, Davey et al (2005) found that the individual attitudes predictive of drug-driving were those relating to peers (e.g. my friends think it's OK to drug-drive) and perceptions of harm (it's OK to drug-drive if you're not too high). Those predictive of drink-driving, however, related more to the law and detection (e.g. it's OK to drug-drive if you don't get caught) as well as peer influence norms (e.g. everybody drink-drives sometimes). Thus, it appears that the illegal aspect of drink-driving has a strong influence on the reduction of drink-driving whilst drug-driving attitudes still appear to be at the level of risk of harm (it's OK to drive if you're not too high).

Consistent with these findings, Lobmann and Kreuger (2000) found that the relationship between the amount consumed and driving impaired was closer for driving under the influence of illegal drugs than for drink-driving – the behaviour of drink-drivers was tied more closely to enforcement and the severity of punishment than the behaviour of drug-drivers who relied more so on their own experiences with the drug's effects. As such, moral appeals to drug-drivers are likely to be counteracted by their own experiences.

These differences are likely to reflect multiple factors including uncertainties about the causal association between some types of drugs and crash risk compared to alcohol and recognition of the relatively low risk of apprehension for drug-driving. Moreover, drink-driving behaviour has undoubtedly been shaped by sustained exposure to initiatives to discourage driving under the influence of alcohol, including widely implemented deterrence strategies, education and social sanctions. While more widely promoting accurate messages about the risks of drug-driving is necessary, the responses by participants in most studies on the persuasiveness of factual versus deterrence-based strategies strongly suggest that education alone is not sufficient to discourage drug-driving (Swift et al., 2010; Jones et al., 2006). Taken together, these findings have important implications for drug-driving countermeasures which need to highlight convincingly the illegal and harmful aspects of engaging drug-driving behaviour.

5.6.6 Concluding comment: Knowledge gaps and future opportunities

This review has uncovered a number of important gaps in our knowledge with respect to the attitudes and motivations associated with drug-driving. These insights can provide the basis for designing countermeasures that aim to mitigate drug-driving behaviour. The findings suggest considerable challenges exist in addressing drug driving, but nonetheless provides a basis for moving forward including the delivery of content specific programs designed to educate drug-users on the risks associated with drug-driving; addressing a range of peer behaviours; addressing organisational factors for commercial vehicle drivers; and applying therapeutic models for dependent drug-users (among other factors that need to be addressed).

Given the identified gaps in knowledge, there is a pressing need for research to examine currently held legal risk perceptions among drug-drivers and their relationship with current enforcement practices and drug-driving behaviour in Victoria. Here we note that this is the subject of Report 3 of this MUARC Baseline Research Program. That there is no detailed longitudinal survey of the attitudes of Victorians toward drug-driving limits an assessment of the impact of the current program compared to the past on drug-driving attitudes and behaviours. Implementation of such a longitudinal program ought to be considered, as it can provide the means of tracking the impact of changes to the current enforcement regime, as well as the effects of other programs that might be implemented in the future.

To date, there has been little research that has focused on the relative importance of different predictors of drug-driving, such as legal versus social sanctions. This is important for helping to prioritise countermeasures beyond enforcement initiatives, which in Victoria – apart from a limited number of public education advertisements, currently forms the backbone of drug-driving reduction measures.

Translating these insights into usable actions, the next chapter of this report outlines a number of potential countermeasures aligned to specific target groups with the goal of reducing the incidence of drug-driving.

6 DRUG-DRIVING COUNTERMEASURES

6.1 SCOPE

This chapter sets out to identify and describe countermeasures and approaches aimed at reducing drug-driving and drug-driving related crashes. Of particular interest is the effectiveness of these measures. While the aspect is primarily focussed on outcome rather than process measures, key issues regarding the implementation and likely effectiveness of some types of countermeasures have been included for discussion, where relevant.

The review was restricted to studies conducted from 1995 onwards and focussed on the three illicit drugs under which it is currently an offence to drive under the influence within most states of Australia: namely cannabis, MDMA and meth/amphetamines. The review included national and international research although the international research was limited to that which was considered relevant to the Victorian context.

The review highlighted a large number of studies that examined the impact of various treatment programs on drink-driving and drug-driving. It can be stated at the outset however that these studies did not report the efficacy on drink-drive behaviour and drug-driving outcomes separately. Other studies described treatment programs as being targeted towards alcohol and drug-driving problems but only examined the impact of the program on driving under the influence of alcohol. Still other treatment programs were described as covering drug-driving behaviour; however, the effects of the programs were examined in terms of general health and safety risks associated with drug use rather than drug-driving per se. As the effects of these programs on drug-driving were not able to be specifically identified in these studies, they were not as a rule included in this review.

Other identified studies included information relevant to drug-driving countermeasures but did not evaluate their effect. These studies were not included in the PRISMA statement (See Appendix A and B) though were used to provide relevant context and information in relevant areas of the report.

For completeness in reviewing the literature, the reader is also referred to the 2018 Australian National Transport Commission (NTC) information paper titled *Toward a National Approach to Drug-driving* (NTC, 2018) for an exposition of legislation relating to drug-driving in Australia and overseas. In addition, the European Transport Safety Council (ESTC) also published a report that examined policy actions and made recommendations to address drug-driving (see Atchinson, 2017), some of which are noted below.

6.2 TYPES OF DRUG-DRIVING COUNTERMEASURES

At the outset it can be stated that few countermeasures have been developed to specifically address drug-driving. Based on the identified literature, countermeasures that aim to reduce drug-driving are described below. Countermeasures fall into four categories:

1. Legislation.
2. Enforcement.
3. Education, including media campaigns.
4. Specialized behaviour change programs, including health-based (addiction) treatment programs.

The development and implementation of these countermeasures has largely been modelled on countermeasures associated with drink-driving (Beirness et al., 2010; see also Shinar, 2017, Chapter 12 for discussion of relevant countermeasures).

Despite some parallels between drink and drug-driving, there are numerous differences that must be considered when adapting countermeasure programs. These relate to the effects of various substances on driving, their time-course of action, but perhaps more importantly the antecedents of drug use itself, how illicit drugs are accessed, and perceptions of their effects on the driving task. Overlaid on this are broader societal views concerning the potential legalisation of certain illicit drugs, with the current interest centring on the legalisation of recreational cannabis, and how drug users ought to be managed more broadly in the health and justice systems.

6.2.1 Legislation

Legislation aims to authorise, regulate, and provide sanctions for drug-driving behaviour. Broadly speaking, legislative sanctions capture the principles of retribution; deterrence; rehabilitation, and incapacitation. Shinar (2017, Chapter 12) provides an exposition of these concepts in relation to alcohol and driving) while Davey et al. (2017) provide details of drug-driving legislation in Australia.

These concepts are simplistically defined as follows:

- Retribution (punishment) is considered to be an appropriate and necessary consequence of committing an offence and has the aim of discouraging future offending.
- General deterrence can be defined as the impact of the threat of legal punishment on the public at large. This results from the perception of the public that traffic laws are enforced and that there is a risk of detection and punishment when traffic laws are violated.
- Specific deterrence can be defined as the impact of actual legal punishment on those who are apprehended. Specific deterrence results from actual experiences with detection, prosecution, and punishment of offenders.
- Rehabilitation of those who engage in the sanctioned behaviour can initiate an opportunity for addressing the underlying reasons why the person is committing the offence. Within the drug-driving realm, rehabilitation is generally targeted towards high-risk repeat drug offenders. These offenders can be sanctioned by an intensive correction order, which requires the offender to undergo a treatment program either outside or inside a prison.
- Incapacitation involves preventing repeat occurrences of the behaviour by restricting, or completely removing, the person's capacity to drive (for example, by impounding his or her car or by putting the person in prison) for at least a period of time. Note, impoundment is a feature of current legislative practice in Australia for drug-driving offences.

The evidential standard used to define drug-driving offences can be categorised into one of two laws: behaviour-based statutes and per se laws.

Whereas per se laws have become the standard for drink-driving offences, behaviour-based statutes are still relatively common for drug-driving offences in most countries except Australia, Belgium, Denmark, France, Sweden, Slovenia, Israel and Norway. The distinction between the two types of laws has important implications for enforcement and prevention.

Behaviour-based statutes

In Victoria, driving-while-impaired by a drug (s.49(1)(ba) is the act of operating a motor vehicle after having consumed drugs to the degree that cognitive and motor skills necessary to operate a vehicle safely are sufficiently compromised so as to endanger the vehicle occupant(s) and other road users.

Drivers suspected of being impaired by drugs are required to undergo a drug assessment test, known in Victoria as the Standard Impairment Assessment (SIA). This test involves four parts: an interview and observation; a physical impairment test; a walk and turn test; and a one leg stand test. Behavioural evidence from the test, combined with evidence of drug use from a blood sample, provides a reasonable basis on which to pursue impaired driving charges.

In Victoria, the penalties for drug-driving differ depending on whether it is the driver's first or second offence (Table 6.2A); driver are also required to undertake a range of programs prior to relicensing (see https://www.vicroads.vic.gov.au/safety-and-road-rules/road-rules/penalties/drug-driving-penalties for details).

TABLE 6.2A CURRENT PENALTIES IN VICTORIA FOR DRIVING-WHILE-IMPAIRED BY A DRUG

Offence	Penalties
First drug-driving offence	Immediate licence suspended and driver will receive a: • Fine up to the value of 12 penalty units[#], and • Minimum 12 months cancellation of your licence or learner permit. The court may also record a conviction.
Second drug-driving offence	Immediate licence suspended and the driver will receive a: • Fine up to the value of 120 penalty units or 12 months imprisonment, and • Minimum 2 years cancellation of your licence or learner permit. The court may also record a conviction.
More than two drug-driving offences	Immediate licence suspension plus a: • Fine up to the value of 180 penalty units or 18 months imprisonment, and • Minimum 2 years cancellation of your licence or learner permit. The court may also record a conviction.

[#]As a 1 July 2017, 1 penalty unit is $158.57; http://www.justice.vic.gov.au/home/justice+system/fines+and+penalties/penalties+and+values/

Per se laws

Per se laws specify that drivers are considered to have committed an offence if the concentration of a specific drug in their saliva or blood, is found to be above a specified level.

"Zero tolerance" laws are a special case of per se laws, whereby and level above zero is deemed to be an offence; that is, it is the presence of the substance that defines the offence. Threshold values are set at zero or effectively zero when analysis and administrative tolerance is taken into account.

Hence, these laws prohibit drivers from having any measurable quantity of specific drugs in their system. Zero tolerance legislation for drug-driving was implemented in Victoria in December 2004 (s.49 (1) (bb), (h), (i) and since then it has been introduced into all other Australian States and Territories. Roadside salvia screening tests are used, with results confirmed in by laboratory testing.

There are a range of penalties applicable to drug-driving (Table 6.2B), and like driving-while-impaired offences, additional requirements for relicensing. It is also noteworthy that a combined drink-drug-driving offence exists, with severe penalties applicable.

For up-to-date details of penalties in Victoria for drug-driving offences, the reader is referred to https://www.vicroads.vic.gov.au/safety-and-road-rules/road-rules/penalties/drug-driving-penalties.

TABLE 6.2B PENALTIES IN VICTORIA FOR DRUG-DRIVING (AT JULY 2017)

Offence	Penalties
First drug-driving offence and an infringement notice received	• Fine to the value of 3 penalty units, and • 3 months suspension of licence or learner permit.
First drug-driving offence and driver has to go to court	• Fine up to the value of 12 penalty units, and • Minimum 3 months cancellation of licence or learner permit. The court may also record a conviction.
Second drug-driving offence	Driver required to go to court and receive a: • Fine up to the value of 60 penalty units, and • Minimum 6 months cancellation of licence or learner permit. The court may also record a conviction.
More than two drug-driving offences	Driver required to go to court and receive a: • Fine up to the value of 120 penalty units, and • Minimum 6 months cancellation of licence or learner permit. The court may also record a conviction.

Differences between behaviour-based statutes and per se laws

A perceived strength of behaviour-based statutes lies in the fact that they target the impaired behaviours that compromise road safety, regardless of the specific type or amount of substance consumed. This approach considers the variability in effects of the same dose of drugs on different people, avoiding the purported arbitrariness sometimes associated with per se laws.

However, there are a number of limitations associated with behavioural-based statutes, including the degree of training and extensive evidence required to prove the offence, the time required to gather the evidence, the low risk of detection and conviction, and the tendency to charge and convict only those drivers who are severely and obviously impaired.

As such, per se tests are much easier to implement, relying purely on the presence of a proscribed drug at a specified concentration. Under such laws, the issue of impairment or the determination of being incapable of the safe operation of a motor vehicle is moot. Per se laws also have the advantage being clear by eliminating the potential grey areas of assessing impairment; furthermore, per se laws eliminates the need for the driver to assess their ability to drive after consuming drugs.

6.2.2 Enforcement

The primary drug-driving legislation in Victoria is the per se zero tolerance law which is enforced through roadside drug testing (RDT) (Boorman, 2014). There is no requirement for 'probable cause' as is the case for example in the United States, and as such can be considered random. Due to the cost of the roadside testing process, roadside drug testing has had a strong strategic targeting element.

The procedure involves drivers being stopped at random at roadside drug-testing buses (or combined booze and drug buses) and asked to submit a saliva sample. The sample is screened at the roadside and the result is determined within about three minutes. Drivers who return a positive test result are required to leave their vehicle and accompany police to the drug-testing bus where they are required to provide a second saliva sample. If the second sample also returns a positive result, the driver is interviewed. A portion of the second saliva sample is then given to the driver and the rest is sent to a police laboratory for a more accurate test. This procedure can take up to 30 minutes. The driver is permitted to leave after this, although they are not allowed to drive their vehicle. Relevant charges are laid if a positive test result is confirmed by the laboratory results. The driver is notified within a few weeks if the analysis confirms that an illicit drug was present.

The general assumption underlying police enforcement is that it should aim primarily at general deterrence, which is primarily achieved by increasing the subjective risk of apprehension. The subjective risk of apprehension, and hence the effectiveness of police enforcement, is larger if police enforcement is:

- Accompanied by publicity.
- Unpredictable and difficult to avoid.
- A mix of highly visible and less visible activities.
- Primarily focused on times and locations with high violation (maximum feedback to potential offenders).
- Continued over a longer period of time.

For an excellent exposition of general and specific deterrence, the reader is referred to Delaney et. al., (2006).

6.2.3 Social marketing and/or mass media campaigns

The use of social marketing and/or mass media campaigns are a commonly used road safety strategy. The purpose of these campaigns is to disseminate information to a large and diverse public audience in order to increase the acceptability of a social idea or practice and/or to educate the public on a particular topic.

The two main aims of these campaigns within the Australian drug-driving context are 1) to educate the public about the dangers of driving while affected by drugs, including the physiological and psychological effects of drugs on road safety and 2) to inform the public about roadside drug testing and the potential for being charged for driving under the influence of drugs (Mallick et al., 2007).

In Victoria, the Transport Accident Commission's (TAC) drug-driving campaign began in 2004 and was designed to coincide with the introduction of roadside drug saliva testing. At the time of authoring this report, none of the mass media / social marketing campaigns implemented in Australia have been evaluated for their

impact on drug-driving and drug-driving crashes. However, these initiatives likely play an important role in enhancing the general deterrent value of enforcement activities by increasing the perceived probability of detection among the general population (Delaney et al., 2006). Creating a real and credible threat of detection and apprehension is a key element in effective deterrence. This involves a high level of enforcement activity through roadside drug testing combined with a media campaign to ensure the population of drivers is aware of the police activity and enhance the perception of being caught should they engage in the behaviour (e.g. Lacey et al., 1999; Mercer, 1985; Shinar and McKnight, 1986; Shinar, 2017).

At present, it can be stated that deterrence achieved through enforcement appear supported and sustained by mass publicity form the core of drug-driving prevention efforts being used in Australia.

Evidence suggests that several key aspects are important for successful general road safety mass media social marketing campaigns that are likely to be applicable to the drug-driving context (Mallick et al., 2007). First, the most successful road safety campaigns are those based on a theoretical model to inform the development of key messages and execution (Elliot, 1993). Second, the use of public relations and associated publicity appears to be more important to the outcome of the campaign than the use of enforcement (Delaney et al., 2004). However, the use of public relations and publicity combined with enforcement consistently produces the most effective outcomes (Delaney et al., 2004). Third, campaigns with a persuasive orientation and those that use emotional rather than rational appeals have been found to have a greater effect on the relevant measures of effect. Conversely, information-based and educative campaigns have been associated with less effective outcomes (Delaney et al., 2004).

General public education and messages to prevent drug-impaired driving require considerable care and forethought to avoid unintended effects. For example, specifying particular drugs in the message becomes confusing and leaves the impression that if the drug is not on the list, then it must be safe (Beirness, 2010). Messages that tell the public not to drive after taking too much of a drug imply that moderate drug use is acceptable (Beirness, 2010; Mallick et al., 2007). Thus, great care needs to be taken in developing such messages and these need to be tailored not only to specific drug-user groups but tailored to the effects of the drugs in question.

6.2.4 Education programs

Road safety education

Road safety education programs for drug-driving prevention have been developed. Drawing from the wider drug prevention field, these prevention programs operate within a risk-protective framework, aiming to reduce risk factors while enhancing protective factors (Mallick et al., 2007). The most effective drug-prevention programs are considered to be those that teach individuals techniques for resisting drug use in combination with more general social skills and personal development (Botvin, 2000).

Most secondary schools in Victoria include traffic safety education programs that include a component on alcohol and other drugs and their impact on driving. The focus is generally on the illegal nature of drink and drug-driving and the impact of impaired driving on decision making, driving abilities and traffic safety (Australian Drug Foundation, 2010).

The P.A.R.T.Y. (Prevent Alcohol and Risk-Related Trauma in Youth) Program is a Canadian program developed in Toronto in 1986 that addresses issues related to young people taking unsafe risks including alcohol consumption, drug use, and associated behaviours such as unprotected sex and driving under the influence of drugs and or alcohol (Shinar, 2017). The PARTY program is delivered in a hospital setting with the goal of providing youth with "information about trauma that will enable them to recognise potential injury-producing situations, make prevention-oriented choices, and adopt behaviours that minimise unnecessary risk" (Banfield, Gomez & Kiss, 2011, p.732).

Participants learn about road trauma and other causes of injury, as well as hearing of the long-term impacts of these injuries. The program is delivered by a range of health-care professionals, law enforcement officers, social workers and patients who have sustained injuries in crashes and other incidents. The goal is to highlight the consequences of risk-taking behaviour. At the completion of the program, participants sign a "Contract for Life" that represents a commitment to minimise risk and are assigned to follow-up activities to facilitate and encourage discussion with peers and family members.

The PARTY program has been implemented in Australia. In Victoria it is an initiative of the National Trauma Research Institute (NTRI) and has been running fortnightly at The Alfred Hospital throughout school terms since 2009. To date, school students have attended the program from independent and public education

schools. Initially the PARTY program run only as a single day in-hospital model to senior school students (year 10 and over) in groups of 35-40. However, in order to reach more people, programs have been delivered to participants (aged 18-25) from the Victorian Court System and trainees from the Royal Australian Navy. P.A.R.T.Y. has also been delivered multiple times via an offsite duplicate day model to year 11 secondary students in regional centres.

As Shinar (2017) notes, whilst programs such as P.A.R.T.Y. have been in place for more than two decades, their efficacy in reducing crash risk is unknown.

Education following loss of licence due to impaired driving

Education programs include those aimed at persons who have already been convicted of a drug-driving offence. In Victoria, as in other jurisdictions, convicted drug-drivers are required by law to complete a drug-driving education program in addition to a range of other tasks (including court hearings, payment of fines and undertaking clinical assessments) before their licence will be restored (for details of course requirements refer to: https://www.vicroads.vic.gov.au/safety-and-road-rules/road-rules/penalties/drug-driving-penalties).[2]

Driver education is considered to be an essential part of the rehabilitation/licence restoration system and, when combined with fines and disqualification periods, has been shown to be an effective deterrent for drink-drivers (e.g., Freeman & Liossis, 2002). Programs aim to educate participants on the risks associated with drug-driving and promote an attitude shift.

6.2.5 Treatment programs

Brief interventions (BI)

A Brief Intervention (BI) is a technique used to initiate change for an unhealthy or risky behaviour including drug-driving. Brief Interventions focussed on drink and drug-driving are typically targeted to non-dependent users whose drinking/drug use and driving may still be harmful (see Fischer et al., 2012, 2013, 2014; Wells-Parker et al., 2002; Wilk et al., 1997 for a discussion of brief interventions)

Brief Interventions are a much less 'traditional' form of intervention option and can be a useful tool for working with people who may be impulsive and erratic in their decision-making. Brief Interventions involve making the most of an opportunity to raise awareness, share knowledge and get a person thinking about making changes to improve their health and behaviours. The intervention can therefore be brief and 'opportunistic', lasting as little as 30 seconds, or extending over a few sessions lasting 5-60 minutes. Brief Interventions often consist of informal counselling and the provision of information on certain types of harms and risks associated with unhealthy behaviour.

The aims of Brief Interventions are to:

- Engage with those people not yet ready for change.
- Increase the person's perception of real and potential risks and problems associated with drug-driving and associated practices.
- Encourage change by helping the person to consider the reasons for change and the risks of not changing.

Brief interventions utilise a range of techniques such as motivational interviewing, problem solving, decisional-balancing and goal setting and focus primarily on the process of change. The interventions are low-cost, client-centred and non-confrontational and are designed to encourage engagement and behaviour change by helping clients explore and resolve ambivalence.

Motivational interviewing

Motivational interviewing (MI) is described as a type of counselling approach that evolved from experience in the treatment of problem drinkers. MI is used for exploring a person's motivation to change through interview in order to assist them towards a state of action (Evans, Martin, Neeson et al., 2011).

According to Rollnick and Miller (1995, p.12) Motivational interviewing is "...a directive, client-centred counselling style for eliciting behaviour change by helping clients to explore and resolve ambivalence.

[2] A revised behaviour change program informed by best-practice principles for all drink and drug drivers was implemented in Victoria as of 30 April 2018, the efficacy of which is yet to be documented due to the lack of sufficient follow-up time.

Compared with nondirective counselling, it is more focused and goal-directed. The examination and resolution of ambivalence is its central purpose, and the counsellor is intentionally directive in pursuing this goal."

Whilst motivational interviewing is still most commonly used to treat problem drinking and drug use, it has been used to address drug-driving (Stein, Colby, Barnett et al (2006).

6.2.6 Strategies to reduce drug use and associated risks at electronic music dance events (EMDE)

Miller, Holder & Voas (2009) describe a number of environmental strategies designed to reduce drug use and associated risks including drug-driving at electronic music dance events (EMDEs). EMDEs occur in clubs that feature electronically produced music (not live music) and typically attract young adults aged 18-25. The environmental strategies are similar to those that have successfully been used to reduce alcohol related harms.

Much of the research on environmental approaches has focused on preventing alcohol related problems in licensed establishments. Alcohol and drugs have quite different use patterns, related policies, and associated risks. However, an environmental prevention approach is appropriate for addressing drug use and related concerns because there is evidence that the environmental context (both physical space of the event and social characteristics) can increase or decrease drug use, and behavioural risks (e.g., Chinet et al. (2007).

Strategies involving changes to the external environment that are likely to be relevant to preventing drug use include improving exterior lighting and parking; and having door staff or security monitor the external space. Although a number of environmental strategies suggested for the internal environment have been effective in reducing alcohol consumption and related risky behaviours, it is difficult to know how applicable these would be in reducing drug use and driving. For example, responsible beverage service would not apply since drug use is illegal. However, training that assists staff to limit levels of intoxication attained by customers, provide relevant information on harms of drug use and suggest alternative means of transport to patrons may help to reduce the likelihood of drug-driving.

Venues can also enlist the services of peer education programs to convey this information. For example, in Victoria, a program called DanceWize, one of Harm Reduction Victoria's (HRVic) outreach programs, utilises a peer education model to reduce drug and alcohol related harm at Victorian dance parties, festivals and nightclubs. Key Peer Educators [KPEs] attend up to 28 events per year: hosting a chill-out space; discussing safer drug use with peers and disseminating health resources. DanceWize staff can provide information and referral advice on a wide range of health and related issues including drug-driving and how to get home safely from an event. Anecdotal evidence from youth and community organisations have attested to peer education being an effective means for educating young people and illicit drug users (Turner & Shepherd, 1999; Orme & Starkey, 1999).

It has been suggested that to be effective, programs and principles designed to reduce harms associated with alcohol and drug use need to be wholly supported by venue management as well as law enforcement and the general community (Australian Drug Foundation, Miller et al., 2009). Club owners are likely to be invested in adopting environmental approaches to change the social, economic, and physical environment of their clubs, particularly in situations where drug use has caused or has potential to cause problems including: an increased propensity for police interference and community complaints; a propensity for drug using patrons to be less likely to drink alcohol, thereby reducing profits from serving alcoholic beverages; and the threat of license revocation should drug use become prevalent within the club. However, clubs also need to maintain an overall image that is attractive to potential patrons. Overly restrictive and controlling policies can result in losing the customer base. Thus, the club owners/managers are forced to maintain a balance between overly restrictive activities that discourage patrons from attending and policies that are too permissive.

It is not known to what extent environmental approaches to reduce drug use and associated risks have been implemented at EMDEs.

6.3 EVALUATIONS OF THE EFFECTIVENESS OF DRUG-DRIVING COUNTERMEASURES

With few evaluations of drug-driving countermeasures available there is a distinct lack of evidence demonstrating the effectiveness of countermeasures aimed at reducing drug-driving.

6.3.1 Enforcement through roadside drug testing

To date, there have been no evaluations of the effect of roadside drug testing on the prevalence of drug impaired driving or crashes in Australia or elsewhere. As such, the road safety benefit of this form of enforcement is unknown.

Barriers to roadside drug testing evaluations

Evaluation of roadside drug testing programs has been hampered by a lack of available data. As stated by Baldock et al (2013), while information concerning detection rates is available, the more detailed data that is required to assess trends in drug-driving crash rates has proved more difficult to obtain.

Comparisons of the effectiveness of approaches to mitigate drug-driving across jurisdictions is made more challenging by differences in both crash reporting and drug test protocols for crash-involved drivers. Baldock (2013) notes that not all jurisdictions require routine testing for drugs following involvement in a crash; the implication here being that a proportion of drug positive drivers will not be detected. For crashes of low injury severity, data on drug involvement is largely unavailable. In contrast, toxicology analysis is routinely performed for fatality crashes, and in Victoria for serious injury crashes. In time, the critical mass of data needed to conduct a comprehensive evaluation of drug-driving countermeasures will be available.

For any such evaluation it will be important that the processes used in roadside drug testing are consistent in the periods before and after the introduction of enforcement programs. A change in the way in which biological samples are tested, a change in the likelihood of a sample being taken for testing (e.g. a shift from discretionary to mandatory drug testing), or the drug detection thresholds will affect the comparability of results from the two time periods.

With no crash-based evaluation of the efficacy of roadside drug testing programs currently available, the need for this to be undertaken is a priority.

To date, most research has focused on the potential benefits of RDT through process evaluations based on consultations or interviews with police organisations (Mallick, Johnston, Goren & Kennedy, 2007) or by examining self-reported intentions to drive under the influence of illicit substances (Armstrong et al., 2005; Armstrong et al., 2014; Davey et al., 2008; Jones et al., 2006; Freeman et al., 2010; Matthews et al., 2009; Matthews et al., 2014; Swift et al., 2010; Watling & Freeman, 2010; Watling et al., 2010).

Analyses of enforcement and/or detection data in each of Victoria, South Australia, New South Wales, Western Australia and Tasmania have generally been positive and supportive of the RDT programs introduced across Australia (See Baldock et al., 2013 for a review).

Further, a number of studies have reported reductions in offending (Verstraete & Raes, 2006) or an increased detection of drug-drivers (see Baldock et al., 2013). As outlined in the previous chapter of this report, a number of studies have highlighted intentions to continue offending in instances where perceived risk of detection is low (Davey et al., 2008; Freeman et al., 2010; Jones et al., 2006; Matthews et al., 2014; Matthews et al., 2009), or where punishment avoidance is perceived to be common (Armstrong et al., 2005; 2014; Watling et al., 2010).

Collectively these findings suggest that enforcement *could* be an effective deterrent to drug-driving. Programs such as these need to be widely implemented and highly publicised so that drug-drivers perceive a real threat of apprehension and sanction. Whether enforcement countermeasures demonstrate a different level of efficacy across different drug user / drug-driving sub-groups (as defined by type of substance use) remains an important question to address.

6.3.2 Social marketing and/or mass media campaigns

No publicly available evaluations of the effect of drug-related mass media/social marketing campaigns on drug-driving or drug-driving crashes in Australia were identified in this review.

Most of the social marketing campaigns focussed on program reach and/or attitude change as opposed to observable reductions in drug-driving or drug-driving associated road trauma.

In one example, an evaluation of the '*Drug-driving… You'd Be Off Your Head*' campaign implemented in the UK in 2003 found that drug-related road deaths decreased from 12 to zero over the life of the campaign in the area in which the campaign was launched (Raes, Pil, Van den Neste & Verstraete, 2007). However, it is not known whether the reduction in road trauma was due to the campaign or to other factors.

Social marketing campaigns have been seen to be effective in raising awareness of the penalties and social consequences of drug-driving. However, in some cases the campaigns were unsuccessful due to a perceived lack of enforcement accompanying the advertisements (Ormston, 2003). An evaluation of the Think! Drug-driving road safety advertisement '*Eyes*' implemented in the UK in 2009 found that there was no significant change in the perception of being caught by police for drug-driving following exposure to the campaign (Angle, Bone, Goddard & Johns, 2009).

The relatively low level of drug-driving (compared to drink-driving) enforcement is an important barrier to general drug-driving deterrence. This also limits the effectiveness of social marketing campaigns designed to educate the general public about the dangers and legal penalties associated with drug-driving (Hall, 2012).

However, it must be noted that drug-driving enforcement is relatively expensive to implement and is conducted at much lower levels than drink-driving enforcement which has a long history, has been widely publicised, is highly visible, and is seen to be highly cost-effective. The high volume of drink-drive testing creates the credible view that anyone who drives while intoxicated is likely to be detected. In contrast, roadside drug testing has typically been implemented on a much more modest scale and with considerably less publicity. Given this, it would be unlikely that drug-driving enforcement would match the well-established efficacy of drink-drive enforcement.

6.3.3 Education programs

Road safety education

To date there have been few publicly available evaluations of drug-driver education programs on drug-driving or on drug-driving related crashes.

Licciardone et al (2003) found that a series of post-secondary school programs designed to reduce drug use and attendant risks did not produce significant reductions in drug-driving as measured by pre- and post-program items on the Core Alcohol and Drug Survey and adjusted prevalence of alcohol and other drug-use (AOD) use. Specific details of the program were not described in the paper.

Banfield, Gomez and Kiss (2011) matched a study group of 1,281 P.A.R.T.Y program participants with a control group based on age, gender, residential area and initial year in database. Hospital discharge database information and provincial health claim data were collected to determine the incidence of traumatic brain injury for both the study and control groups. Fewer traumatic injuries were found to occur among the study group (43.3%) compared to the control group (47.4%) ($p=0.02$). Individuals in the control group were at a 21.8% greater risk of traumatic injury. Although the P.A.R.T.Y program has not been evaluated for its impact on drug-driving specifically, it is possible that some of the injury events examined by P.A.R.T.Y participants included drug-driving traffic crashes, although this is unknown (Banfield et al., 2011).

Galey, Jakaitis, King and Monroe (2011) examined the impact of parental involvement on self-reported teenage risky driving behaviour in a sample of 1301 participants. They found that teenage participants whose parents had spoken with them about safe driving ($n=975$, 75%) were significantly less likely to drive whilst affected by cannabis compared to participants whose parents had not spoken with them about safe driving.

Education following loss of licence due to impaired driving

The drink- and drug-driver education programs in Victoria and elsewhere, have been criticised for having a "one size fits all" approach, with substance-dependent offenders, first-time and low-level offenders all completing the same education program (Australian Drug Foundation, 2010, DRUID, 2012). Evaluations of programs for drink-driving suggest that the current programs in Victoria may have limited capacity to change drug-driving, especially for people with dependence issues (Sheehan, Watson & Schonfeld, 2005).

The current system has been criticised as it does not consider access and equity issues. The program is a "user pays" system and as such it is unlikely that some groups (unemployed, disadvantaged, serious and recidivist offenders) will comply and will simply slip through the cracks. Another issue with the current licence restoration process is that assessment, rehabilitation or treatment is not undertaken at the time of the offence but at the time of re-licensing, thereby forgoing a significant opportunity to intervene from a rehabilitation perspective.

A more effective system may be a streamed approach that would cater for the different offender groups and ensure that education and rehabilitation can be tailored to each type of offender (Australian Drug Foundation, 2010). Best practice for the treatment and rehabilitation of drink-drive offenders is to combine education with case management, clinical therapy based on the principles of cognitive-behaviour therapy, combined with comprehensive follow-up monitoring and aftercare.

6.3.4 Treatment programs

Brief interventions (BI)

Fischer et al (2012) examined the impact of a brief intervention designed to reduce driving under the influence of cannabis in high frequent cannabis users. One-hundred-and-thirty-four participants were recruited from among university students, randomized to either an oral or a written cannabis BI, or corresponding health controls, and assessed in-person at baseline, 3-months, and 12-months.

The cannabis interventions consisted of short information elements on cannabis-related health risks, concrete suggestions for risk modification, and brief motivational components. The main aims of the BI were to inform users about key modifiable health risks related to use, and to suggest tangible ways to reduce these risks without principally focusing on or requiring abstinence. The control interventions were similarly structured and included general health information content (e.g., nutrition, stress, exercise). The results showed significant reductions in driving after cannabis use in the experimental groups (n=72) at 3-months and 12-months post intervention.

Using a randomized controlled trial, Walton, Bohnert, Resko et al (2013) examined the impact of BI delivered by a computer (CBI) or therapist (TBI) among adolescents in urban primary care clinics. Adolescents reporting past year cannabis use completed a baseline survey and were randomized to control, CBI or TBI group with driving under the influence of cannabis assessed as a secondary outcome at 3, 6, and 12 months.

The BI incorporated motivational interviewing with a focus on: goals/values; feedback for cannabis, alcohol and other drug use, including consequences and DUI; decisional balance exercise about cannabis; tricky situations (e.g., role plays) including refusal skills for cannabis and other drug use, safe ways to get home/prevent driving high/drunk, dealing with peer pressure for delinquency (e.g., stealing a car/joy riding), coping with negative affect such as boredom, anger or sadness, and consequences (i.e., problem identification, getting help). Participants in the control were handed a tri-fold brochure containing warning signs of cannabis problems, resources (substance use treatment, suicide hotlines, employment services, leisure activities), and cannabis information websites. This “enhanced usual care” control (clinics did not routinely provide this information) was chosen for ethical reasons.

The therapist-supported BI reduced the frequency of driving under the influence of cannabis (with moderate effect sizes of 0.33), but did not significantly decrease frequency of cannabis use, cannabis consequences, or other drug use relative to the control. The reduction in driving under the influence of cannabis was not sustained at 12 months.

Motivational interviewing (MI)

Stein, Colby, Barnett et al (2006) examined the impact on marijuana-related driving events of motivational Interviewing (MI) among 105 incarcerated adolescents aged 14-19. Adolescents were randomly assigned to receive MI or Relaxation Training (RT).

The research counsellors’ therapeutic style focussed on empathy, not arguing, developing discrepancy, self-efficacy, and personal choice. Sections of the MI included developing rapport, exploration of motivation (pros and cons), personalised assessment feedback, imagining the future with and without change, and establishing goals. Handouts were provided (e.g., goals chosen). A large portion of the personalised feedback was devoted specifically to their episodes of driving under the influence of alcohol and marijuana. The Relaxation Training included instruction in relaxation and meditation, as well as received feedback in the use of the relaxation techniques and handouts on relaxation techniques. Through the program, research counsellors acted to maintain rapport whilst providing generalized advice to stop risky activities such as driving under the influence of alcohol and marijuana.

Although adolescents who received MI had lower rates of marijuana consumption, fewer drug-driving episodes, and were less likely to be a passenger in a car with someone who had been taking marijuana, the effects were not significant.

6.3.5 Number of evaluations of effectiveness of drug-driving countermeasures

Only six evaluations of countermeasures designed to reduce drug-driving were identified in this review. This included three evaluations of treatment programs for sentinel samples (i.e., incarcerated individuals or those in full time treatment); three evaluations of drug-driving education programs; and one evaluation of a brief intervention for high frequency drug users.

A number of process evaluations of drug-driving countermeasures were identified in this review, but these have not been included for discussion here (e.g., Marko & Watt, 2011). The literature search did not identify any evaluations of the effect of drug-driving countermeasures on crashes.

6.4 POTENTIAL DRUG-DRIVING COUNTERMEASURES FOR VICTORIA

A number of drug-driving countermeasures have been identified in conduct of the literature review. These are measures that are being examined for their potential to minimise drug-driving or are currently in operation in jurisdictions other than Victoria. While none have been evaluated for their impact on drug-driving they may be worthy of consideration to prevent drug-driving in the Victorian context.

In outlining these measures, the present roadside random drug testing program in Victoria is recognised to be a critical tool in reducing the incidence of drug-driving (Boorman, 2014), despite a lack of formal evaluation of the program on crash rates (Shinar, 2017). The measures below are those identified in the literature and would act in combination with the current operational enforcement approach in Victoria.

6.4.1 Linking enforcement with social support services

Forsman, Hrelja, Per Henriksson & Wiklund (2011) described a local Swedish based program that forms part of the national cooperation against drink and drug-driving in traffic (SMADIT) in Sweden. The program attempts to link drink and drug-driving enforcement with on-the-spot referral to social support services. Suspected drink-drivers or drug-drivers are offered contact with the social services or the dependency care and treatment service, which can offer a consultation and, if needed, suitable treatment.

A process evaluation of the program found that about 20% of all those who receive an offer from the police accept contact with the social services or the care and treatment service, and approximately 40% of these also attend the consultation. One of the original ideas of the model is that an initial contact should be established between the drink-driver or drug-driver and social treatment services within 24 hours of the arrest. However, the process evaluation showed that this was fulfilled in only about 26 percent of the cases. This outcome was largely due to the fact that the social services are often not staffed in the evenings or over the weekends, making it very difficult to process new patients at short notice.

In the context of repeat drink-driving, Fitzharris et al. (2015) noted a number of integrated enforcement and social support / counselling services designed to address underlying alcohol dependency and other psychological health issues. These programs have considerable merit, noting they vary in their intensity and program requirements.

6.4.2 A role for specialist courts in managing offenders with a drug and/or alcohol dependency: an application to drug-driving offenders

Specialist court lists and dedicated courts for the management of drink-drive offenders, as well as those with drug and/or alcohol dependency have been established (Payne, 2006; Richardson, 2013; Fitzharris et al., 2015). These courts and specialist lists have been established in recognition of the high degree of recidivism among individuals with these drug and alcohol dependency issues, which is also related to the pattern of offending. While recognising the need for sanctions – including custodial sentences that are served in the community, these courts take a broader treatment and supervision approach that can involve case managers, allied health and specialists in drug and alcohol treatment.

In Victoria, the 'Drug Court' is a specialist court within the Magistrates Court of Victoria, and is based in Dandenong in the south-eastern suburbs 35 kilometres (23 miles) from the central business district (see: https://www.mcv.vic.gov.au/about_us/drug-court). The Court was established in 2002, focusing on the rehabilitation of offenders with a drug and/or alcohol depending, and to aid in community re-integration (KPMG, 2014; Parsons, T. & Lauritsen, 2015). The Drug Court has become integrated with the Victorian

Government's 'Ice Action Plan'3 which was informed by the 2014 Victorian Parliamentary Inquiry into the Supply and Use of Methamphetamines, Particularly 'Ice' In Victoria.

The goal is to improve the health of those under Drug Treatment Orders, and to reduce the frequency and severity of offending. The evaluation by KPMG (2014, 2016) of the Dandenong Drug Court highlighted significant success as indexed by lower re-offending rates, a reduction in the number of offences, as well as a reduction in serious offences, such as drug trafficking offences and assault; furthermore, the Drug Court was demonstrated to be cost-effective and less expensive than imprisonment. KPMG state that these outcomes are 'in line with other therapeutic justice models' (p.7). The KPMG (2014) report provides an excellent overview of diversion programs in Victoria and the rationale for drug-courts and their benefits, while Parsons and Lauritsen (2015) describe the operation and outcomes of the Drug Court in detail.4

A question remains: would this approach be of value in reducing drug-driving? In the United States, for example, DWI Courts as they are known (i.e., Driving While Impaired; https://www.dwicourts.org/) have been demonstrated to be effective, not only in reducing repeat DWI episodes but have demonstrated crash-reduction effects as well (see Harron & Kavanaugh, 2015 for a review of evidence).

It is notable too that among the cohort of offenders that formed the basis for KPMG's (2014, 2016) evaluation of the Dandenong Drug Court, 20% of clients' offences prior to the drug-treatment order were driving-related offences. As a group, these clients had high levels of mental health illness. With respect to drug use at 'intake', 60% reported using amphetamines, 59% used heroin, 55% consumed alcohol, 38% used MDMA and 33% used cocaine. The pattern of criminal behaviour was described as 'deeply entrenched' (p.33). The effect on 'minor' driving-related offences was evident, albeit small off a base of low numbers; it was unclear what these offences were. Of particular interest was the response from one drug-court client, '…I used to drive without a license without a care. Now I don't even consider it. I'm not going to jeopardise going back to jail.' (p.129).

The evidence base concerning the efficacy of Drug Courts and DWI courts on offender behaviour, including in reducing driving-related offending, is highly promising. For these reasons, these programs ought to be considered as a viable policy option in addressing drug-driving (and drink-driving) behaviour in Victoria and other jurisdictions in Australia. However, effort needs to be made to ensure that these programs remain efficacious, are targeted appropriately, and refined where required to manage what would be a significant expansion given the number of drug-driving offenders detected in Victoria (see Report 2).

6.4.3 Strategies to prevent drug-driving through primary care providers

Researchers in Queensland have investigated the effectiveness of intercepting and treating drivers suspected of risky drug and or alcohol use when they make initial contact with their primary health care provider (Tackling drink-driving at the doctor's door, 2016).

The aim of the study was to reduce the incidence of impaired driving in Australia and reduce the rates of offender involvement in the criminal justice system. One of the benefits of the strategy over other approaches is that it aims to be preventive rather than reactive – persons suspected of being at risk for impaired driving are offered strategies to reduce the likelihood that they will drive whilst impaired before this occurs.

6.5 REQUIREMENTS FOR EFFECTIVE DRUG-DRIVING COUNTERMEASURES

This review has found that there are few currently available drug-driving countermeasures, and further, that very few evaluations of drug-driving countermeasures have been carried out. This makes it difficult to recommend best practice drug-driving countermeasures for use in Victoria.

One of the key requirements for developing effective drug-driving countermeasures is to understand the characteristics of the different drug user and drug-driving groups. This information is important both for prioritising the groups for targeting countermeasures and in ensuring that the design of countermeasures is tailored to suit any specific requirements of the different groups.

Based on the information provided in this report, a number of driver cohorts ought to be targeted for drug-driving countermeasures. These key groups include young drivers, males, polydrug users, and frequent (but nondependent) drug users. A range of countermeasures for these and other key sub-groups are outlined below. Analysis of police offence drug-driving data and crash data, as per Report 2 of this Series, will provide an

[3] For details of the Ice Action Plan (Victoria), see: https://www2.health.vic.gov.au/alcohol-and-drugs/aod-policy-research-legislation/ice-action-plan
[4] Note: Report author Mr Tony Parsons is the Presiding Magistrate of the Drug Court of Victoria.

understanding of the relative contribution each of these groups makes to the current drug-driving problem in Victoria.

We note here that drug-drivers with specific concerns including drug use dependency, poor mental health, criminal convictions and high sensation-seeking tendencies should also be a focus for countermeasures. Reducing the incidence of drug-driving among these sub-groups is likely to be particularly challenging, and it is likely that a range of interventions and novel approaches will be required.

It is important to note that this is not an exhaustive list but is limited by the information available in the literature. Little is known about the characteristics of the different road user groups including truck drivers, motorcyclists and cyclists who are known to drive under the influence of drugs.

It can be stated that the identified measures, whilst grouped under key target groups, may also be relevant to more than one driver group and drug-class.

Target Group: Young Drivers

Key issues:

- More likely to be detected for drug-driving and to self-report driving under the influence of drugs than older drivers (noting non-random nature of drug-driving test).
- Higher crash risk associated with driving under the influence of drugs compared to older drivers.
- Ravers/clubbers much more likely to self-report drug-driving than the 'general' drug-driving population.
- Convenience and a lack of reliable or alternative transport options were the main reasons for drug-driving among rave party and night club attendees.
- Drug-driving was predicted by a permissive attitude within the social / peer network, with those whose friends perceived drug-driving to be favourable being more likely to drive under the influence of drugs.
- Drug-driving and drug use in one's peer group were significantly related, with drug-driving being more likely among those reporting that their best friends drove under the influence of drugs.
- Risk-taking was consistently found to predict drug-driving although it was measured differently across the studies. In general, compared to non-drug-drivers, drug-drivers were significantly more likely to speed, commit driving errors, engage in general risky driving behaviours, carry passengers in risky situations, drink-drive, report stronger risky driving intentions, and report having had an offence detected.
- In some studies, perceptions regarding what one's peers thought about drug-driving were stronger predictors of drug-driving than perceptions about the likelihood of being apprehended by police for drug-driving.

Identified measures and interpretation of the literature to address drug-driving among young-drivers:

- Interventions need to address the cultural normalisation of recreational drug use in club and rave settings.
- Greater use should be made of peer education approaches inside clubs and raves in disseminating drug-driving prevention information.
- Improving alternative transport options, including public transport, particularly at night.
- Effects of social sanctions including normative peer factors that can potentially dissuade individuals to drug-drive is important particularly given the relatively scant research in this area (compared to that for drink-driving) and the finding that peer group norms can sometimes negate the effects of deterrence.
- Context specific public education and distributed across appropriate social media channels. The public education should have direct links to specific drugs and factors underpinning the choice to a) consume drugs, and b) to then drive. A focus on the consequences of sanctions might also be useful for the young driver group in particular.

Target Group: Driver Gender

Key issues:

- Males more likely to be detected for drug-driving and to self-report driving under the influence of drugs than females (noting non-random nature of drug-driving test).
- Being male was associated with more frequent driving under the influence of cannabis, ecstasy and meth/amphetamines.
- Some evidence that males have a higher crash risk associated with driving under the influence of drugs than females.
- Male drug users were less likely than female drug users to implement strategies that they believed reduced the risks associated with drug-driving.
- Improved understanding of gender differences in drug-driving prevalence and crash risk.

Identified measures and interpretation of the literature to address drug-driving among males and females:

- Define and demonstrate to males in particular, the options available to avoid drug-driving, including pre-planning transport to-from social events.
- Highlight the consequences of crash-involvement and detection to both males and females, particularly in relation to the ability to be employed and the loss of social standing associated with sanctions.

Target Group: Dependent Drug Users

Key issues:

- Dependent drug users much more likely to drug-drive than infrequent drug users. Drug use dependency was consistently found to be a significant predictor of drug-driving behaviour, with drug-driving occurring more frequently as the level of drug dependency increased.
- Higher crash risk associated with dependent drug users especially in those receiving treatment.
- Dependent drug users were less likely than non-dependent drug users to implement strategies that they believed reduced the risks associated with drug-driving.
- Obtaining and/or dealing drugs was the primary reason for drug-driving.
- The need for the drug in heavily dependent drug users took precedence over concerns about being apprehended by police for driving impaired.
- High frequency cannabis users were more likely than low frequency cannabis users to perceive their own driving ability not to be impaired by cannabis use. This was particularly the case for dependent drug users.
- Dependent drug users never considered implementing any of the types of 'compensatory' behaviours implemented by recreational drug users, including waiting for the effects of the drugs to wear off and driving more slowly and/or carefully (noting the lack of efficacy of these latter mentioned approaches).
- Difficult to assess whether the higher crash risk is associated with acute or long-term use, or both, as most studies failed to control for acute use.

Identified measures and interpretation of the literature to address drug-driving among dependent drug users:

- Given the position that obtaining and using drugs occupies in their lives, it is likely that for most dependent drug users any attempt to change their drug-driving behaviour will only succeed in the context of changes in their drug use as a whole. This suggests that the most realistic approach may be to incorporate drug-driving interventions within drug treatment programs.
- Dependent drug users are unlikely to be deterred by a sanctions-based approach to drug-driving. This highlights the importance of treating drug-driving within the context of their overriding drug addiction problem. A combined health-based approach, supported by a potentially less punitive sanction-based approach, is likely to have greater success than a harsh sanction-based approach alone.

- Vehicle impoundment is likely to be effective in preventing this group from drug-driving, but only to the extent that these individuals do not engage in other criminal activities, including the theft of motor vehicles, or driving whilst unlicensed or using other vehicles belonging to others.

Target Group: Polydrug Users

Key issues:

- Polydrug use and driving is associated with a higher crash risk than taking single drugs in isolation especially when combined with alcohol.
- Polydrug use was consistently found to be a significant predictor of drug-driving behaviour, with drug-driving occurring more frequently as the number of drugs used increased.

Identified measures and interpretation of the literature to address drug-driving among polydrug users:

- Need to highlight increased risk of polydrug use (particularly when combined with alcohol use) and driving through appropriation educational messages. This can be supported by combined sanctions, as is the case in Victoria (alcohol + illicit drugs being present).

Target Group: Frequent Drug Users (Not dependent on drugs)

Key issues:

- More frequent drug use and driving is associated with a higher crash risk than less frequent drug use and driving.
- Drug use frequency was consistently found to be a significant predictor of drug-driving behaviour, with drug-driving occurring more frequently as levels of drug usage increased.
- Frequency of drug use consistently emerged as the strongest predictor of drug-driving in the small number of studies examining multiple predictors of drug-driving including perceptions of deterrence; perceptions of crash risk; peer group perceptions and behaviour; deviance and defiance and having a criminal history; and perceptions of driving impairment.

Identified measures and interpretation of the literature to address drug-driving among frequent drug users:

- Interventions that reduce levels of drug use or dependence may have flow on effects in terms of reducing driving under the influence of drugs.
- Increased testing, supplemented by public education programs, may be effective for this group as specific deterrence may be most effective for these individuals reducing drug-driving. The transition to dependent users is a risk for these individuals.
- This group could benefit by improved access to alternative transport means.
- These findings present a serious challenge for drug-driving enforcement as they suggest that past behaviours may be negating the deterrent impact suggested to stop the offending behaviour (i.e. punishment avoidance). However heavy drug users do however comprise a smaller proportion of the population than recreational drug users but may pose a greater risk due to increased exposure (or driving) whilst under influence of illicit substances.

Target Group: Commercial Vehicle Drivers (Mostly truck)

Key issues:

- The main reasons for drug-driving were to reduce fatigue. Drug-driving also occurred as a consequence of addiction problems, for socialisation and/or to fit the trucking image; or for relaxation/to feel good.

Identified measures and interpretation of the literature to address drug-driving among commercial vehicle drivers:

- Better management practices within the workplace safety culture, including routine drug-testing at the company level.
- Address unsafe norms associated with the trucking culture (note: need to examine association between organizational issues such as pay types and scheduling and drug-use).

- Treatment of drug addiction.
- Targeting of drivers both from an enforcement perspective, but also from a health-perspective by identifying the long-term risks associated with drug-use.

Target Group: Sensation-Seekers

Key issues:

- Sensation-seeking was consistently shown to be predictive of drug-driving. Those who scored high on the measure of sensation-seeking were significantly more likely to report driving under the influence of drugs than those who scored low on the measure of sensation-seeking.

Identified measures and interpretation of the literature to address drug-driving among drivers with high predisposition of sensation-seeking:

- Media campaigns promoting traffic safety tend to emphasize rational decision-making processes involved in driving. However, personality factors such as sensation-seeking can modulate these cognitive processes, leading high-risk individuals to be insensitive to such interventions. High sensation seekers tend to be more receptive to messages with high sensation value or inducing high stimulation. It is therefore important that media campaigns strike a balance between arousing and educational messages.
- Programs designed to address issues of impulsivity and behavioural urgency are likely to be effective, perhaps not in the consumption of drugs among this group but taking the next step to drive. Behavioural and physical interventions such as denying access to vehicles at certain times through time release lock boxes for car-keys (for example), or engaging age-appropriate mentors could be an effective, additional intervention for this group.

Target Group: Persons with Criminal Convictions

Key issues:

- Defiance-type behaviours and deviance were significantly predictive of intentions to drug-drive, as was having a criminal record.

Identified measures and interpretation of the literature to address drug-driving among persons with criminal convictions:

- Persons with criminal convictions are unlikely to be deterred by a sanctions-based approach to drug use and drug-driving, highlighting the importance of treating drug-driving within the context of their overriding criminal behaviour.
- It is the case that a small sub-set of drivers have had a high degree of contact with the criminal justice system. This group might benefit from more intensive monitoring of car-based offences, with proactive licensing management with broader support and input where appropriate. Technology-based solutions (i.e., in-vehicle, person-based monitoring) may provide an important basis for improving the drug-use and associated drug-driving behaviour of this group.
- Vehicle impoundment may be effective for this group, but only to the extent that they do not engage in other criminal activities, including the theft of motor vehicles, or driving whilst unlicensed or other unregistered vehicles.

Target Group: Persons with Mental Health Concerns

Key issues:

- In general, there was a significant relationship between measures of health and wellbeing and drug-driving behaviour, although this was measured in different ways across the studies. Those who drove under the influence of drugs showed more evidence of mental health problems than those who did not report driving after drug use.

Identified measures and interpretation of the literature to address drug-driving among persons with identified mental health concerns:

- Persons with mental health issues are unlikely to be deterred by a sanctions-based approach to drug use and drug-driving, highlighting the importance of treating drug-driving within the context of their mental health issues.
- Once detected, a therapeutic-justice model is likely to be more successful than a sanctions-based model.
- Health professionals can play a proactive role with respect to safe driving, with support from the relevant road authority.

Target Group: Drug-Users / Known Drug-Drivers (Generic)

Key issues:

- Drug-driving was motivated by functional reasons (where it was seen as part of the driver's every day or normal activity) rather than for the sole purpose of enjoyment and/or thrill seeking.
- Most drug-drivers perceived that nothing would deter them from drug-driving.
- When asked to suggest the extent to which a number of factors would affect their decision to drug-drive, most drug-drivers perceived that the risk of being apprehended by police was the biggest deterrent.
- A fear of crashing or injuring someone else was the biggest perceived deterrent for drug users who did not drive under the influence of drugs.
- Most respondents perceived that the risk of being caught for drug-driving was 'very unlikely' or 'unlikely'.
- There was little difference in the proportion of respondents who perceived the risk of being apprehended by police for driving under the influence of cannabis, ecstasy and methamphetamine was 'very unlikely' or 'unlikely'.
- 43% of Victorians reported that they had changed their behaviour since the introduction of roadside drug testing. The most commonly reported changes were not driving after using drugs, waiting longer before driving, taking a taxi, and arranging an alternative driver.
- It has been proposed that when an individual perceives the certainty of apprehension as high, the punishment as severe, and the administration of punishment as swift then the likelihood of illegal behaviour will be deterred. However, perceived certainty, severity or swiftness of sanctions were generally not significant predictors of self-reported drug-driving behaviour or intentions to drug-drive in future. Direct punishment avoidance (i.e., having avoided apprehension by police) and vicarious punishment avoidance (i.e., knowing of others that have avoided apprehension by police) were found to be significant predictors of reported intentions to drug-drive in future.
- In some studies, perceptions regarding what one's peers thought about drug-driving were stronger predictors of drug-driving than perceptions about the likelihood of being apprehended by police for drug-driving.
- Most drug-drivers were less likely to perceive that cannabis, ecstasy or meth/amphetamine had a positive effect on driving skill, but such an effect was still consistently reported.
- Over half of respondents perceived the risk of crash involvement to be 'very unlikely' or 'unlikely' for cannabis, ecstasy, and methamphetamine.
- A higher perception of crash risk associated with drug use and driving was consistently found to be associated with a lower likelihood of driving under the influence of drugs.
- Strategies to reduce drug-driving were generally not common (cited by less 50% of drivers).
- Drivers were less likely to report using strategies that involved avoiding drug-driving altogether.

- Drivers were more likely to implement a range of potentially unreliable/unproven methods including eating or drinking; driving more slowly; concentrating more; taking the back streets; limiting the number and/or quantity of drugs taken or waiting for effects to disappear/decrease before driving.
- Overall, knowledge of drug use and its effects on driving performance is poor. Alcohol was the only substance for which the majority knew 'a lot' or 'quite a lot' about its effects on driving ability.

Identified measures and interpretation of the literature to address drug-driving among, among all drug-users:

- There is a need to capitalise on enforcement and publicising enforcement given it is currently the largest perceived deterrent for drug-drivers.
- Drug-driving interventions need to consider factors beyond drug use frequency and legal risk perceptions which are strongly linked to drug-driving behaviour, particularly as these have been found to negate the effectiveness of legal sanctions.
- Need to address crash risks in education programs and publicity campaigns.
- Education needed to dispel myths around the effectiveness of strategies to reduce risks associated with drug use and its impact on driving.

Target Group: Methamphetamine Users

Key issues:

- Methamphetamine is the most commonly detected drug in studies of roadside drug testing (note: higher detection rates may reflect the ability of roadside screening technology to better detect methamphetamine compared to cannabis).
- Methamphetamine is associated with a higher crash risk than other drugs.
- Drivers were more likely to perceive that amphetamine/methamphetamine improved their driving ability compared to cannabis and ecstasy.
- The small proportion of drivers who reported on how methamphetamine could improve their driving said that the drug increased alertness and awareness and made them more considerate of others.
- Perception by most drug-drivers surveyed/interviewed that meth/amphetamine has no impact on driving ability.
- Over half of respondents perceived the risk of crash involvement associated with driving under the influence of meth/amphetamine to be 'very unlikely' or 'unlikely'.
- Perceptions of the risk of crash involvement increased among regular ecstasy users between 2007 and 2011 in Australia for driving under the influence of methamphetamine. This change was consistent with reductions in reports of driving under the influence of methamphetamine.
- Perceptions of the likelihood of being apprehended for drug-driving increased between 2007 and 2011 for methamphetamine.
- Low legal risk perceptions were associated with increased risk of driving under the influence of methamphetamine.

Identified measures and interpretation of the literature to address drug-driving associated with Methamphetamine / Amphetamine use:

- See below – combined discussion with MDMA

Target Group: Ecstasy (MDMA) Users

Key issues:

- Perception by most drug-drivers surveyed/interviewed that ecstasy has no impact or a slightly worse impact on driving ability.
- Drivers under the influence of ecstasy argued that the drug made them feel more alert and aware of their surroundings and improved their reflexes and concentration.
- The less concerned respondents were about the impairing or dangerous effects of ecstasy on driving, the more likely they were to drive under the influence of ecstasy.
- Perceptions of the risk of crash involvement increased among regular ecstasy users between 2007 and 2011 in Australia for driving under the influence of ecstasy. This change was consistent with reductions in reports of driving under the influence of ecstasy.
- Perceptions of the likelihood of being apprehended for drug-driving increased between 2007 and 2011 for ecstasy.
- Low legal risk perceptions were associated with increased risk of driving under the influence of methamphetamine.

Identified measures and interpretation of the literature to address drug-driving associated with Methamphetamine / Amphetamine / MDMA use:

- Education to dispel misperceptions around the impact of meth/amphetamine on driving performance.
- The increase in the perception of being apprehended for drug-driving, given that some studies have linked reductions in the prevalence of drug-driving with enforcement and/or education / mass media campaigns. Of note however was that a causal link between attitude change and drug-driving prevalence was not established in these studies. Accordingly, prevention strategies should target both attitude and behaviour change simultaneously.
- The increase in perceived likelihood of police apprehension for drug-driving and the changes in behaviour since the introduction of roadside drug testing suggests that enforcement has some effect on general deterrence and should be expanded.
- Education campaigns need to communicate the message that drug-drivers will be caught since increased perceptions of apprehension were associated with abstaining from drug-driving.

Target Group: Cannabis Users

Key issues:

- Cannabis most commonly reported drug to drive under the influence of (self-report studies).
- Cannabis use associated with a lower crash risk than meth/amphetamine use.
- Meta-analysis demonstrates a statistically significant increase in crash-risk, and of being culpable, associated with cannabis use.
- Perception by most drug-drivers surveyed that cannabis has no impact on driving ability.
- Cannabis was more likely than other drugs to be perceived as having no impact on driving ability and to be rated as 'not at all dangerous'.
- Cannabis was perceived to encourage slower and more cautious driving and improve concentration and alertness.
- Drivers under the influence of cannabis were more likely to ascribe higher levels of impairment to others than to themselves, and most believed they had ways to compensate for at least some of the potentially impairing effects of the drug.
- The less concerned respondents were about the impairing or dangerous effects of cannabis use on driving, the more likely they were to drive under the influence of cannabis.

- Over half of respondents perceived the risk of crash involvement associated with driving under the influence of cannabis to be 'very unlikely' or 'unlikely'.
- Jones et al (2006) examined the impact of providing factual information about drug use and crash risk on willingness to drug-drive in participants who had driven within one hour of cannabis use and who believed that driving under the influence of cannabis on its own either reduced or did not affect their risk of accident. They found that very few participants (less than ten percent) would be unlikely to drive if they could be convinced of the facts about risks.
- Perceptions of the risk of crash involvement increased among regular ecstasy users between 2007 and 2011 in Australia for driving under the influence of ecstasy and methamphetamine but no change in perceptions were evident over this period for cannabis or alcohol. These changes were consistent with reductions in reports of driving under the influence of these substances.
- Perceptions of the likelihood of being apprehended for drug-driving increased between 2007 and 2011 for ecstasy and methamphetamine, but not for cannabis or alcohol.

Identified measures and interpretation of the literature to address drug-driving associated with cannabis use:

- Need to challenge the prevailing perception among drug-drivers that it is safe (or relatively safe) to drive under the influence of cannabis. Research demonstrates that users who regard their own drug-driving as unproblematic are unlikely to be receptive to preventive measures; this sub-group do not see these measures as applying to themselves.
- The messages delivered via education and education campaigns need to be based on the observed the contribution of cannabis to accident risk, referring to actual percent increases rather than descriptions of the size of the increased risk (e.g., moderate).
- The implications of polydrug use on crash risk needs to be communicated explicitly, particularly with respect to alcohol given it is commonly used in combination with cannabis and the demonstrated higher crash risk associated with combined use.
- In the absence of clear messaging on this, drug-drivers will likely base their decision to drug-drive according to their own perceptions of risk. This is important as cannabis is currently perceived to be the least dangerous drug.
- Roadside drug-driving enforcement needs to be maintained and continue to be highly publicised. This links to general deterrence.
- The poor deterrent effect associated with education for cannabis users may point to great shortcomings in the current state or impact of education and prevention efforts or may reflect a self-serving bias whereby people overestimate their own abilities relative to others (similar to the tendency for people to rate themselves as above average drivers). This effect is more commonly observed in high frequency drug users and requires careful consideration in the development of any effective education campaigns.
- Informing cannabis users of the implications of sanctions is likely to be effective, particularly if designed with age-appropriate content and delivered through appropriate channels (print, social media, radio, stress-press and so on).

6.6 CONCLUSION

This chapter aimed to provide an overview of countermeasures aimed at reducing drug-driving. The identified countermeasures can be based on legislation, enforcement, education-related, and specialized behaviour change programs, including health-based (addiction) treatment programs. The efficacy of these countermeasures in reducing drug-driving is poorly understood. Taking the lead from drink-drive programs, legislation and enforcement approaches represent the core plank in current deterrence regimes. Given the nature of drug-use, including addiction, and differences across the type of substances used with respect to acute intoxication and impairment (among other factors), adopting a range of strategies will be required in addressing drug-drive behaviour. To this end, key issues relating to a range drug-use and drug-driving sub-groups are outlined, against which potential countermeasures are presented. In the absence of evidence, there is a need to explore – and evaluate, a range of these measures so that effective policy decisions can be made in the long-term.

7 CONCLUDING STATEMENT

This report provides a detailed analysis of recent published literature on drug-driving. The purpose of this review was to provide the basis of future policy actions, and also to contextualise Report 2 (analysis of offence and crash data) and Report 3 (drug and alcohol specialists, community survey) conducted under the MUARC Baseline Illicit Drugs and Driving Project.

While the report presents a range of measures to address drug-driving among drug-driving sub-groups, these need to be considered in the context and nature of drug use among drivers in a particular jurisdiction. This is particularly pertinent in the context of the clear differences in crash risks of different illicit drugs. The high increased crash risk associated with amphetamine use and use of other stimulants is not controversial. Given the magnitude of the increased crash risk, the negative impacts on road safety are likely to be significant even in the context of a small number of users.

As a contrast, the crash risk associated with cannabis – whilst inflated, is nonetheless lower than for example amphetamines-and-related substances. While there has been considerable debate in the academic literature concerning the magnitude of the increased crash risk associated with cannabis use, there is no such disagreement that cannabis use is in fact associated with a higher crash risk compared to non-use. The implication is that combined with the larger cannabis user base, cannabis-affected driving poses as a significant threat to achieving reductions in road trauma. In turn, this has important implications when considering in the design of enforcement and other intervention programs.

While this report did not examine the technical aspects of roadside illicit drug detection, we make the point here that the detection threshold settings of both saliva screening and blood are critical to understand, as is the relationship of detectable levels and crash risk. Related to this is the technical aspects of drug pharmacokinetics, the time-course of impairment and elimination from the body, which differs for each particular substance. Public education programs addressing these concepts, whilst highly technical, would likely see an improved understanding of the rationale of roadside drug-testing laws.

Given the findings of this review, future policy actions would be well served to consider the nature of drug use, preferences of users and their motivations for use, as well as their geographic distribution in the community in designing road safety and associated health-related harm minimisation and judicial programs. Indeed, multi-component programs that incorporates high levels of general and specific drug-driving deterrence, as well as a range of treatment and rehabilitation options post-detection based on the broad concept of therapeutic justice, will be required to successfully address drug-driving behaviour.

Finally, we assert that a 'one-size-fits-all' approach will be less successful than a flexible system that accounts for individual differences in motivations for using drugs, the types of substances used, and the broader health needs of a subset of chronic and/or dependent drug users.

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APPENDIX A KEY SEARCH CONCEPTS AND TERMS

How prevalent is drug-driving in Victoria and Australia and what is the prevalence of drugs in fatal and serious injury crashes in Victoria and Australia?

Concept 1 Drugs	Concept 2 Driving	Concept 3 Prevalence	Concept 4 Victoria/Australia
Drug*	Driv*	Prevalen*	Victoria
Methamphetamine*	Rid*		Australia
Ice	Cycl*		
Cannabi*	Motorcycl*		
Marijuana			
THC			
Dronabinol			
MDMA			
N-Methyl-3,4-methylenedioxyamphetamine			
Ecstasy			
Cocaine			
Amphetamine*			

What are the trends and patterns associated with drugs and driving in Victoria and Australia?

Concept 1 Drugs	Concept 2 Driving	Concept 3 Trends	Concept 4 Victoria/Australia
Drug*	Driv*	Trend*	Victoria
Methamphetamine*	Rid*	Pattern*	Australia
Ice	Cycl*		
Cannabi*	Motorcycl*		
Marijuana			
THC			
Dronabinol			
MDMA			
N-Methyl-3,4-methylenedioxyamphetamine			
Ecstasy			
Cocaine			
Amphetamine*			

What is the crash risk associated with drugs and driving?

Concept 1 Drugs	Concept 2 Driving	Concept 3 Crash	Concept 4 Risk
Drug*	Driv*	Crash*	Risk*
Methamphetamine*	Rid*	Accident*	
Ice	Cycl*	Collision*	
Cannabi*	Motorcycl*	Collid*	
Marijuana			
THC			
Dronabinol			
MDMA			
N-Methyl-3,4-methylenedioxyamphetamine			
Ecstasy			
Cocaine			
Amphetamine*			

What are the attitudes, motivations and perceptions associated with drug-driving among those who take drugs and drive?

Concept 1 Drugs	Concept 2 Driving	Concept 3 Attitudes
Drug*	Driv*	Attitude*
Methamphetamine*	Rid*	Motiv*
Ice	Cycl*	Perce*
Cannabi*	Motorcycl*	Belie*
Marijuana		Perspective*
THC		
Dronabinol		
MDMA		
N-Methyl-3,4-methylenedioxyamphetamine		
Ecstasy		
Cocaine		
Amphetamine*		

What countermeasures are in place or being proposed to prevent drug-driving and drug-driving related trauma?

Concept 1 Drugs	Concept 2 Driving	Concept 3 Countermeasures
Drug*	Driv*	Countermeasure*
Methamphetamine*	Rid*	Education
Ice	Cycl*	Sanction*
Cannabi*	Motorcycl*	Campaign*
Marijuana		Enforce*
THC		Legislat*
Dronabinol		Intervention*
MDMA		
N-Methyl-3,4-methylenedioxyamphetamine		
Ecstasy		
Cocaine		
Amphetamine*		

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APPENDIX B PUBLICATIONS EXAMINED AND SEARCH STRATEGIES

The total number of publications identified for each research question is given below in Table 8.1, with totals shown separately for each stage of the search (automatic removal of duplicates, manual removal of duplicates, and removal of irrelevant/ineligible papers based on title and abstract screening). See Figures 8.1-8.3 for details of the search and review process according to the PRISMA-P protocol for Research Questions 1-3.

TABLE B.1 NUMBER OF PUBLICATIONS RETURNED FROM THE SYSTEMATIC LITERATURE SEARCH FOR EACH RESEARCH QUESTION

Database	Q1 Prevalence	Q2 Trends & Patterns	Q3 Risk	Q4 Attitudes	Q5 Countermeasures
Compendex	15	51	146	886	886
Scopus	20	10	2,414	473	473
OVID Medline	53	75	553	6,371	6,371
OVID Transport	19	14	411	618	618
Cochrane Library	1	2	9	122	122
Informit	237	399	354	1,815	1,815
Web of Science	108	143	977	23,102	14,286
EBSCO Host	216	548	856	23,243	17,109
EMBASE	127	199	2,042	34,218	23,803
PsycInfo	14	26	251	2,467	1,695
TRID	70	56	907	2,005	1,624
Total articles	880	1,523	8,920	97,904	68,802
Total articles after duplicates removed					
Automated	592	1,097	6,594	56,114	43,117
Manual	469	944	5,497		
After screening on title and abstract	38	63	49		

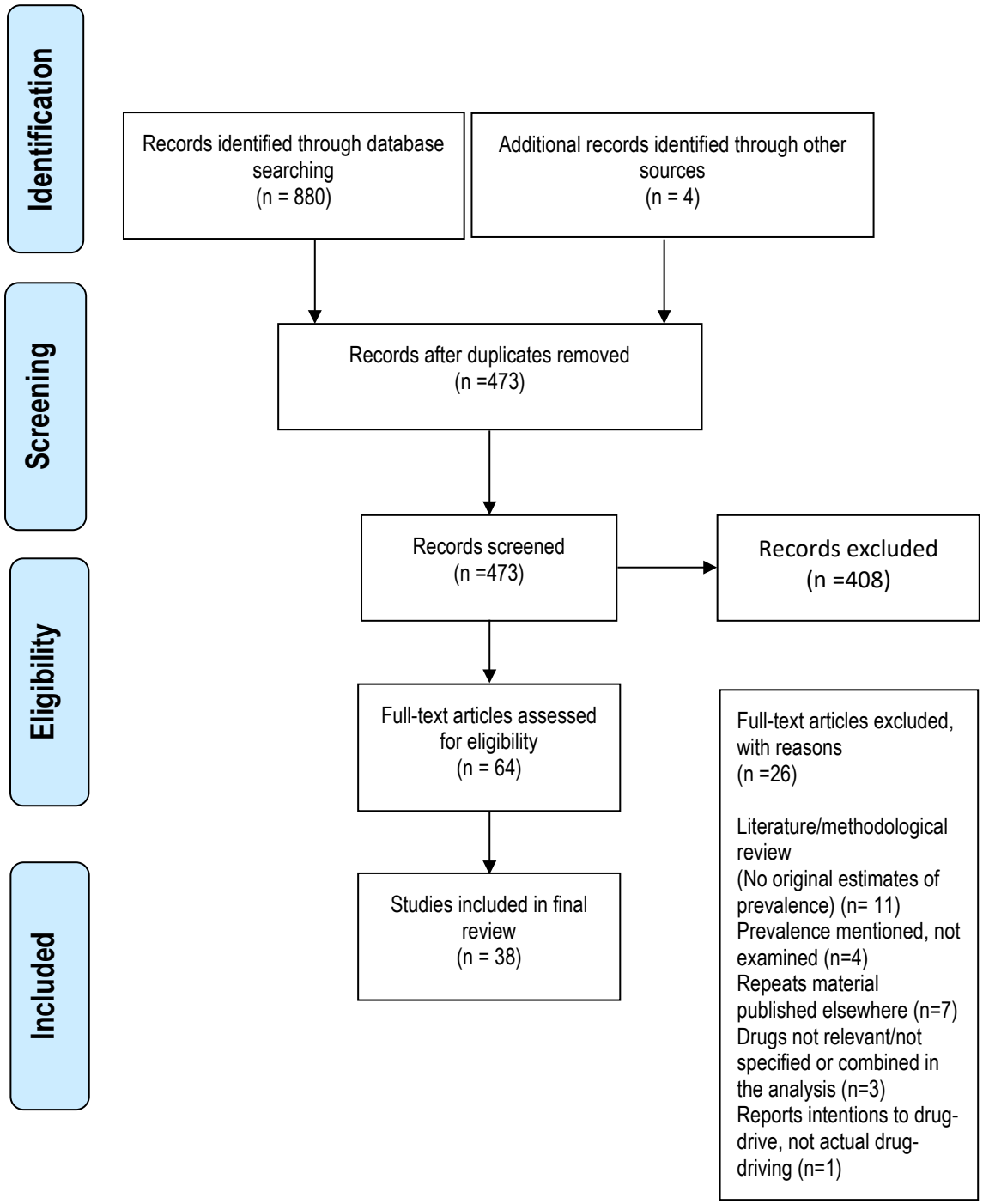

FIGURE B.3 PRISMA FLOW DIAGRAM. PUBLICATION IDENTIFICATION, SCREENING, ELIGIBILITY AND INCLUSION FOR PREVALENCE OF: DRUG USE, DRUG-DRIVING AND DRUG-DRIVING CRASHES, VICTORIA AND AUSTRALIA

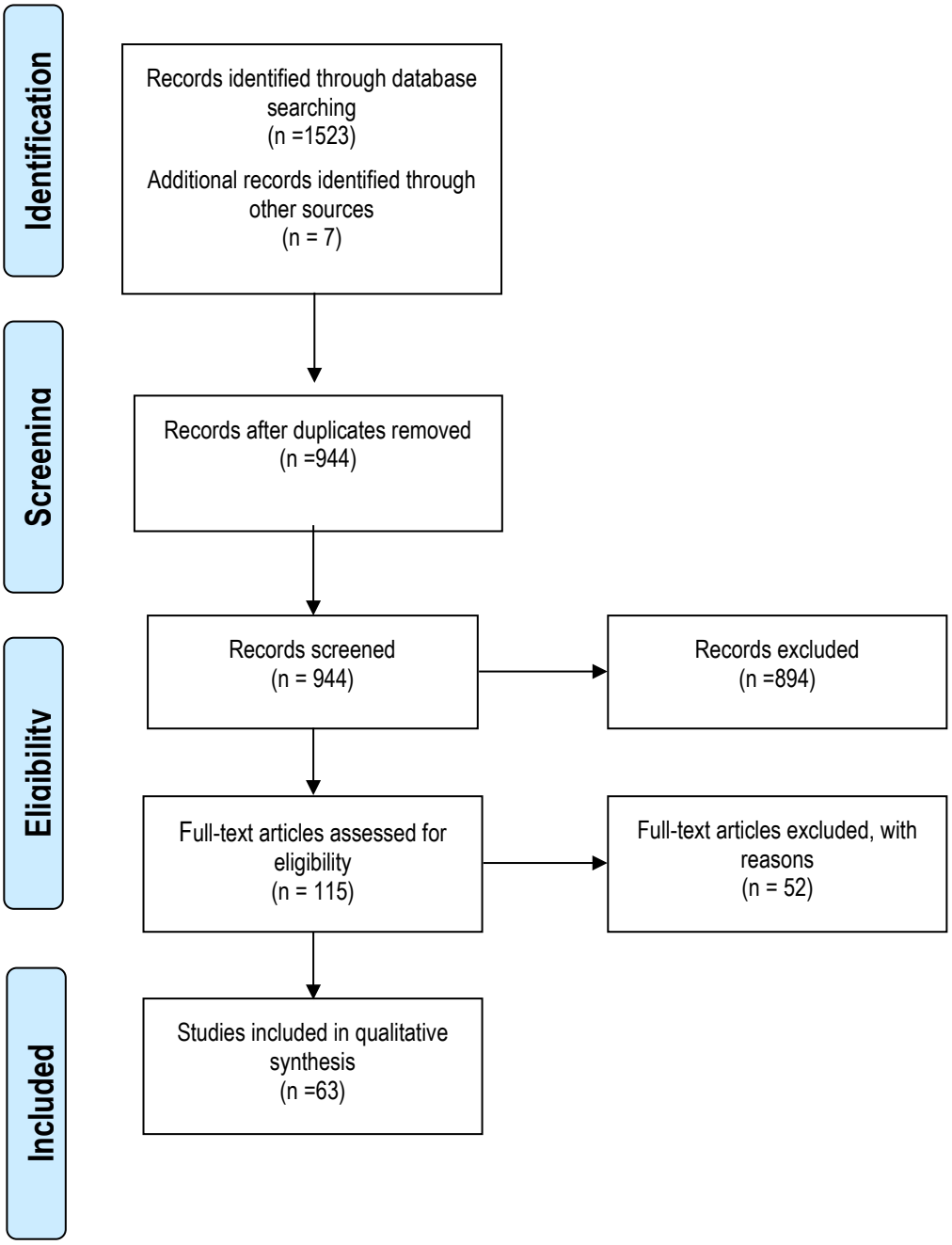

FIGURE B.4 PRISMA FLOW DIAGRAM. PUBLICATION IDENTIFICATION, SCREENING, ELIGIBILITY AND INCLUSION FOR TRENDS AND PATTERNS ASSOCIATED WITH DRIVING UNDER THE INFLUENCE OF DRUGS, VICTORIA AND AUSTRALIA

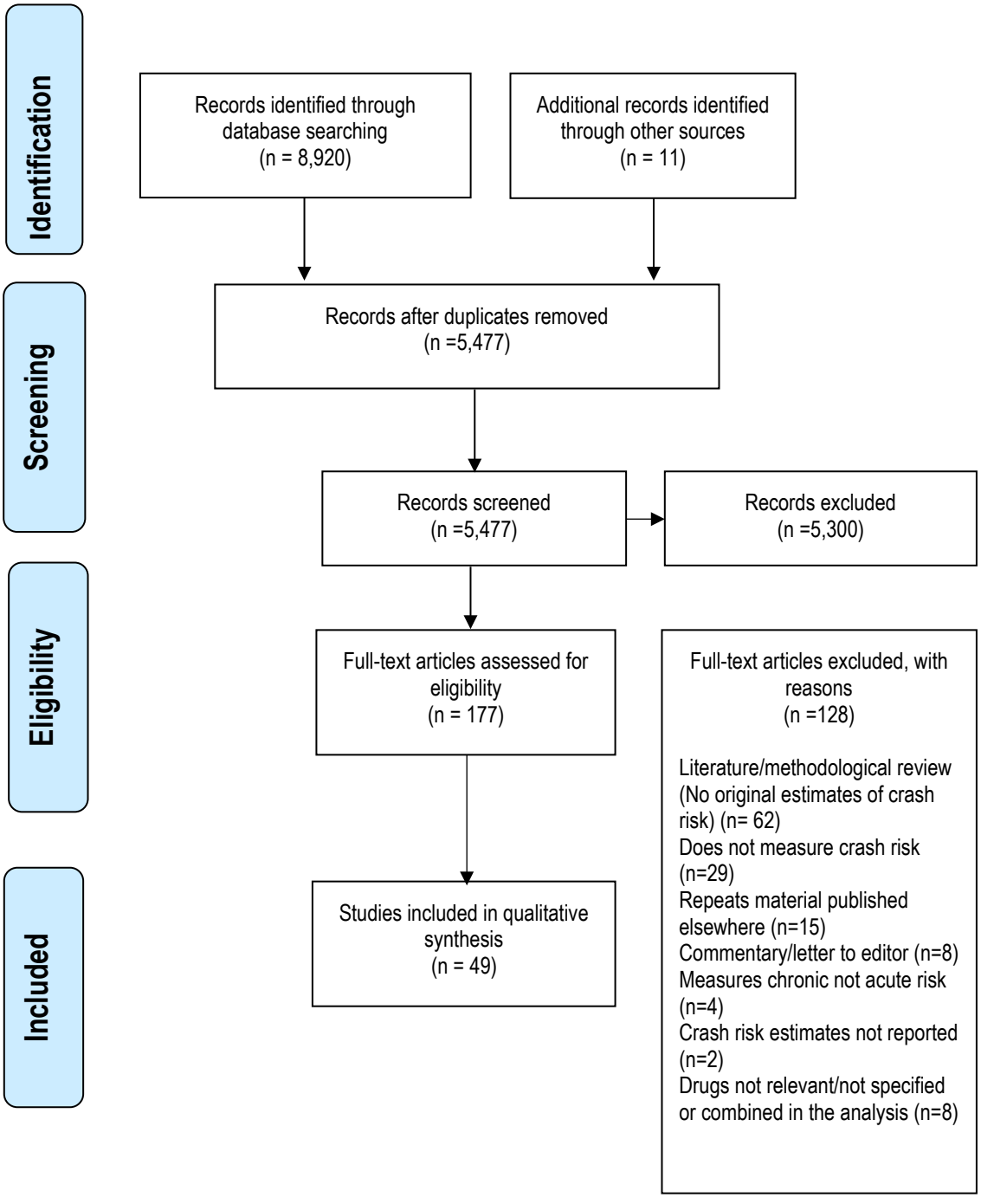

FIGURE B.5 PRISMA FLOW DIAGRAM. PUBLICATION IDENTIFICATION, SCREENING, ELIGIBILITY AND INCLUSION FOR CRASH RISK ASSOCIATED WITH DRIVING UNDER THE INFLUENCE OF DRUGS

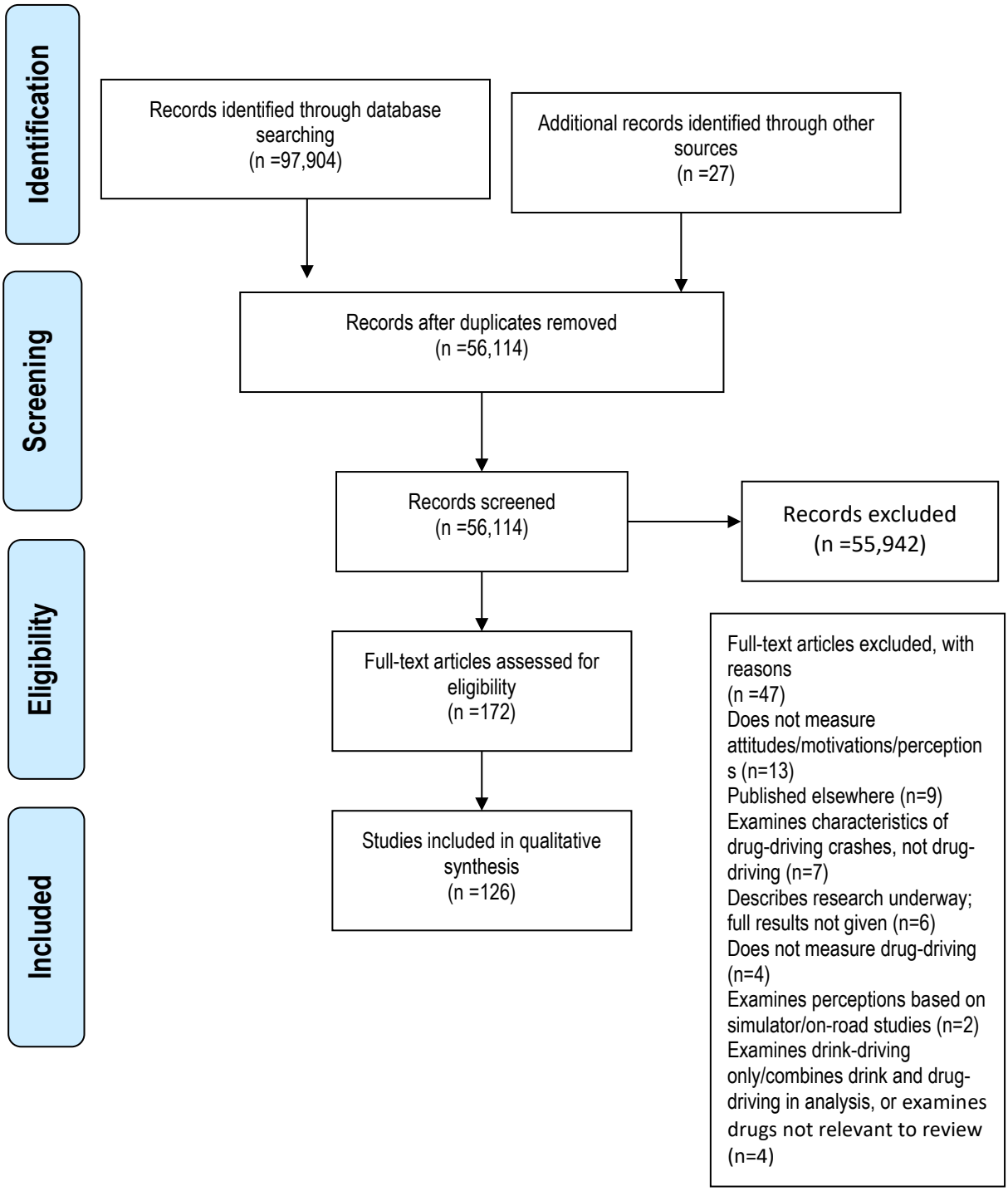

FIGURE B.6 PRISMA FLOW DIAGRAM. PUBLICATION IDENTIFICATION, SCREENING, ELIGIBILITY AND INCLUSION FOR ATTITUDES, MOTIVATIONS AND PERCEPTIONS ASSOCIATED WITH DRUG-DRIVING IN THOSE WHO TAKE DRUGS AND DRIVE

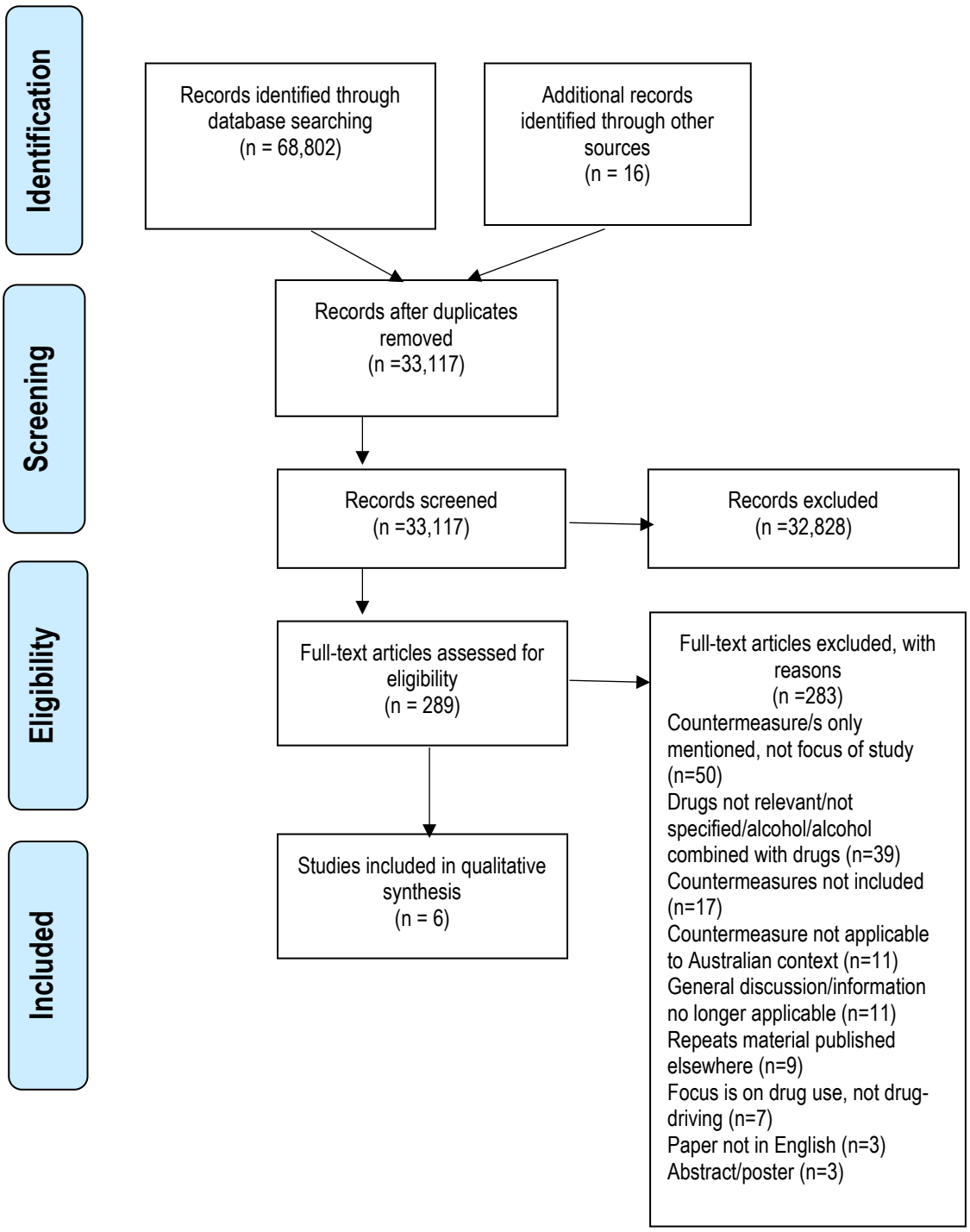

FIGURE B.7 PRISMA FLOW DIAGRAM. PUBLICATION IDENTIFICATION, SCREENING, ELIGIBILITY AND INCLUSION FOR COUNTERMEASURES TO PREVENT DRUG-DRIVING AND DRUG-DRIVING RELATED ROAD TRAUMA

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APPENDIX C LITERATURE ON CRASH RISK (CHAPTER 4)

TABLE C.1 SUMMARY OF STUDIES EXAMINING THE IMPACT OF CANNABIS USE ON CRASH RISK (1995-2015)

Case-Crossover						
Author/s, Year, Location	Method and Sample	Data Source	Other Substances Assessed	Covariates	Key Findings	Limitations
Asbridge et al. (2014a) Canada	Case-crossover study 393 seriously injured cyclists in crash	Blood samples (active THC metabolite > 0.2 ng/ml) or questionnaire (self-reported drug use 6 hours before collision)	Alcohol	Benzodiazepines, cocaine	Two-fold increase in risk of injury collision (OR 2.38, 95% CI 1.04 – 5.43) Nine-fold increase in risk of injury collision (OR 9, 95% CI 2.09-38.8) based on blood results only No significant association with self-report measures only Crash risk was not increased when using frequency of RUI in last 6 months as control measure	Discrepancy between blood and self-report cannabis risk estimates call into question validity of results (pre-crash substance use rates were higher in biological samples than self-report and there was mismatch in some cases between the two measures. If under reporting is restricted to case period, then the estimates of association between cannabis use and crash risk would be conservative Control used self-report measures only while cases used both self-report and biological measures If under reporting occurred in controls then the association would be over-estimated (removal of discordant estimates resulted in a non-significant association) Key covariates not controlled for including age, sex, driving experience and behaviour
Asbridge et al (2014b) Canada	Case-crossover study 860 seriously injured drivers in crash	Blood samples (active THC metabolite > 0.2 ng/ml) or questionnaire (self-reported drug use 6 hours before collision)	Alcohol	Benzodiazepines, cocaine	Four-fold increase in risk of injury collision (OR 4.11, 95% CI 1.98 – 8.52) No significant association with self-report measures only Collision risk was higher when cannabis was used with other drugs (alcohol, benzos and cocaine) (OR 6.30; 95% CI 3.23-12.3)	As above

Case-Control Studies

Author/s, Year, Location	Method and Sample	Data Source	Other Substances Assessed	Covariates	Key Findings	Limitations
Dubois et al. (2015) USA	Cases: 4,347 fatally injured drivers with at least one potentially unsafe driving action (UDA) recorded in relation to the crash (e.g., weaving) Controls: unspecified number without a potentially unsafe driving action (UDA) recorded in relation to the crash	Blood (THC levels not specified) Driver crash data from Fatality Analysis Reporting System (FARS) From this dataset proxy measures of responsibility were derived (i.e., presence of one or more unsafe driver actions)	Analysed: Depressants, narcotics, stimulants, hallucinogens, PCP, anabolic steroids, inhalants Assessed: Alcohol	Age, sex, alcohol, polydrug use (drugs not specified), and previous driving record	Drivers positive for both alcohol and cannabis had greater odds of making an error than drivers positive for either alcohol or cannabis only. Each 0.01 BAC unit increased the odds of an UDA by approximately 9–11%. Drivers positive for THC alone had 16% increased odds of an UDA. When alcohol and THC were combined the odds increased by 8-10% for each 0.01 BAC unit increase over alcohol or THC alone.	FARS database does not show concentration level at the time of crash, or dosage level, only a dichotomous marker of THC presence. However, THC can remain in the blood for hours or even days which increases the possibility that some drivers testing positive for THC were not impaired resulting in an underestimation of the true culpability odds. Given the increasing use of THC for medicinal purposes, some of the increase in crash risk associated with culpability may reflect other health conditions which were not controlled for Impossible to determine the time of marijuana use relative to the crash in the FARS database Time between crash and blood sampling not specified FARS does not record all drug findings in the database so other drug use was not controlled for
Compton & Berning (2015) Virginia Beach, USA	Cases: 3,095 crash involved drivers (all severity) Controls: 6,190 matched non-crash involved drivers in normal traffic	Oral fluid and blood samples (THC) (details not provided on whether equivalent cut off concentrations were used)	Analysed: Alcohol, anti-depressants, opioids, stimulants, sedatives Assessed: Anti-depressants, opioids, stimulants, sedatives	Age, gender, geographical area, season of the year, time of day or week, alcohol	No significant increase in crash risk for drivers testing positive to cannabis (OR 1.05, 95% CI 0.86-1.27)	Localised sample of crashes with low generalisability Bias towards less severe crashes

Case-Control Studies

Author/s, Year, Location	Method and Sample	Data Source	Other Substances Assessed	Covariates	Key Findings	Limitations
Romano et al (2014) USA	Cases: 1,766 killed drivers (participation unknown) from Fatality Analysis Reporting System (FARS) Controls: 3,424 drivers in normal traffic (71.7% participated) from the 2007 Roadside Survey	Alcohol: blood or breath Drugs: blood (THC) or urine (cases), oral fluid (controls)	Analysed: Alcohol, amphetamines, antidepressants, antihistamines, benzodiazepines, carisoprodol, cocaine, ecstasy, ketamine, opioids, z-hypnotics Assessed: Opioids, stimulants	Age, ethnicity, sex, alcohol	No significant increase in fatal crash risk for drivers testing positive to cannabis (adjusted results not reported) Unadjusted OR was significant: 1.55 (95% CI 1.42-1.94)	FARS has limitations that do not allow calculation of reliable estimates of crash risk due to inconsistencies in drug testing between states, a bias in selecting cases for drug testing (only half of all fatal drivers are tested for drugs), failure to record all drug findings in the database, and lack of uniformity in drug testing methods (blood/urine for cases and oral fluid for controls) – urine Equivalent cut off concentrations not used - FARS does not show concentration level at time of crash, or dosage level, only a dichotomous marker of THC presence Time between crash and blood sampling not specified – not possible to determine the time of marijuana use relative to the crash in the FARS database
Li et al (2013) USA	Cases: 737 killed drivers (35.6% participated) from Fatality Analysis Reporting System (FARS) Controls: 7,719 drivers in normal traffic (70.7% participated) from the 2007 Roadside Survey	Alcohol: blood or breath Drugs: blood or urine (cases), oral fluid (controls) (levels not specified)	Assessed: Opioids, stimulants, multiple drug use Analysed: amphetamines, alcohol, antidepressants, antihistamines, benzodiazepines, carisoprodol, ecstasy, ketamine, opioids, z-hypnotics	Age, geographical area, sex, time of day or week	Estimated odds ratios of fatal crash involvement 1.83 (95% CI 1.39-2.39) Higher risk for both alcohol and drug use relative to non-alcohol and drug use but risk estimates for individual drugs were not reported	As above

Case-Control Studies

Author/s, Year, Location	Method and Sample	Data Source	Other Substances Assessed	Covariates	Key Findings	Limitations
Beirness et al (2013), Canada	Cases: 902 fatally injured drivers (unknown participation) Controls: 4,711 (68.4% participation)	Alcohol: Blood or Breath Drugs: Blood (Cases) Oral fluid (Controls)	Substances analysed: Alcohol, amphetamines, opioids		Significant OR of 4.95 (95% CI 3.70-6.62)	The study is not very well described and the cut-off concentrations in oral fluid for controls and blood for cases were most likely not equivalent
Gjerde et al (2013), Norway	Cases: 508 killed car/van drivers (61% participation) Controls: 9261 drivers in normal traffic (94% participation)	Cases: Blood Controls: Oral fluid Equivalent cut-off concentrations used between case and control samples	Analysed: Alcohol, amphetamines, benzodiazepines, cocaine, ecstasy, opioids, z-hypnotics Assessed: Amphetamines, benzodiazepines, multiple drug use, z-hypnotics	Age, geographical area, season, sex, time of day or week	No significant association for use of THC alone (OR 1.9, 95% CI 0.8-4.6) but significant increase in risk with cannabis in combination with other drugs (specific drug types not specified) (OR 8.9, 95% CI 5.2-15.4)	Confounding factors related to risk-taking personality traits could not be adjusted for in the analysis. 40% of drivers killed in crashes were not included in the study 6% of controls did not provide an oral fluid sample – assuming the proportion of drug and alcohol use in these drivers was higher than among controls who participated then the ORs might be an overestimate No data on crash culpability was available
Kuypers et al. (2012) Belgium (part of DRUID study)	Cases: 337 seriously injured car/van drivers (27% participated) Controls: 2,726 drivers in normal traffic (44.8% participated)	Alcohol: Breath Drugs: Blood (THC, 1 ng/ml, equivalent across cases and controls) collected not longer than 4 hours post-crash	Substances analysed: alcohol, amphetamines, benzodiazepines, cocaine, ecstasy, opioids, z-hypnotics Substances assessed: amphetamines, benzodiazepines, cocaine, multiple drug use, opioids, z-hypnotics	Age, sex, time of day or week	Significant OR for cannabis use 1- > 5 ng/ml (13.4, 95% CI 3.95-45.42) Non-significant OR for cannabis use 1-1.99 ng/ml Significant OR for cannabis use 2-4.99 ng/ml (OR: 24.83, 95% CI 2.58-238.93) and >/ 5 ng/ml, OR: 14.32, 95% CI 2.03-101.13)	Small sample size for some drugs High refusal rate for blood sample among controls (52%) leading to possible selection bias and an underestimation of the prevalence of drugs in the general driving population and an overestimation of the risk associated with particular drugs. Inspection of demographic variables of participants and refusers showed that there were significant differences between both groups

Case-Control Studies						
Author/s, Year, Location	Method and Sample	Data Source	Other Substances Assessed	Covariates	Key Findings	Limitations
Hels et al (2011) & Bernhoft et al (2012) DRUID Europe – 4 countries (Finland, Norway, Sweden & Portugal)	Cases: 1,112 killed car/van drivers (59 – 94.3% participated) Controls: 21,917 drivers in normal traffic (52-97% participated)	Alcohol: blood or breath. Drugs: Blood (cases) taken less than 3-hours post-crash Oral fluid (controls) Cut-off concentration not specified; equivalent across sample types	Substances analysed: alcohol, amphetamines, benzodiazepines, cocaine, ecstasy, opioids, z-hypnotics Substances assessed: amphetamines, benzodiazepines, z-hypnotics, cocaine, multiple drugs, opioids	Age, sex, geographical location	No statistically significant association between THC and fatal crashes (OR 1.25, 95% CI 0.45-3.51)	
Hels et al (2013) & Hells et al (2011) & Bernhoft et al (2012) DRUID Europe – 6 countries (Belgium, Denmark, Finland, Italy, Lithuania, Netherlands)	Cases: 2,490 seriously injured car/van drivers (91.5 – 100% participation) Controls: 15,832 drivers in normal traffic (48-100% participation)	Alcohol: blood or breath Drugs: Blood (cases) taken less than 3 hours post-crash Blood or oral fluid (controls) Cut-off concentrations used (not specified) and equivalent across sample types	Substances analysed: alcohol, amphetamines, benzodiazepines, cocaine, ecstasy, opioids, z-hypnotics Substances assessed: amphetamines, benzodiazepines, z-hypnotics, cocaine, multiple drugs, opioids	Age, sex, geographical location	Significant association between THC and injury crash (OR 1.91, 95% CI 1.15-3.17)	The high non-response rates in some countries may have affected the risk estimates even though the difference between respondents and non-respondents was not significant. The non-respondents in the control sample may be more likely to be positive to psychoactive substances, and in the case samples, the hospital staff may be more likely to include patients believed to be positive. Thus, the non-respondents in both case and control samples may have led to an overestimation of risk

Case-Control Studies

Author/s, Year, Location	Method and Sample	Data Source	Other Substances Assessed	Covariates	Key Findings	Limitations
Gjerde et al (2011), Norway	Cases: 204 killed car/van drivers (61% participation) Controls: 10,540 drivers in normal traffic (88% participation)	Cases: Blood Controls: Oral fluid Equivalent cut-off concentrations used between case and control samples	Analysed: Alcohol, amphetamines, benzodiazepines, carisoprodol, cocaine, ecstasy, opioids, z-hypnotics Assessed: Amphetamines, benzodiazepines, multiple drug use, zopiclone	Age, season, sex, time of day or week	No significant increase in risk associated with THC only (OR 0.9, 95% CI 0.1-7.3) but significant increase in risk with cannabis in combination with other drugs (drug types not specified) (OR 8.6, 95% CI 3.9-13.3)	Confounding factors related to risk-taking personality traits could not be adjusted for in the analysis 40% of drivers killed in crashes were not included in the study. Control drivers who refused participation may have drugs in their system. Similarly, if cases for whom blood samples were not taken were drug free then the ORs may be an overestimate
Woratanarat et al (2009) Thailand	Cases: 200 injured drivers or riders (n=178 riders) (unknown participation rate) Controls: 849 drivers or riders at petrol station (n=761 riders) (unknown participation rate)	Alcohol: blood or breath Drugs: questionnaire and urine (positive = > 50 ng/ml) equivalent between cases and controls	Analysed: Alcohol, amphetamines, antidepressants, anti-epileptics, antihistamines, barbiturates, benzodiazepines, morphine, cocaine, mitragynine, muscle relaxants, opioids. Assessed: Amphetamines, antidepressants, antihistamines, morphine, multiple drug use		No significant association between marijuana use and injury crash risk (OR 0.78, (95% CI 0.25-2.40) Alcohol and multiple drug use (drugs not specified) OR 43.03 (95% CI 9.14-202.51)	Very few samples from cases and controls were positive for cannabis Since urine samples were used, the study did not determine cannabis use immediately prior to crash but rather only in the week prior to it
Assum (2005) Norway	Cases: 87 killed/injured car/van/minibus drivers (unknown % participation) Controls: 410 drivers in normal traffic (87% participation)	Alcohol: Blood or Breath Drugs: Blood (Cases) Oral fluid (Controls) Cut-off concentrations in oral fluid and blood were not equivalent	Substances analysed: Alcohol, amphetamines, benzodiazepines, cocaine, ecstasy, opioids Substances assessed: amphetamines, benzodiazepines, opioids, multiple drug use		No significant association between cannabis use and crash involvement	Number of cases and controls were too low to give sufficient statistical power The cut-off concentrations in oral fluid and blood were not equivalent

Case-Control Studies

Author/s, Year, Location	Method and Sample	Data Source	Other Substances Assessed	Covariates	Key Findings	Limitations
Blows et al (2005) New Zealand	Cases: 571 involved in serious injury or fatal crashes (92.8% participation) Controls: 588 random (78.8% participation)	Alcohol: blood or breath Cannabis: questionnaire (self-reported drug use 3 hours before collision/survey and in the last 12 months)		Age, alcohol, seatbelt use, education level, ethnicity, driving experience or mileage, passengers in car, sex, speed, time of day or week, vehicle age	No significant association between acute marijuana use and injury crash risk (OR 0.8, 95% CI 0.2-3.3) but there was an association between habitual marijuana use and injury crash risk (OR 9.5, 95% CI 2.8-32.8)	Self-report measures only
Mathijssen & Houwing (2005) Netherlands	Cases: 184 seriously injured car/van drivers (88.9% participated) Controls: 3,374 drivers in normal traffic (87.6% participated)	Alcohol: Blood or Breath Drugs: Blood (THC metabolites) (Cases) Blood, urine (THC metabolites) or questionnaire (Controls) Cut off concentrations not specified and not equivalent across cases and controls	Substances analysed: alcohol, amphetamines, antidepressants, benzodiazepines, cocaine, opioids Substances assessed: benzodiazepines, codeine, morphine, multiple drug use		No statistically significant association with crashes and cannabis use (OR 1.45, 95% CI 0.64-3.29)	Urine samples may be positive for cannabinoids for weeks after use. Thus, urine samples are unsuitable for case-control studies on the association between cannabis use and crashes, except if only urine samples are collected from both cases and controls Number of included cases was low
Brault et al (2004) Canada	512 killed drivers in passenger cars (38.3% participation) 5,931 drivers in normal traffic (49.6% participation)	Alcohol: Blood or Breath Drugs: Urine (inactive THC metabolites) with equivalent cut off concentrations	Substances analysed: Alcohol, amphetamines, barbiturates, benzodiazepines, cocaine, opioids, Substances assessed: amphetamines, barbiturates, benzodiazepines, cocaine, opioids	Age, sex, time of day or week	OR for crashes associated with cannabis alone of 1.6 (96% CI 1.1-2.4); for all cannabis cases (with or without other substances) the OR was 4.5 (95% CI 3.3-6.0)	Only measured carboxy-THC (i.e. urine) so the calculated OR was for the risk of crashes given marijuana use at all rather than for marijuana use while driving, or specifically recent use) Large proportion of control group refused testing, potentially depressing the incidence of use in the control group and artificially inflating the risk

Case-Control Studies

Author/s, Year, Location	Method and Sample	Data Source	Other Substances Assessed	Covariates	Key Findings	Limitations
Movig et al. (2004) Netherlands	Cases: 110 seriously injured drivers (participation rate unknown) Controls: 816 drivers in normal traffic (79.3% participation)	Alcohol: blood or breath Drugs: Blood or urine (THC metabolites) (cut off concentration not specified and not equivalent between cases and controls)	Analysed: Alcohol, amphetamines, antidepressants, barbiturates, benzodiazepines, opioids, Assessed: amphetamines, benzodiazepines cocaine, opioids, multiple drug use	Age, drug exposure, alcohol, season of year, sex, time of day or week	No significant association between cannabis use and injury crash involvement (OR 1.22, 95% CI 0.55-2.73) Significant association between drug-alcohol combination use (drug types not specified) and injury crash involvement (OR 112.22 (95% CI 14.10-893)	Proportion giving urine samples was significantly higher in controls than cases thus underestimating the calculated OR because urine samples are positive for drugs for a significantly longer time than blood samples after drug use Sample size was low giving poor statistical power
Mura et al (2003) France	Cases: 900 car drivers in serious injury crashes (96% participation) Controls: 900 non-trauma patients (96% participation)	Blood (> 1 ng/ml THC) and either urine or sweat (cut offs were equivalent between cases and controls)	Analysed: Alcohol, amphetamines, antidepressants, barbiturates, benzodiazepines, cocaine, opiates Assessed: Benzodiazepines, morphine	Age, sex	OR 2.5 (95% CI 1.5-4.2) for crash involved drivers aged under 27 Alcohol and cannabis OR 4.6 (95% CI 2.0-10.7) for crash involved drivers aged under 27	Selection bias in controls - use of non-drivers means the control group is not representative of the population from which cases are derived and potentially renders the results invalid
Marquet et al. (1998) France	Cases: 296 seriously injured drivers (aged 18-35) Controls: 278 other patients (age 18-35)	Urine: 50 ng/ml inactive metabolites	Substances analysed: amphetamine, cocaine, ecstasy Substances assessed: opioids	Age, sex, geographical location	Significant difference in cannabis findings in urine samples from female drivers involved in crashes in France compared to non-trauma patients (p = 0.02) but not for male drivers	Number of cases and controls were low, giving low statistical power Alcohol and sedative therapeutic drugs were not analysed

Responsibility Studies						
Author/s, Year, Location	Method and Sample	Data Source	Other Substances Assessed	Covariates	Key Findings	Limitations
Laumon et al. (2005) France	10,748 drivers killed in crash	Alcohol: blood if breath test positive Drugs: blood if urine test positive (THC > 1 ng/ml) Traffic crash database		Age, alcohol, time of day or week, vehicle type	Significant (unadjusted) association between cannabis use (> 1 ng/ml) and culpable fatal crash involvement (OR 3.32 (95% CI 2.63-4.18) Dose-response effect for THC 1-2, 3-4, and 5 or above 1-2: OR 1.54, 95% CI 1.09-2.18. 3-4: OR 2.13, 95% CI 1.22-3.73. 5+: OR 2.12, 95% CI 1.32-3.38)	Other drug use not controlled for Only reported unadjusted odds ratio for cannabis (> 1 ng/ml) Methods used to determine responsibility for the crash can suggest but not prove driver impairment
Gates et al (2013) USA	Recorded unsafe driving action (used as proxy for responsibility) 8,325 male truck drivers involved in non-alcohol fatal crash	Blood or urine (concentration levels not specified) FARS Database	Analysed: Alcohol, amphetamine, benzodiazepines, cocaine, opioids, other psychoactive drugs Assessed: Opioids, stimulants	Age, drugs used, previous driving record	Non-significant OR of 1.14 (95% CI 0.84-1.53) for performing an unsafe driving action associated with cannabinoids	FARS has limitations that do not allow calculation of reliable estimates of crash risk due to inconsistencies in drug testing between States, a bias in selecting cases for drug testing (only half of all fatal drivers are tested for drugs), failure to record all drug findings in the database, and lack of uniformity in drug testing methods (blood or urine). FARS does not show concentration level at time of crash, or dosage level, only a dichotomous marker of THC presence Methods used to determine responsibility for the crash can suggest but not prove driver impairment

Responsibility Studies						
Author/s, Year, Location	Method and Sample	Data Source	Other Substances Assessed	Covariates	Key Findings	Limitations
Gadegbeku et al. (2011) France	Responsibility study 6,932 involved in fatal crashes Controls: 1,986 drivers non-responsible for the crash (a sub-sample of the 2,509 non-responsible drivers: 523 excluded because they were the only fatality in the crash)	Alcohol: Blood if breath positive) Drugs: Blood if urine positive (THC > 1 ng/ml) generally between 1-4 hours post-crash Crash database	Analysed: Alcohol, amphetamines, cannabis, cocaine, opioids Assessed: Amphetamines, cannabis, cocaine, opiates	Age, sex, alcohol	Significant OR of 1.89 for fatal crash responsibility (95% CI 1.43-2.51) Increasing risk of responsibility for fatal crashes with increased cannabis levels Significant OR of 8.39 (95% CI 6.95-10.11) when under the influence of both alcohol and cannabis and being responsible for the crash.	Threshold is slightly higher than that set in DRUID, thus the ORs may be underestimates of the true ORs Drug levels for killed drivers may be overestimates due to blood loss or postmortem redistribution, whilst for non-killed drivers drug levels may be underestimates because of the elapsed time between the crash and blood sampling Methods used to determine responsibility for the crash can suggest but not prove driver impairment
van Elslande et al. (2012) France	Recorded unsafe driving action (as proxy for crash responsibility) 174 matched killed controls	Blood (THC, concentration not specified) Crash database	Alcohol, other psychoactive drugs (not specified)	Age, sex	Drivers killed with THC in blood (and no detection of other drugs or alcohol) had significantly higher rates of driving failures than matched controls, i.e., fatally injured drivers without any alcohol or drugs detected in their blood test. THC-positive drivers had significantly lower levels of attention (p <0 .0 I) and significantly higher level of risky driving (p <0.01) and significantly higher frequencies of other failures.	Methods used to determine responsibility for the crash can suggest but not prove driver impairment

Responsibility Studies						
Author/s, Year, Location	Method and Sample	Data Source	Other Substances Assessed	Covariates	Key Findings	Limitations
Drummer et al. (2004) Australia	Responsibility study 3,398 drivers killed in crash	Blood (THC <5 or > or equal to 5) taken within four hours of crash Police crash reports	Substances analysed: Alcohol, amphetamines, benzodiazepines, cocaine, ecstasy, opioids Substances assessed: benzodiazepines, cocaine, opioids, stimulants	Age, alcohol, geographical area, single vehicle crash, sex, year of crash	THC positive drivers had a significantly higher likelihood of being culpable for a crash than drug-free drivers (OR 2.7, 95% CI 1.02-7.0); for drivers with THC concentrations of 5 ng/mL or higher the OR was 6.6 (95% CI 1.5-28.0) Odds of culpability in drivers who were THC positive and had BAC greater than or equal to 0.05 g% alone was 2.9 times the odds of drivers who had BAC greater than or equal to 0.05 g% alone	Methods used to determine responsibility for the crash can suggest but not prove driver impairment
Drummer et al. (1995) Australia	Responsibility analysis 1,052 drivers killed in crashes	Blood (metabolites of cannabis only, not THC) (concentration levels not specified) Police crash reports	Substances analysed: Alcohol, benzodiazepines, stimulants, opiates, analgesics Substances assessed: benzodiazepines, stimulants, opiates, analgesics	Age, sex	No significant relationship between cannabis and responsibility for fatal crash (OR 0.6, 95% CI 0.3-1.0)	Measured metabolites of cannabis rather than THC so culpable drivers may not have been impaired at the time of the crash Methods used to determine responsibility for the crash can suggest but not prove driver impairment
Longo et al (2000) South Australia	Responsibility analysis 2,500 drivers seriously injured in crash	Blood (THC and THC-acid) (concentrations not specified) Police crash reports	Substances analysed: alcohol, benzodiazepines, cannabis, stimulants Substances assessed: stimulants		No significant association between THC and crash responsibility No significant concentration dependent relationship between THC and crash culpability Alcohol and THC produced a significant increase in culpability (OR 5.4), but it was not greater than that for alcohol alone	CIs not reported Methods used to determine responsibility for the crash can suggest but not prove driver impairment

Responsibility Studies						
Author/s, Year, Location	Method and Sample	Data Source	Other Substances Assessed	Covariates	Key Findings	Limitations
Lowenstein & Koziol-McLain (2001) USA	Responsibility analysis 414 drivers seriously injured in crash	Urine (cut off 5 ng/ml) with different concentrations examined: acute use (THC), recent use (11-OH-THC) or remote use (COOH-THC) Traffic crash database	Substances analysed: alcohol, amphetamines, barbiturates, benzodiazepines, cocaine, LSD, meprobamate, opioids, xylene	Age, seatbelt use, sex, time of day or week	Marijuana alone was not significantly associated with crash responsibility for acute use (OR 0.7, 95% CI 0.1-3.3), recent use (OR 0.8, 95% CI 0.3-2.0), or any acute, recent or remote use (OR 1.1, 95% CI 0.5-2.4)	Concentration levels were not examined. Methods used to determine responsibility for the crash can suggest but not prove driver impairment Urine samples were thawed for one year before analysis – this process may have led to some degradation of the drug and possibly to an underestimate of the prevalence of acute and recent marijuana use It is possible that some of the control group of non-responsible drivers may have borne some of the responsibility – this would underestimate crash risk
Soderstrom et al. (2005) USA	Responsibility analysis 2,537 drivers seriously injured in crash	Alcohol: Blood Drugs: Urine (inactive metabolites of THC, concentration levels not specified) Hospital and traffic crash databases	Substances analysed: Not specified Substances assessed: Cocaine	Age, sex	Marijuana alone was not significantly associated with crash responsibility (OR 1.18, 95% CI 0.84-1.64)	Used urine only (metabolites in urine as an indicator of cannabis are not reliable) It is possible that some of the control group of non-responsible drivers may have borne some of the responsibility – this would underestimate crash risk Methods used to determine responsibility for the crash can suggest but not prove driver impairment

Responsibility Studies						
Author/s, Year, Location	Method and Sample	Data Source	Other Substances Assessed	Covariates	Key Findings	Limitations
Poulsen et al (2014), New Zealand	Responsibility analysis 1,046 killed in crashes	Blood (THC <2, 2-5, >5 ng/ml) Police crash reports	Substances analysed: Alcohol, amphetamines, benzodiazepines, cannabis, ecstasy, opioids, other psychoactive drugs	Age, driver licence status, sex, single vehicle crash, urban/rural location, vehicle type	Non-significant association between THC alone in blood and culpability for fatal crashes (OR 1.3, 95% CI 0.8-2.3) The OR for drivers with THC concentrations greater than 5 ng/mL was lower (OR 1.0, 95% CI 0.4–2.4) than drivers with blood THC concentrations less than 2 ng/mL (OR 3.1, 95% CI 0.9–10). This is inconsistent with results reported by other studies where a significant increase in crash risk was found with blood THC levels greater than 5 ng/mL The OR for all drivers who had combined alcohol and cannabis was 6.9 (95% CI 3.0–16), less than that determined for the drivers who had used alcohol alone, which was 13.7	Methods used to determine responsibility for the crash can suggest but not prove driver impairment

Population / Cohort Studies

Author/s, Year, Location	Method	Data Source	Other Substances Analysed & Assessed	Covariates	Key Findings	Limitations
Pulido et al. (2011) Spain	17,484 drivers or motorcycle riders (15,952 drivers, 17,484 riders & 3,927 persons who both drive and ride)	Questionnaire or interview	Assessed: Cocaine	Age, alcohol and drugs used, education level, ethnicity, occupation, driver experience or mileage, sex	Significant association between cannabis use for car and motorcycle riders combined more than 4 days/week last 12 m and non-fatal injury crash involvement (OR 1.6, 95% CI 1 - 2.6) but no significant association for less frequent use. Significant association between cannabis use for car drivers (more than 4 days / week (OR 2.5, 95% CI .12-5.1) but no significant association for less frequent use Significant association between cocaine use for car drivers and motorcyclists combined weekly use (OR 2.8, 95% CI .11-7.1) and motorcyclists less than weekly use (OR 1.9, 95% CI 1-3.6)	Self-report measures Small sample sizes when broken down by road user type limits statistical power of the study to detect an effect Includes crashes of all severity levels No indication of period between drug use and driving
Lasebikan (2010)	422 commercial drivers	Questionnaire or interview		Driving under the influence of alcohol	Significant increase in risk of crash associated with previous driving under the influence of cannabis crashes (OR 4.5, 95% CI 2.2-11.0); previous driving under the influence of cannabis and alcohol (OR 5.1, 95% CI 2.7-14.0); and cannabis abuse or dependence plus alcohol abuse or dependence (OR 7.2, 95% CI 3.4-31.6)	Definition of crash not given Other drug use not examined and therefore not controlled for Self-report measures
Mann et al (2010) Canada	8,481 drivers	Questionnaire or interview (driving within one hour of marijuana use)		Age, drinking habits, education level, driver experience or mileage, income, marital status, sex	Driving one hour after cannabis use within last 12 months associated with an increased risk of crash involvement (OR 1.84, 95% CI 1.23-2.76) compared to those who never drove after using cannabis	Self-report measures Dichotomous treatment of substance use only Small sample reporting driving after cannabis use Frequency of cannabis use and driving after cannabis use was not considered Included accidents of all severity levels

Population / Cohort Studies						
Author/s, Year, Location	Method	Data Source	Other Substances Analysed & Assessed	Covariates	Key Findings	Limitations
Richer & Bergeron (2009) Canada	29 drivers	Questionnaire or interview Self-reported frequency of driving in the hour following smoking cannabis over the previous 12 months		Age, driving exposure, dangerous driving, and driving under the influence of alcohol	Non-significant increase in risk of crash associated with driving after using cannabis (OR 1.58, 95% CI 0.98-2.54).	Self-report measures Very small sample size Other drug use not examined and therefore not controlled for Includes crashes of all severity levels
Fergusson & Horwood (2008) New Zealand	Birth cohort study; 936 aged 21-25	Questionnaire or interview		Driving behaviour, previous driving under the influence, driver experience or mileage	Significant relationship between frequency of cannabis use (more than 20 times per year) and self-reported accident rate (OR 2.25, 95% CI:1.65-3.07) that was eliminated once confounding variables were controlled	Self-report measures Not known how recently cannabis was used prior to driving Dichotomous treatment of substance use only Alcohol and other drug use was not assessed Included accidents of all severity levels
Mann et al (2007) Canada	2,676	Questionnaire or interview (driving within one hour of marijuana use)		Age, education level, region, income, marital status, sex	Significant association between cannabis use more than once per week and crash involvement (OR 2.76, 95% CI 1.50-5.08) and between driving within one-hour post cannabis use at least once in past year and crash involvement (OR 2.61, 95% CI 1.45-4.68. Significant association between cannabis dependence and crash involvement (OR 1.72, 95% CI 1-2.96)	Self-report measures Small sample reporting driving after cannabis use Included accidents of all severity levels Frequency of cannabis use and driving after cannabis use was not considered

Population / Cohort Studies						
Author/s, Year, Location	Method	Data Source	Other Substances Analysed & Assessed	Covariates	Key Findings	Limitations
Wadsworth et al. (2006) UK	4,754 drivers	Questionnaire or interview		Age, disease or health status, drinking habits, education level, income, occupation, personality, sex, smoking	Cannabis use during the previous year was significantly associated with involvement in crashes (OR 1.92, 95% CI 1.04-3.54)	Timings of cannabis use in relation to crashes were not available No information about amount, frequency or duration of cannabis use Includes crashes of all severity levels
Asbridge et al. (2005) Canada	Cross-sectional study 6,087 students	Questionnaire or interview (driving within one hour of cannabis use)		Gender, education level, driving experience, used fake ID to buy alcohol, place of residence (urban/rural)	Almost two-fold (1.84) increase in risk of collision in those who drove under the influence of cannabis compared to those who did not.	All data were self-reported – collision involvement and drug usage No assessment of the involvement of other drugs on crash risk Culpability for collision was not assessed
Fergusson & Horwood (2001) New Zealand	Birth-cohort study 907 adults aged 18-21	Questionnaire or interview		Age, attitudes to risky driving, driving behaviour, drink-driving behaviour, driver experience or mileage, sex	Significant relationship between frequency of cannabis use (more than 50 times per year) and self-reported crash rate (OR 1.6, 95% CI:1.2-2.0) for crashes.	Self-report measures Not known how recently cannabis was used prior to driving Dichotomous treatment of substance use only Alcohol and other drug use was not assessed Included accidents of all severity levels

MONASH University

TABLE C.2 SUMMARY OF STUDIES EXAMINING THE IMPACT OF AMPHETAMINE USE ON CRASH RISK (1995-2015)

Studies Examining Amphetamine Use on Crash Risk						
Author, Year, Location	Method and Sample	Data source	Substances Assessed	Co-variates	Key Findings	Limitations
Gjerde et al (2013) Norway	Case-control study Cases: 508 killed car/van drivers (61% participation) Controls: 9261 drivers in normal traffic (94% participation)	Cases: Blood Controls: Oral fluid Equivalent cut-off concentrations used between case and control samples	Analysed: Alcohol, amphetamines, benzodiazepines, cocaine, ecstasy, opioids, z-hypnotics Assessed: Amphetamines, benzodiazepines, multiple drug use, z-hypnotics	Age, geographical area, season, sex, time of day or week	A much higher risk for fatal crash for the use of amphetamines combined with other substances (OR 76.9, 95% CI 38.7-152.9) compared to the use of amphetamines alone (OR 42.0, 95% CI 12.2-145.1). Significant OR of 98.2, 95% CI 24.9-386.9 following combined use of amphetamines and benzodiazepines	40% of drivers killed in crashes were not included in the study 6% of controls did not provide an oral fluid sample – assuming the proportion of drug and alcohol use in these drivers was higher than among controls who participated then the OR's might be an overestimate No data on crash culpability was available
Kuypers et al (2012) Belgium (DRUID)	Case-control study Cases: 337 injured car/van drivers (27% participated) Controls: 2,726 drivers in normal traffic (44.8% participated)	Alcohol: Breath Drugs: Blood	Substances analysed: alcohol, amphetamines, benzodiazepines, cocaine, ecstasy, opioids, z-hypnotics Substances assessed: amphetamines, benzodiazepines, cocaine, multiple drug use, opioids, z-hypnotics	Age, sex, time of day or week	Significant crude (unadjusted) OR for being injured in a crash for single use amphetamines 54.82 (95% CI 6.09-493.12); an adjusted OR was not calculated	
Hels et al (2011) & Bernhoft et al (2012), DRUID Europe – 4 countries (Finland, Norway, Sweden & Portugal)	Case-control study Cases: 1,112 killed car/van drivers (59 – 94.3% participated) Controls: 21,917 drivers in normal traffic (52-97% participated)	Alcohol: blood or breath Drugs: Blood (cases) Oral fluid (controls)	Substances analysed: alcohol, amphetamines, benzodiazepines, cocaine, ecstasy, opioids, z-hypnotics Substances assessed: amphetamines, benzodiazepines, z-hypnotics, cocaine, multiple drugs, opioids	Age, sex, geographical location	Significant association between amphetamines alone and fatal crash 34.34 (95% CI 13.18-89.49)	

Studies Examining Amphetamine Use on Crash Risk						
Author, Year, Location	Method and Sample	Data source	Substances Assessed	Co-variates	Key Findings	Limitations
Hels et al (2013) & Hells et al (2011) & Bernhoft et al (2012), DRUID Europe – 6 countries (Belgium, Denmark, Finland, Italy, Lithuania, Netherlands)	Case-control Cases: 2,490 injured car/van drivers (91.5 – 100% participation) Controls: 15,832 drivers in normal traffic (48-100% participation)	Alcohol: blood or breath Drugs: Blood (cases) Blood or oral fluid (controls)	Substances analysed: alcohol, amphetamines, benzodiazepines, cocaine, ecstasy, opioids, z-hypnotics Substances assessed: amphetamines, benzodiazepines, z-hypnotics, cocaine, multiple drugs, opioids	Age, sex, geographical location	Significant association between amphetamines alone and injury crash (OR 14.15, 95% CI 5.82 - 34.42)	Small sample sizes for some drug types The high non-response rates in some countries may have affected the risk estimates even though the difference between respondents and non-respondents was not significant. The non-respondents in the control sample may be more likely to be positive to psychoactive substances, and in the case samples, the hospital staff may be more likely to include patients believed to be positive. Thus, the non-respondents in both case and control samples may have led to an overestimation of risk
Gjerde et al (2011) Norway	Case-control study Cases: 204 killed car/van drivers (61% participation) Controls: 10,540 drivers in normal traffic (88% participation)	Cases: Blood Controls: Oral fluid Equivalent cut-off concentrations used between case and control samples	Analysed: Alcohol, amphetamines, benzodiazepines, carisoprodol, cocaine, ecstasy, opioids, z-hypnotics Assessed: Amphetamines, benzodiazepines, multiple drug use, zopiclone	Age, season, sex, time of day or week	Significantly higher risk associated with only methamphetamine or amphetamine (OR 20.9, 95% CI 7.3-60) Significantly higher risk associated with methamphetamine or amphetamine combined with other substances (OR 57.1, 95% CI 27.3-119.5)	Confounding factors related to risk-taking personality traits could not be adjusted for in the analysis 40% of drivers killed in crashes were not included in the study Control drivers who refused participation may have drugs in their system. Similarly, if cases for whom blood samples were not taken were drug free then the ORs may be an overestimate

Studies Examining Amphetamine Use on Crash Risk						
Author, Year, Location	Method and Sample	Data source	Substances Assessed	Co-variates	Key Findings	Limitations
Gadegbeku et al. (2011), France	Responsibility study 6,932 involved in fatal crashes Cases: 4,946 drivers responsible for the crash Controls: 1,986 drivers non-responsible for the crash (a sub-sample of the 2,509 non-responsible drivers: 523 excluded because they were the only fatality in the crash)	Alcohol: Blood if breath positive Drugs: Blood if urine positive Crash database	Analysed: Alcohol, amphetamines, cannabis, cocaine, opioids Assessed: Amphetamines, cannabis, cocaine, opiates	Age, sex	Non-significant OR (1.54, 95% CI 0.66-3.56)	Very low sample size for amphetamines (n=54) Methods used to determine responsibility for the crash can suggest but not prove driver impairment
Woratanarat et al (2009) Thailand	Case-control study Cases: 200 injured drivers or riders (n=178 riders) Controls: 849 drivers or riders at petrol station (n=761 riders)	Alcohol: blood or breath Drugs: questionnaire and urine (positive = > 50 ng/ml)	Analysed: Alcohol, cannabis, antidepressants, anti-epileptics, antihistamines, barbiturates, benzodiazepines, morphine, cocaine, mitragynine, muscle relaxants, opioids Assessed: Cannabis, antidepressants, antihistamines, morphine, multiple drug use		8.9 times increased crash risk (OR 8.89, 95% CI 4.54-17.39)	Very few samples from cases and controls were positive for amphetamines

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Studies Examining Amphetamine Use on Crash Risk						
Author, Year, Location	Method and Sample	Data source	Substances Assessed	Co-variates	Key Findings	Limitations
Movig et al (2004) Netherlands	Population based case-control study Cases: 110 injured drivers (participation rate unknown) Controls: 816 drivers in normal traffic (79.3% participation)	Alcohol: blood or breath Drugs: Blood or urine	Analysed: Alcohol, cannabis, antidepressants, barbiturates, benzodiazepines, opioids Assessed: cannabis, benzodiazepines cocaine, opioids, multiple drug use	Age, drug exposure, alcohol, season of year, sex, time of day or week	No significant association between amphetamine use and injury crash involvement (OR 2.10, 95% CI 0.66-6.73)	Proportion giving urine samples was sig higher in controls than cases thus underestimating the calculated OR because urine samples are positive for drugs for a significantly longer time than blood samples after drug use Sample size was low giving poor statistical power
Assum (2005) Norway	Case-control study Cases: 87 killed/injured car/van/minibus drivers (unknown % participation) Controls: 410 drivers in normal traffic (87% participation)	Alcohol: Blood or Breath Drugs: Blood (Cases) Oral fluid (Controls)	Substances analysed: Alcohol, cannabis, benzodiazepines, cocaine, ecstasy, opioids Substances assessed: cannabis, benzodiazepines, opioids, multiple drug use		Significant OR for crash involvement 29.5 (95% CI 1.5-575.6)	Number of cases and controls were far too low to give sufficient statistical power The cut-off concentrations in oral fluid and blood were not equivalent
Brault et al (2004) Canada	Case-control study 512 killed drivers in passenger cars (38.3% participation) 5,931 drivers in normal traffic (49.6% participation)	Alcohol: Blood or Breath Drugs: Urine	Substances analysed: Alcohol, amphetamines, barbiturates, benzodiazepines, cocaine, opioids, Substances assessed: amphetamines, barbiturates, benzodiazepines, cocaine, opioids	Age, sex, time of day or week	OR for being killed in a crash after use of amphetamines in combination with other substances = 11.0 (95% CI 2.9-41.3)	

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TABLE C.3 SUMMARY OF STUDIES EXAMINING THE IMPACT OF STIMULANTS (NOT SPECIFIED) ON CRASH RISK (1995-2015)

Studies Examining Stimulant Use on Crash Risk						
Author, Year, Location	Method and Sample	Data source	Substances Assessed	Co-variates	Key Findings	Limitations
Compton & Berning (2015) Virginia Beach, USA	Cases: 3,095 crash involved drivers (all severity) Controls: 6,190 matched non-crash involved drivers in normal traffic	Oral fluid and blood samples (THC) (details not provided on whether equivalent cut off concentrations were used)	Analysed: Alcohol, anti-depressants, opioids, stimulants, sedatives Assessed: Anti-depressants, opioids, stimulants, sedatives	Age, gender, geographical area, season of the year, time of day or week, alcohol	No significant increase in crash risk for drivers testing positive to cannabis (OR 1.05, 95% CI 0.86-1.27)	Localised sample of crashes with low generalisability Bias towards less severe crashes
Drummer et al. (2004) Australia	Responsibility study 3,398 drivers killed in crash	Blood Police crash reports	Substances analysed: Alcohol, cannabis, benzodiazepines, cocaine, ecstasy, opioids Substances assessed: benzodiazepines, cocaine, opioids, cannabis	Age, alcohol, geographical area, single vehicle crash, sex, year of crash	OR of 2.27 (95% CI 0.9-5.6) stimulant use and culpability; for truck drivers the calculated OR was 8.83 (95% CI 1.00-78).	Methods used to determine responsibility for the crash can suggest but not prove driver impairment

Studies Examining Stimulant Use on Crash Risk						
Author, Year, Location	Method and Sample	Data source	Substances Assessed	Co-variates	Key Findings	Limitations
Gates et al (2013) USA	Recorded unsafe driving action (used as proxy for responsibility) 8,325 male truck drivers involved in non-alcohol fatal crash	Blood or urine FARS Database	Analysed: Alcohol, amphetamine, benzodiazepines, cannabis, opioids, other psychoactive drugs Assessed: Opioids, cannabis stimulants (amphetamine, methamphetamine, cocaine), chlorphentermine and phentermine)	Age, drugs used, previous driving record	Significant OR for unsafe driving actions of 1.78 (95% CI 1.41-2.26) among stimulant-positive truck drivers compared to stimulant-negative truck drivers	FARS does not allow calculation of reliable estimates of crash risk due to inconsistencies in drug testing between states, bias in selecting cases for drug testing (only half of all fatal drivers are tested for drugs), failure to record all drug findings in the database, and lack of uniformity in drug testing methods (blood or urine). Concentration level at time of crash not provided, or dosage level (dichotomous present/not). All stimulant drugs were combined and concentration levels were not specified; inclusion of positive results for low stimulant blood concentrations may have led to an underestimation of the overall effect. No information given as to how drivers were or were not selected for drug testing within the FARS database. It is possible that drivers who appeared intoxicated were likely to be selected for drug testing compared to those stimulant-positive drivers who did not appear intoxicated, thereby leaving the more seriously impaired stimulant users for the current sample and artificially inflating the association
Li et al (2013) USA	Cases: 737 killed drivers (35.6% participated) from Fatality Analysis Reporting System (FARS) Controls: 7,719 drivers in normal traffic (70.7% participated) from the 2007 Roadside Survey	Alcohol: blood or breath Drugs: blood or urine (cases), oral fluid (controls) (levels not specified)	Assessed: Opioids, stimulants, multiple drug use. Analysed: amphetamines, alcohol, antidepressants, antihistamines, benzodiazepines, carisoprodol, ecstasy, ketamine, opioids, z-hypnotics	Age, geographical area, sex, time of day or week	Crude OR of 3.57 (95% CI 2.63-4.76)	As above

Studies Examining Stimulant Use on Crash Risk						
Author, Year, Location	Method and Sample	Data source	Substances Assessed	Co-variates	Key Findings	Limitations
Longo et al (2000) South Australia	Responsibility study 2500 injured in crash	Blood Police crash reports	Substances analysed: alcohol, benzodiazepines, cannabis, stimulants Substances assessed: cannabis, stimulants		A higher proportion of drivers positive for stimulants in blood were culpable compared to those who were drug-free although difference was not statistically significant	Small sample size of drivers tested positive for stimulants Methods used to determine responsibility for the crash can suggest but not prove driver impairment
Romano et al (2014) USA	Cases: 1,766 killed drivers (participation unknown) from Fatality Analysis Reporting System (FARS) Controls: 3,424 drivers in normal traffic (71.7% participated) from the 2007 Roadside Survey	Alcohol: blood or breath Drugs: blood (THC) or urine (cases), oral fluid (controls)	Analysed: Alcohol, amphetamines, antidepressants, antihistamines, benzodiazepines, carisoprodol, cocaine, ecstasy, ketamine, opioids, z-hypnotics Assessed: Opioids, stimulants	Age, ethnicity, sex, alcohol	Crude OR 1.87 (95% CI 1.45-2.43)	FARS has limitations that do not allow calculation of reliable estimates of crash risk due to inconsistencies in drug testing between states, a bias in selecting cases for drug testing (only half of all fatal drivers are tested for drugs), failure to record all drug findings in the database, and lack of uniformity in drug testing methods (blood/urine for cases and oral fluid for controls) – urine. Equivalent cut off concentrations not used - FARS does not show concentration level at time of crash, or dosage level, only a dichotomous marker of THC presence Time between crash and blood sampling not specified – not possible to determine the time of marijuana use relative to the crash in the FARS database

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APPENDIX D LITERATURE ON ATTITUDES, PERCEPTIONS AND MOTIVATIONS (CHAPTER 5)

TABLE D.1 SUMMARY OF STUDIES ADDRESSING SELF-REPORTED REASONS FOR DRUG-DRIVING

Studies Addressing Self-Reported Reasons for Drug-Driving					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Barrie et al (2011) ACT, Australia	Six focus groups with 6-8 young drivers (aged 18-25)	Key reasons for drug-driving	Cannabis, speed, ecstasy, alcohol (but key focus was on cannabis)	• Lack of reliable and appropriate alternative transport options was the primary reason • Some participants mentioned the overall reduced costs of drug-driving compared to drink-driving (in terms of financial costs, the relatively lower perceived likelihood of getting caught for drug-driving, and the relatively lower perceived impact of drugs on driving performance) • For convenience (where drug-driving was seen as part of everyday activities) • Past experience of being able to drive on drugs without getting caught or having an incident/accident	Not explicit that all participants were drug-drivers, although most appear to have been based on the results
Darke, Kelly & Ross (2004) Sydney, Australia	Cross-sectional structured interview survey of 300 regular injecting drug users, 88% of whom had driven soon after using drug in the last 12 months	Respondents who reported drug-driving in the last year were asked their main reasons for doing so	Most common drugs used before driving in last 12 months were cannabis, heroin, amphetamines and cocaine	The main reasons given for drug-driving revolved around drug use itself, hence the reasons were circumstantial and logistical rather than a deliberate intention to drive on drugs • To get home after 'scoring drugs' 28% • To get around 26% • To give others a lift 11% • To score drugs 11%	

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Studies Addressing Self-Reported Reasons for Drug-Driving					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Davey et al (2007) QLD, Australia	Semi-structured interviews with 35 long-haul truck drivers, 20 (57%) of whom used drugs whilst at work (presumably while they were driving). Recruitment largely through snowball sampling	Main reason for drug-driving - all drivers (31% reported not taking drugs currently or previously)	Amphetamines, cannabis, cocaine and pharmaceutical stimulants used illegally	• To combat fatigue = 31 (88%), however, only 7 (20%) reported that drug use was solely a fatigue countermeasure • 18 (51%) = socialisation • 10 (28%) = fitting the trucking image • 10 (28%) = relaxation/to feel good • 8 (22%) = addiction	Survey includes drivers who were not current or previous drug users (31%)
Donald et al (2006) South Australia, Australia	91 participants who had used an illicit drug/s at least once a month and driven a vehicle at least once a month in previous 6 months 89 had drug-driven in last 12 months	Participants self-reported likelihood of driving within an hour or two of using illicit drugs under various pre-defined situations Also examined by gender	Alcohol, cannabis, methamphetamine, ecstasy, cocaine, heroin, LSD	Most common reasons (% who selected 'very likely option'): • If I am only driving a short distance (60.4%) • If I have only had a small amount of drugs (59.3%) • If I don't think the drugs will have any effect on my driving (53.8%) • Out of 85, 'alternative' answers, the most common was the need to drive as part of their everyday existence cited as 'very likely' by 62%	
Duff & Rowland (2006) Melbourne, Australia	455 semi structured interview surveys with night club patrons, 281 of whom reported driving within 4 hours of consuming an illicit substance in the past year Recruited through convenience sampling	Drug-drivers Main reasons for driving on last occasion following drug use	Cannabis, ecstasy, speed, LSD, cocaine, heroin	• Easiest/most convenient way to get to destination (34%) • No other transport available (23%) • Felt capable of driving (20%) • There is nothing wrong with it (13%) • Felt confident they would not be caught (9%) • Enjoyed it, designated driver or an emergency (less than 3%)	

Studies Addressing Self-Reported Reasons for Drug-Driving					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Gavin et al (2008)	Random telephone survey, 10,391 licensed drivers 501 admitted to having taken recreational drugs within the last 3 months 240 admitted to drug-driving NSW, Australia	Drug-drivers Main reasons for driving on last occasion following drug use	Marijuana, ecstasy and cocaine	• No choice or other transport options (29%) • Felt fine and did not see why they should not drive (22%) • Convenience (had to get home/to destination/work next day) (19%) • Quickest way (17%) • Convenience/comfort (7%) • Designated driver (13%) • Didn't want to leave the car (12%)	
Hawkins et al (2004) NSW, Australia	N= 5074 drivers aged over 17 years – random telephone survey 429 were licensed drivers who admitted to being drug users (in last 3 months) 205 were drug-drivers (in last 12 months)	Drug-drivers Main reasons for feeling OK to drive after taking drugs	Cannabis, ecstasy, speed, cocaine, LSD and heroin	• Stated the drugs they took did not affect their ability to drive safely (59%)	
Kayani et al (2013) Lahore, Rawalpindi and Islamabad in Pakistan	37 interviews with bus, truck, taxi drivers, police officers and policy makers	Key reasons for drug-driving	Not stated	• Recreation • To remain awake and alert while driving • A consequence of substance addiction	Not explicit that all participants were drug-drivers, although most appear to have been based on the results No % reported

Studies Addressing Self-Reported Reasons for Drug-Driving					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Mabbott & Hartley (1999) 3 truck stops in Western Australia	Interviews with 236 truck drivers aged 21-69 (mix of short and long-haul operations)	Main reason for drug-driving All respondents	Stimulants (illicit and prescription)	• 161 of 165 drivers who responded indicated drugs were used to remain vigilant to combat fatigue	% who had drug-driven not known but 27% reported using stimulants as a countermeasure for fatigue
McIntosh et al (2008) Scotland	26 heroin dependent drug users who had driven under the influence of illegal drugs in the last 3 months	Main reason for drug-driving	Heroin and other illicit drugs (unspecified)	• One of the main uses of the car was to get drugs: ○ the car was quicker and more convenient than public transport and served as a place to administer the drug once it had been obtained from the dealer • Some also reported using the car to deal in drugs	No numbers or percentages reported in relation to the key questions so not possible to gauge an indication of the proportion of participants who held certain attitudes

Studies Addressing Self-Reported Reasons for Drug-Driving					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Neale (2001) Scotland	Interviews with 61 nightclub attendees, 52 of whom (85%) had ever driven after taking illicit drugs	Reasons for drug-driving across the different drug types	Cannabis, ecstasy, amphetamine, cocaine, LSD	**Cannabis (n=44 had driven with a 'few' hours of use)**: • Journeys mostly made on all days of the week and mostly in the evenings. • As both cannabis use and driving were fundamental aspects of their lives, driving after consuming the drug was almost inevitable with much cannabis driving involving day to day travel to or from work; family; friends or local shops. Occasionally it was smoked deliberately to relieve monotony of a long journey or before leisure driving. **Ecstasy (n=26 had driven within a few hours of use):** • Almost all reported ecstasy driving occurred at weekends following club attendance – between 2 am and midday for the explicit purpose of transporting themselves and their friends home from a night out. Unlike driving on cannabis, driving on ecstasy was not a regular behaviour **Amphetamine (n=15 had driven within a few hours of use):** • Similar to driving under the influence of ecstasy	No indication of the proportion of respondents in the group who held certain attitudes/beliefs

Studies Addressing Self-Reported Reasons for Drug-Driving					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Swift, Jones & Donnelly (2010) NSW, Australia	Survey 320 who had used cannabis in the last 12 m and had driven they a car within this period Drug-driving defined as driving with one hour of drug use	Reason for driving under the influence of cannabis (DUIC), driving under the influence of cannabis and alcohol (DUICA) and driving under the influence of cannabis and other drugs –with or without alcohol (DUICO)	Alcohol, cannabis and other drugs	Reasons for driving (all groups): • Need to get somewhere >70% (i.e., to socialise, get home, drive intoxicated passengers, do tasks such as shopping or get drugs) • For fun <10% Reasons for not driving (all groups): • Concerns over perceived impact of drugs on driving ability and safety risks posed to self and others (43% of those who did not DUIC, 42% of those who did not DUICO) • Reasons for not driving (DUICA) • Refusal to drive after drinking regardless of other drugs being used 35% (most frequent response) • Increased risk posed by cannabis and alcohol 10% • Legal concerns were rare, 5%	
Townsend et al (1998)	Findings from questions in the 1996 National Household Survey on Drug Abuse (NHSDA). 11,847 respondents aged 16 and older who reported driving in the past year and answered the question on whether or not they drove within two hours after substance use			The most commonly reported reasons for driving following marijuana use were that: • the drivers "had no other way to get there" (68.5% 16-20 years, 58.6% 21+ years), and: • felt they were "not high enough to cause a crash" (57.3% 16-20 years, 60.4% 21+ years)	

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TABLE D.2 SUMMARY OF STUDIES ADDRESSING PERCEIVED IMPACT OF DRUG USE ON DRIVING ABILITY/SKILL

Studies Addressing Perceived Impact on Drug Use on Driving Ability / Skill					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Adams et al (2008) Australia	1,714 police detainees who provided information about their drug-driving experiences, of which 1,215 had driven a vehicle in the last 12 months, 65% of whom 789 had driven after using drugs and or alcohol and agreed to participate in an interview	Perceived effect of substance intoxication on driving ability (negative, positive, not affected)	Alcohol, cannabis, amphetamine, methamphetamine, benzodiazepines, cocaine and heroin	44% reported that drugs had an effect on their driving ability at least some of the time. Benzodiazepines were rated as most likely to negatively impact driving ability (85%). Cannabis was the most commonly reported drug perceived to have a positive effect (15%) or no effect (36%). 9% perceived alcohol and 22% amphetamine/methamphetamine to have a positive effect on driving. 7% perceived heroin to have a positive effect on driving ability Detainees who more commonly reported that drugs never had an effect on their driving were: 68% cannabis, 74% cocaine, 59% amphetamine/methamphetamine, 49% alcohol, 40% heroin	
Barrie et al (2011) ACT, Australia	Six focus groups with 6-8 young drivers (aged 18-25)	Perception of risk (to driving performance)	Cannabis, speed, ecstasy, alcohol (but key focus was on cannabis)	Most participants do not perceive (or do not think their friends perceive) the negative consequences of drug-driving to be severe or to affect them personally In contrast, all participants perceived drink-driving to be very dangerous in terms of affecting driving skills The participants felt that many young people believed their driving would improve with drugs (e.g., marijuana makes people drive slower because you are relaxed; and speed/ecstasy will improve your driving skills as you are more alert) Most participants felt there was no information available regarding how drugs affect driving skills and thus personal experience played a large role in forming their beliefs	Perceptions appear to be based on their own as well as others' experiences of drug-driving and so not all participants were drug-drivers

Studies Addressing Perceived Impact on Drug Use on Driving Ability / Skill					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Bergeron et al (2014) Canada	48 males aged 18-26 who had used cannabis at least once in the last year and drove at least once per week	Perception of risk associated with driving under the influence of cannabis as measured on 4-point Likert scale (1 least agreement – 4 most agreement) 'In my opinion, smoking cannabis has no effect on my driving abilities at all' Is there a distinction between different types of cannabis users (i.e. frequency of use) and driving under the influence of cannabis?	Cannabis	Driving under the influence of cannabis was perceived by cannabis users as having little or very little effect on driving with 25% believing cannabis had no effect on driving at all The more frequently participants consumed cannabis, the lower their perceived risk of driving under the influence of cannabis	
Calabria et al (2012) Australia	Survey of 918 persons aged 18-87	'Does cannabis effect a person's ability to drive a car?' All respondents (% who had drug-driven not known)	Cannabis	90.6% of respondents believed that cannabis can affect a person's ability to drive a car, 2.3% believed that it did not and 7% did not know	Not known what proportion had drug-driven
Danton et al (2003) England, UK	Focus groups with drug users (n=29 aged 16-25)		Cannabis and alcohol	General acceptance of drug-driving seemed to be based on the perception that cannabis does not affect driving ability and in some cases, improves driving ability. This was in stark contrast to the perceptions of the dangers associated with drink-driving The risk of causing an accident when drug-driving was either not acknowledged or treated with little concern	Not all participants had drug-driven (28% had not) and so attitudes were also based on perceptions of their peers

Studies Addressing Perceived Impact on Drug Use on Driving Ability / Skill					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Donald et al (2006) South Australia, Australia	91 participants who had used an illicit drug/s at least once a month and driven a vehicle at least once a month in previous 6 months 89 had drug-driven in last 12 months	Participants asked to what degree they thought that various illicit drugs could adversely affect or improve their driving Also examined by gender	Alcohol, cannabis, methamphetamine, ecstasy, cocaine, heroin, LSD	Alcohol perceived to the be the substance that could most affect ability to drive: 90% reporting it could adversely affect their driving 40% believed cannabis and methamphetamine could contribute to at least a small degree of improvement in driving About 20% and 14% reported cocaine and ecstasy respectively could contribute to at least a small degree of improvement in their driving Few reported that heroin, LSD could improve their ability to drive Gender differences: a larger proportion of females than males (85% v 68%) believed alcohol could adversely affect their ability to drive Males more likely to believe cannabis could affect a small degree of improvement in their driving ability than females (31% v 17%) Females, overall, less likely to believe that methamphetamine could improve their driving compared to males (59% v 47%) although more females believed that meth could moderately improve their driving compared to males (17% v 10%) Ways in which cannabis was perceived to improve driving (n=36): drive more slowly; drive more cautiously; improves concentration; more alert Ways in which meth was perceived to improve driving (n=39): more alert and aware of surroundings; improve reflexes and quicken responses; improve concentration Fewer reported on how ecstasy could improve their driving (n=13): increased alertness and awareness; more considerate of others Many participants reported caveats to these perceptions of improvement when coming down and feeling tired or if they had consumed large amounts	

Studies Addressing Perceived Impact on Drug Use on Driving Ability / Skill					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Forward (2010) Sweden	Interviews with 15 drug-drivers aged 22-57 who were receiving rehabilitation for drug use	Perceptions of the impact of drugs on driving skills	Not specified	Tendency for drivers to believe they became better drivers when under the influence of drugs especially if they had taken amphetamines (made them more alert). Contrasts with perceptions of drink-driving which was believed to be dangerous	
Gavin et al (2008)	Random telephone survey, 10,391 licensed drivers 501 admitted to having taken recreational drugs within the last 3 months 240 admitted to drug-driving NSW, Australia	Comparison of perceived level of impact of drugs on driving ability between drug-drivers and non-drug-drivers	Marijuana, ecstasy and cocaine	Drug-drivers (67%) were less likely to believe that drug-driving is unsafe compared to non-drug-drivers (91%) Drug-drivers were more likely to believe that the drugs they took did not diminish their driving ability (32%) compared with non-drug-drivers (10%)	
Goldsmith et al (2015) Australia	534 interviews with police detainees from the Drug Use Monitoring in Australia (DUMA) program, 285 of whom had driven a vehicle within the last 12 months and agreed to take part	Perceived effect of substance intoxication on driving ability (improvement or impairment – small, noticeable or large)	Alcohol, cannabis, methamphetamine, MDMA, cocaine and heroin	Detainees were more likely to report drug use as impairing their driving ability within an hour of use (either small, noticeable or large) than having no impact or improving ability. Impairing driving ability - heroin and MDMA (81% of users); alcohol (79%); cocaine (67%); cannabis (64%); methamphetamine (50%) Less than 20% of detainees reported that their driving ability would demonstrate a small, noticeable or large improvement within an hour of consuming: cannabis (18%); cocaine (16%); alcohol (7.5%); heroin (9%); MDMA (3%). However, 36% of methamphetamine users believed this drug had a positive effect on driving ability	The offending history of the detainees may have impacted on their perceived risk of being tested by police for substance use (it is possible that a history of interactions with police may have increased the perceived risk for some detainees, who may be more likely to be stopped by police than other members of the community)

Studies Addressing Perceived Impact on Drug Use on Driving Ability / Skill					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Hammond et al (2009) New Zealand	Internet survey n= 1,124 drug users who had driven Drug-driving defined as driving within 3 hours after use	Drug users who had drug-driven within 3 hours of each substance in previous 12 months "The last time you drove within three hours after using [substance], what impact did it have on your driving ability?" (a lot worse, slightly worse, no change, slightly better, a lot better)	Alcohol (n=241), cannabis (n=275), meth(amphetamine) (n=44), LSD (n=27), ecstasy (n=37), cocaine (n=13), heroin (n=4), benzos (n=32), BZP party pills (n=44), legal party pills (n=23), drug combinations (n=99)	Substance most commonly perceived to have the greatest negative effect on driving ability was drug combinations. 100% of polydrug-drivers felt their driving was a lot worse the last time they drove under the influence of more than one substance. There was no other single substance for which the majority of drug-drivers felt their ability to drive was a lot worse For most other substances, the majority believed there was no effect on their driving abilities including cannabis (57.8%, amphetamine or methamphetamine (54.5%), ecstasy (45.9%), cocaine (69.2%), benzodiazepines (46.9%), BZP party pills (61.4%), and BZP-free party pills (65.2%) Most drink-drivers said their driving was slightly (56.4%), as did drivers under the influence of LSD/hallucinogens (48.1%), Ketamine (50.0%), and heroin (75.0%) Most cannabis drivers felt that their driving was not affected by the drug, however similar numbers of cannabis drivers felt their driving was either better (20.8%) or worse (21.5%) than usual	

Studies Addressing Perceived Impact on Drug Use on Driving Ability / Skill

Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Jonah (2013) Canada	1,500 licensed drivers who had driven in the past 30 days	Perceived effects of alcohol and drugs on driving; rated extent of agreement on 7-point Likert scale	Cannabis, alcohol and other street drugs (unspecified)	% who strongly agreed that each substance impairs driving ability Other street drugs: 87%-97% across 8 regions Alcohol: between 87%-94% across 8 regions Cannabis: between 63%-75% across 8 regions	Not known what % had drug-driven
Lenné et al (2001) Melbourne, Australia	Convenience sample 67 18–25-year-olds who had driven under the influence of cannabis and had used cannabis within last month	Perceptions of driving ability following cannabis use alone and cannabis use combined with alcohol Comparisons in perceptions of driving ability in terms of driving experience and gender	Cannabis and alcohol	46% believed that cannabis use alone had a negative impact on their driving abilities (slowing reaction times and reducing alertness) 12% felt their driving was improved following cannabis use due to compensatory behaviours that 'increased awareness and concentration' 90% believed that cannabis combined with alcohol negatively impacted driving ability There was no effect of experience level on perceptions about whether cannabis, both alone and in combination with alcohol, affected their driving ability but there was an effect of gender with males more likely to admit that driving cannabis used alone does affect driving ability – but similar proportions of males and females believe that cannabis with alcohol does impair driving ability	
MacDonald et al (2008) Ontario, Canada	Survey of 1,021 clients in treatment for drug abuse N=493 had ever driven under the influence of cannabis N=326 had ever driven under the influence of cocaine	'How does being under the influence of cannabis or cocaine affect your ability to drive a car?' (5-point Likert scales with questions derived from the dangerous styles of driving under the influence scale)	Cannabis, cocaine	467 provided comments on how cannabis affected their ability to drive a car and 306 provided comments on how cocaine affected their ability to drive a car 29.7% of responses for those who drove under the influence of cocaine indicated that reckless driving was a common behaviour, compared with only 2.4% of responses for driving under the influence of cannabis 39.9% of those who drove under the influence of cannabis reported the attempt to drive more carefully or cautiously, compared with 19% for driving under the influence of cocaine A higher proportion of responses by the cannabis subjects (27.9%) indicated that they drive normally when under the influence of cannabis, compared with 11.8% of cocaine subjects who drove under the influence of cocaine	The study addressed the effects of either cannabis or cocaine alone, but many of the participants likely frequently used these drugs in combination with alcohol or other drugs

Studies Addressing Perceived Impact on Drug Use on Driving Ability / Skill					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Mallick et al (2007) Australia	Internet survey of 6,801 Australian drivers, 16.9% of whom had driven under the influence of any illicit drug other than alcohol and 12.6% of whom had driven under the influence of alcohol (i.e. over 0.05)	Respondents' perceptions of driving ability the last time they drove within 3 hours of alcohol or illicit drug use from 'a lot worse' to 'a lot better'	Alcohol, cannabis, cocaine, methamphetamine, ecstasy	Alcohol: 68.1% (n=868) reported that their driving had been impaired; 54.7% 'slightly worse', 13.4% 'a lot worse', 28.5% 'no change' Cannabis: 59% (n=839) 'no change', 24.6% 'slightly worse' Cocaine: 67.5% reported 'no change' Methamphetamine: 56% (n=472) 'no change', 22.5% 'slightly better' and 5% 'a lot better' Ecstasy: 37.1% 'no change', 40.6% 'slightly worse' and 7.8% 'a lot worse'	
Neale et al (2001) Scotland	Surveys of 88 individuals attending nightclubs, 36 (41%) of whom had driven within 12 hours of consuming an illegal drug (excluding alcohol)	Perceptions of the impact of drug use on driving skills in individuals who had drug-driven compared to individuals who had never drug-driven Perceptions of the risks associated with drug-driving compared with drink-driving in individuals who had drug-driven compared to individuals who had never drug-driven Perceptions of the impact of drug use on driving skills and of the risks associated with drug-driving compared with drink-driving in night-clubbers compared with a survey of 536 drivers crossing Scotland's four toll bridges between 11 pm and 6 am on weekend nights	Cannabis, ecstasy, amphetamine, cocaine, LSD	Most believed drug-driving did not improve driving skills (72% never drug-driven v 67% drug-driven) with never drug-drivers being more accepting of this than drug-drivers, Male clubbers more likely than female clubbers to believe this might be the case Respondents tended to believe drink-driving was more dangerous than drug-driving with men (60%) and individuals who had drug-driven (58%) being more likely to hold this viewpoint than women (47%) and individuals who had never drug-driven (42%) Clubbers were more likely than toll bridge respondents to believe that some illegal drugs can improve driving skills and toll bridge respondents were more likely to believe that drink-driving is more dangerous than drug-driving	

Studies Addressing Perceived Impact on Drug Use on Driving Ability / Skill					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Payne et al (2013) Australia	857 police detainees who provided information about their drug-driving experiences, of whom 562 had driven a vehicle in the last 12 months, of whom 159 had driven at least once after taking cannabis in the last 12 months	Perceived effect of cannabis use on driving ability (much worse, slightly worse, slightly better, much better, not affected on last occasion)	Cannabis	70% reported that cannabis had never affected their driving abilities Of the remaining 30%, 10% reported that cannabis had only affected their driving ability some of the time, 9% reported being affected about half or most of the time, 12% reported being affected all of the time Of the 30% who had been affected, 55% reported that cannabis impaired their driving on the last occasion (only slight); 24% reported it had improved their driving either slightly or a lot; and 20% reported that their driving was unaffected	
Plancherel et al (2005)	Interviews with 163 adolescents and young adults aged between 13-20	Beliefs of regular current (n=78) versus regular past (n=35) versus never/occasional cannabis users (n=50) about whether cannabis reduces driving ability All respondents (% who had drug-driven is not given)	Cannabis	Regular present cannabis users were significantly more likely to believe that cannabis use reduces driving ability than regular past cannabis users who in turn were significantly more likely to believe that cannabis use reduces driving ability than never/occasional cannabis users	
Porath-Waller (2008)	812 students in years 9-12			Participants perceived that their ability to drive after using a combination of marijuana and alcohol would be significantly poorer and it would be more difficult to drive, as compared to driving after using either of these substances separately As youth perceived the difficulty of driving following the use of marijuana, alcohol and both drugs to increase, their perceived ability to drive after using these substances decreased	

Studies Addressing Perceived Impact on Drug Use on Driving Ability / Skill					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Townsend et al (1998)	Findings from questions in the 1996 National Household Survey on Drug Abuse (NHSDA). 11,847 respondents aged 16 and older who reported driving in the past year and answered the question on whether or not they drove within two hours after substance use	Perceptions of effect of cannabis on driving ability (based on most recent experience of driving within 2 hours of substance use)	Cannabis	Those who reported driving within two hours of using marijuana, with or without alcohol, were slightly more likely to believe that their ability to drive safely was 'not at all' affected" than "affected a lot" or "affected a little"	

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TABLE D.3 SUMMARY OF STUDIES ADDRESSING PERCEPTIONS OF DRIVING IMPAIRMENT AND DRUG USE

Studies Addressing Perception of Impact on Drug Use on Driving Impairment

Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Albery et al (2000) UK	Survey of 210 out-of-treatment current drug users (n=71 drivers of which 58 had drug-driven)	Differences within illicit drug users between three levels of illicit drug use and driving within last 12 months (never, n= 13; sometimes 1-20 times, n=30); frequently once per week or more, n=28) regarding beliefs about the impairing effects of the different drugs on driving skills	Cannabis, stimulants, alcohol, heroin, methadone	In general, never drug-drivers reported increased agreement that drugs impair driving skills Never drug-drivers agreed more that heroin, methadone, and alcohol would impair driving skills than cannabis, and that alcohol and methadone impair skills more than stimulants Sometimes drug-drivers agreed more that alcohol would decrease driving skills compared to cannabis, stimulants, heroin and methadone As above for frequent drug-drivers but participants reported significantly more agreement	Severity of dependence was not shown to differentiate those who drive after taking drugs from those who do not. But for perceptions of the impairing influence of drugs on driving skills, differential beliefs about such effects were shown to be dependent on frequency of illicit drugs and driving behaviour
Arora & Burns (2011) ACT, NSW	Interviews with 98 regular injecting drug users (PWID) from the Illicit Drugs Reporting System (IDRS)	Drug users who had driven within half an hour of consuming one or more drugs in the last 6 months (n=28) Perceptions of driving impairment (quite impaired, slightly impaired, no impact, slightly improved, quite improved)	Heroin, crystal, cannabis, methadone, benzodiazepines	68% of participants reported that drugs had no impact on their driving ability	

Studies Addressing Perception of Impact on Drug Use on Driving Impairment					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Davey et al (2005)	Face to face interviews using snowball technique with 211 illicit drug users (dependent users and recreational users) who had used an illicit drug within the last 12 months and driven within 6 hours of ingestion of a drug	Perceived level of impairment by drug-drivers when driving under the influence of drugs	Drug-driving had occurred under the influence of: marijuana (77%), amphetamines (41%), heroin (42%), ecstasy (21%), cocaine (5%), LSD/other hallucinogen (2%)	A common theme among all types of users was that drug use improved their driving skills (feeling more focused and confident in their ability or enabling better concentration and more relaxation) Some felt that drug taking prevented their involvement in accidents Very few dependent users felt that drugs affected their driving skills or if they did they acknowledged that this awareness did not deter them from drug-driving. About half of dependent users stated that they had never driven a car without being under the influence of drugs Almost all recreational users noted impairment that may affect their driving. But this not necessarily a deterrent to driving, with most unconvinced that drug-driving was a safety issue for them personally – most noted that they were capable of compensating for the impairing effects of the drug by driving more slowly or carefully (particularly marijuana users) Any changes in driving behaviour were to avoid detecting of drug use rather than to reduce risks to safety However, any compensatory behaviours were almost exclusively performed by social/recreational users who timed their driving after using drugs, however timing rarely extended beyond 30 minutes. Dependent users were not concerned with timing their driving and drove immediately after use because they were not fearful of being caught	Largely qualitative with little descriptive
Fischer et al (2006) Canada	45 university students who had driven within four hours of cannabis use in the past year	Perceptions of impairment effects of cannabis on driving – others and self Perceptions of impairment effects of cannabis compared to alcohol and cannabis compared to cannabis and alcohol	Cannabis	95.1% believed cannabis produced at least some driving impairment but only 57.8% believed that they themselves were affected by any impairment and most of these believed they had ways to compensate for at least some of these effects 86.7% perceived cannabis' impairment effects on driving to be less than those of alcohol, yet most (81.8%) believed the impairment effects of cannabis and alcohol combined to be stronger than those of alcohol alone	

Studies Addressing Perception of Impact on Drug Use on Driving Impairment					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Fischer et al (2014) Canada (Toronto, Ottawa, Ontario)	272 university students (18-28) who had identified as having driven a car within 4 hours of cannabis use in the last year, final sample = 248 Snowball recruitment technique	Perception of extent of impairment when driving under the influence of cannabis Compared cannabis users who frequently drove under the influence of cannabis (more than 12 times in last year) with cannabis users who infrequently drove under the influence of cannabis (12 or less times in last year)	Cannabis	High frequency cannabis users were more likely than low frequency cannabis users to perceive their own driving ability not to be impaired by cannabis use	No comparison group (i.e. cannabis users not reporting driving under the influence of cannabis in the past year)
Kohn et al (2014) US	Surveys of 675 of young college students, 444 of whom replied and 97 of whom drove under the influence of drugs	'Do you agree or disagree that using x substance impairs driving?' (strongly disagree to strongly agree; 5-point Likert scale)	Cannabinoids, stimulants, depressants, hallucinogens, alcohol	Respondents disagreed that cannabinoids impair driving (18%) compared to other drugs (17%), stimulants (13%), depressants (11%), hallucinogens (8%), and alcohol (7%)	Not evident if those who responded were only those who took drugs and drove or the entire sample (i.e. including non-drug-drivers)
Matthews et al (2009) Australia	573 regular ecstasy users (REU) in Australian capital territories participating in the Ecstasy & Related Drugs Reporting System (EDRS) who reported driving a vehicle in the 6 months prior to interview	Perception of driving impairment due to drugs among those who had drug-driven (last drug-driving experience)	Ecstasy, alcohol, cannabis, methamphetamine	No differences in the perception of driving impairment due to ecstasy, cannabis, or methamphetamine For all drugs, 42%-43% indicated that their driving ability had been 'slightly impaired' and less than one-tenth (2-7%) indicated that their driving ability had been 'quite impaired' One third (34-36%) indicated that drug use had 'no impact' on driving ability The remainder indicated that their driving ability was 'slightly improved' (16-19%) or 'quite improved' (1%-3%)	

Studies Addressing Perception of Impact on Drug Use on Driving Impairment					
Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Nguyen et al (2012) Victoria, Australia	Interviews with 100 regular ecstasy users (REU) from the Ecstasy and Related Drugs Reporting System (EDRS)	Drug users who had driven within an hour of consuming one or more drugs in the last 6 months (n=55, 40 of whom participated) Perceptions of driving impairment (quite impaired, slightly impaired, no impact, slightly improved, quite improved)	Cannabis, crystal meth, ecstasy or speed	33% of participants reported that drugs had no impact on their driving ability; 45% reported that their ability was impaired and 22% reported that their ability was improved	
Pashley et al (2013) Canada	Random sample of 1,201 drivers who had driven in the last 30 days and had a licence	Perceptions by the general population regarding drug impaired drivers	Cannabis, alcohol, cocaine	63.5% said they felt drug impaired drivers posed a serious threat to traffic safety compared to 76.7% who thought drink-drivers posed a serious threat to road safety	

Studies Addressing Perception of Impact on Drug Use on Driving Impairment

Author/s, Year, Location	Method & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Sutherland and Burns (2011) South Australia	Interviews with 597 regular injecting drug users (PWID) (2006-2011) from the Illicit Drugs Reporting System (IDRS)	Drug users who had driven within an hour of consuming one or more drugs in the last 6 months (n=58) Perceptions of driving impairment (quite impaired, slightly impaired, no impact, slightly improved, quite improved) Comparisons of perceptions of driving impairment by different drug types	Heroin, cannabis, methamphetamine	74% of participants reported that drugs had no impact on their driving ability; 20% believed that drugs impaired their driving ability and 6% believed that drugs improved their driving ability Those who used methamphetamine prior to their most recent drug-driving episode were more likely to think that this had improved their driving ability whilst those who used heroin and Subutex were more likely to believe that their driving ability had been impaired. Those who used cannabis were less likely to think that this had had no impact upon their ability to drive Those who had been arrested in the last 6 months, had a mental health disorder, and who lived in unstable housing were also more likely to believe that the use of drugs impaired their ability to drive and less likely to believe that it had no impact Those who completed additional courses after leaving school were less likely to believe that drug use impaired their driving ability	Sutherland and Burns (2011) South Australia
Terry & Wright (2005) UK	Surveys of two groups: Regular cannabis users (n=80) Response rate 78% 50 (79%) had drug-driven University students (n=150) Response rate 43% 16 (24%) had drug-driven Interviews: Regular male cannabis users (n=23), 100% had drug-driven		Cannabis	Of the 50 regular cannabis users who reported driving after consuming cannabis only 12% believed their driving to be very much impaired; 58% believed their driving was only slightly impaired; 6% not impaired at all; 24% thought their driving was improved Of the 16 students who drove under the influence of cannabis, only 2 believed their driving was very much impaired; 11 only slightly impaired; 2 not at all impaired; and 1 believed his driving to be improved Of the 23 interviewees (n=19) considered cannabis to impair their driving ability, although all but one thought their driving ability was only slightly impaired as opposed to very much impaired. 3 believed cannabis did not impair their driving at all and 1 believed his driving was improved	

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TABLE D.4 SUMMARY OF STUDIES ADDRESSING PERCEIVED DANGER ASSOCIATED WITH DRUG-DRIVING

Studies Addressing Perception of Danger Associated with Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Aitken et al (2000)	Survey of injecting drug users who used heroin and/or amphetamines N=160 (84 were current drivers) Melbourne, Australia	Drivers asked to indicate (from a list of options identified in focus group research conducted as part of the same study) the behaviour they believed was most serious in terms of accident risk	Heroin main drug used (99%), cannabis (34.6%) and amphetamines (13.2%)	Driving straight after injecting heroin was most prevalent by far but only 5% thought this was the most dangerous behaviour The two 'tiredness' factors were regarded as the most dangerous by the largest proportion of respondents (started nodding = 38.8% and fallen asleep at the wheel = 36.3%) and nodding was the second most commonly reported behaviour Craving heroin was perceived by more participants (12.5%) as being the most dangerous behaviour than driving stoned (1.3%)	
Darke, Kelly & Ross (2004) Sydney, Australia	Cross-sectional structured interview survey of 300 regular injecting drug users, 88% of whom had driven soon after using drug in the last 12 months	Perceptions of the level of danger associated with driving under the influence of different types of illicit drugs (Likert scale ranging from 1 not dangerous to 4 very dangerous) Comparisons between drug-drivers and non-drug-drivers	Most common drugs used before driving in last 12 months were cannabis, heroin, amphetamines and cocaine	Alcohol most dangerous = 84% 'very dangerous' Other drugs in order of perceived danger were: hallucinogens 71%, benzodiazepines 68%, heroin 58%, other opioids 47%, inhalants 45%, cocaine 37%, amphetamines 31% and cannabis 18% No significant differences between danger rating scores for alcohol and hallucinogens Alcohol perceived to be more dangerous than benzos (the third most dangerous drug) and heroin (the four most dangerous drug). Cannabis with the lowest risk score was perceived to be significantly less dangerous than amphetamines, the second least dangerous drug Recent drug-drivers generally perceived drug-driving to be less dangerous than non-drug-drivers. Recent drug-drivers perceived a lower level of danger than non-drug-drivers for heroin, opioids, cocaine, and cannabis	

Studies Addressing Perception of Danger Associated with Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Degenhardt et al (2006) Melbourne, Australia	Brief interviews with a convenience sample of 273 young night club attendees, 10% of whom had consumed drugs or alcohol and intended to drive home on the night of the interview	Perceptions of risk associated with driving under the influence of drugs – very dangerous, quite dangerous, not very dangerous, not dangerous and unsure	Alcohol, cannabis, ecstasy, methamphetamine (speed), crystal methamphetamine, cocaine, heroin	High proportions perceived that driving under the influence of heroin (71%) or alcohol (59%) was very dangerous Driving under the influence of methamphetamine (48%), cocaine (46%), or ecstasy (44%), speed (39%) was very dangerous cf. 36% who viewed cannabis in this way	
As above	As above	Rate drug-driving risk on a five-point scale from 'safe' (one) to 'dangerous' (five) (all drug users)	Alcohol, cannabis, amphetamine/methamphetamine, LSD/hallucinogens, ecstasy, cocaine, ketamine, GHB-type	All drugs were rated towards the dangerous end of the scale; none were rated three (neutral) or less. The substance identified as most dangerous was alcohol, with a mean risk rating score (m) of 4.80 (SD=.53). Other drugs perceived to be most dangerous tended to be illegal, with LSD/hallucinogens (m=4.79, SD=.57), heroin (m=4.69, SD=.66) and GHB-type drugs (m=4.67, SD=.67) being rated as next most dangerous after alcohol. The drug perceived to be least dangerous was cannabis (m=3.96, SD=1.29). Cannabis had the largest standard deviation of all the drugs, indicating the most variation in perceived risk among the sample. Other drugs that were perceived to be less dangerous were all stimulants and included legal party pills (m=4.09, SD=1.13), prescription stimulants (m=4.12, SD=1.10), and BZP party pills (m=4.16, SD=1.10)	

Studies Addressing Perception of Danger Associated with Drug-Driving

Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Donald et al (2006) South Australia, Australia	91 participants who had used an illicit drug/s at least once a month and driven a vehicle at least once a month in previous 6 months 89 had drug-driven in last 12 months	Respondents' perceptions of the risk of driving under the influence of alcohol or illicit drugs within an hour or two after using: 'not at all dangerous'; 'somewhat dangerous'; 'dangerous', 'very dangerous'; and 'not sure' Also examined by gender	Alcohol, cannabis, methamphetamine, ecstasy, cocaine, heroin, LSD	Over 40% reported that they consider it very dangerous to drive following alcohol use; very few reporting it 'not at all dangerous' or 'not sure' Cannabis and meth largely reported to be not at all dangerous by 58% and 40% of the sample respectively Ecstasy and cocaine: 74% and 55% respectively reported some level of danger but opinion was more spread across the categories of danger compare with the other drugs Compared to alcohol, cannabis, meth, cocaine and ecstasy were ranked as less dangerous to drive on within an hour or two after use Males more likely to believe it was not at all dangerous to drive following cannabis use cf. females (65% v 45%) Females more likely to believe not at all dangerous to drive after ecstasy compared to males (14% v 5%) More females than males considered it would be very dangerous to drive following use of methamphetamine (21% v 7%)	
Hammond et al (2009) New Zealand	Internet survey n=1,166 drug users of whom 1,124 had driven a vehicle Drug-driving defined as driving within 3 hours after use	Rate drug-driving risk on a five-point scale from 'safe' (one) to 'dangerous' (five) All drug users Compares drug users who have driven under the influence with drug users who have not driven under the influence	Alcohol (n=1018), cannabis (n=410), LSD (88), benzos (n=102), party pills (n=113), legal party pills (n=56), ecstasy (n=138), other opiates (n=127), prescription stimulants (n=37), meth(amphetamine) (n=90), cocaine (n=38), heroin (n=6)	All drug users: all drugs were rated towards the dangerous end of the scale with alcohol rating highest (mean 4.8); cannabis least dangerous (mean 3.96) Drug-drivers perceive less risk for driving under the influence than drug users who have not driven under the influence for the previous 12 months: p >0.001 for: alcohol (n=1018), cannabis (n=410), LSD (88), benzos (n=102), party pills (n=113) and legal party pills (n=56) p >0.01 for: ecstasy (n=138), other opiates (n=127), prescription stimulants (n=37) p >0.05 for: meth(amphetamine) (n=90)	

Studies Addressing Perception of Danger Associated with Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Lobmann & Krueger, 2000 Bavaria, Germany	2,779 drivers visiting discos briefly interviewed, 483 of whom participated in detailed interviews (17.4% response rate)	Perceived damnability and dangerousness of driving under the influence of different illegal drugs were assessed on scales from 0-10 and compared to driving under the influence of alcohol (after 4 beers) Comparisons were made between sober and impaired drivers for both alcohol and drug users	Alcohol, cannabis, amphetamines, cocaine, ecstasy, hallucinogens, opiates	Compared to those who drink-drive, drug-drivers show a higher tolerance towards cannabis and driving and perceive driving under the influence of amphetamines, ecstasy or cocaine less damnable than driving drunk. Only driving on hallucinogens and opiates were rated as worse than drunk driving Drug free drivers consider the combination of driving under the influence of all illegal drugs as condemnable as drunk driving Thus, drug-drivers appear to rate damnability according to their experience with the drug, whereas drug free drivers take only illegality into account Drunk and drug-drivers and their friends have a more permissive attitude towards driving under the influence than their respective control groups. Drug-drivers are more permissive of drunk driving and drunk drivers are more permissive of drug-driving than their controls	
Mallick et al (2007) Australia	Internet survey of 6,801 Australian drivers, 16.9% of whom had driven under the influence of any illicit drug other than alcohol and 12.6% of whom had driven under the influence of alcohol (i.e. over 0.05)	Respondents' perceptions of the risk of driving under the influence of alcohol or illicit drugs, from 'very risky/dangerous' to 'not at all risky/dangerous' Comparisons between drug users and non-drug users (listed for 'very risky/dangerous' responses only)	Alcohol, cannabis, cocaine, methamphetamine, ecstasy	Alcohol: drinkers 88.9% (6231), non-drinkers 94% (570) Cannabis: drug users 30% (1635), non-drug users 78.6% (5166) Methamphetamine: drug users 31% (895), non-drug users 88.6% (5906) Ecstasy: drug users 46% (1057), non-drug users 87.6% (5744) Cocaine: drug users 26% (622), non-drug users 83% (6179)	

Studies Addressing Perception of Danger Associated with Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
McIntyre et al (2011) Melbourne, Australia	Sample size and year/s not defined	Comparison of drug-drivers' and the general public's perception of the risk of drug-driving Profile of drug-drivers		40% of drug-drivers saw driving under the influence of illegal drugs as a problem 60% of drug-drivers compared to 90% of the general community thought that enforcing drugs would be beneficial for road safety 42% of drug-drivers compared to 90% of the general community reported that they would not get into a car with a driver who had taken illicit drugs 66% of the general public thought drug-driving was high risk compared to 29% of drug users Drug-drivers were mostly young (aged 18-29) and mostly male Compared to drug users who did not drug-drive, drug-drivers were more likely to travel as a passenger with a drug-driver (66% v 28%), and more likely to report having driven when over 0.05. Drug-drivers are clearly more willing to put their safety at risk than drug users who do not drive	Sample size and year/s not defined % not reported for some analyses
Porath-Waller (2008)	812 year 9-12 students	Perceived period of time following drug or alcohol use after which it is safe to drive Comparisons by gender and patterns of use	Marijuana	Youth perceived that driving following the use of marijuana or alcohol was significantly less dangerous and detectable by police as compared to driving after using both substances together In terms of substance-related accident involvement, students indicated that the greatest likelihood was associated when the driving occurred after using marijuana combined with alcohol, followed by marijuana use, and then alcohol As students' perceptions of the danger associated with substance use and driving increased, so did their perceived likelihood of being involved in an accident and being detected by police	

Studies Addressing Perception of Danger Associated with Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Ross et al (2007) Sydney, Australia	419 nightclub attendees, mean age 23.5 years, of whom between 1% and 15% had driven under the influence of drugs or alcohol in the past month	Perceived risks of driving under the influence of different drug types – very dangerous, quite dangerous, not very dangerous, not dangerous and unsure	Alcohol, ecstasy, cannabis, methamphetamine powder, cocaine, crystal methamphetamine	High proportions believed that driving under the influence of heroin (82%), alcohol (62%) or crystal methamphetamine (58%) was 'very dangerous'. Just under half of the sample thought that driving under the influence of cocaine (45%) or ecstasy (44%) was very dangerous, with 40% viewing speed as very dangerous. 36% believed that driving under the influence of cannabis was very dangerous	No comparison group of non-drug-drivers Responses of drug-drivers appear to be combined with those of non-drug-drivers

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TABLE D.5 SUMMARY OF STUDIES ADDRESSING PERCEIVED RISK OF CRASH INVOLVEMENT AND DRUG-DRIVING

Studies Addressing Perception of Crash-Risk Associated with Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Albery et al (2000) UK	Survey of 210 out-of-treatment current drug users (n=71 drivers of which 58 had drug-driven)	Differences within illicit drug users between three levels of illicit drug use and driving within last 12 months (never, n= 13; sometimes 1-20 times, n=30); frequently once per week or more, n=28) regarding beliefs about accident likelihood	Cannabis, stimulants, alcohol, heroin, methadone	Never drug-drivers considered the chances of accident involvement under cannabis to be less than for heroin, methadone and alcohol. They also showed greater agreement that the chances would be less after taking stimulants than for methadone or alcohol In both the sometimes and frequently groups, participants agreed more that the chances of accident involvement after alcohol were greater than for cannabis, methadone, stimulants and heroin Never drug-drivers agreed more than methadone would increase the chances of accident involvement than both the sometimes and frequently groups	
Jones et al (2007) Australia	Cross sectional sample of 320 cannabis users	Belief that driving under the influence of cannabis increases crash risk All respondents (78% had driven under the influence of cannabis in previous 12 months)	Cannabis	53% of sample believed that driving under the influence of cannabis increases crash risk	Sample included drug users who had and had not driven under the influence of cannabis The purposive sampling framework does not allow generalisation of the results to all cannabis users. However, the large proportion of the sample that could be described as an entrenched subgroup of users is potentially useful for targeting countermeasures since this group is most at risk of drug-driving

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Studies Addressing Perception of Crash-Risk Associated with Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Jones et al (2006) Sydney and Newcastle, NSW	320 people who had used cannabis in the last 12 months and who had driven a motor vehicle in the last 12 months (but not necessarily drug-driven during this period)	Impact of providing factual information about drug use and crash risk on willingness to drug-drive Participants who had driven within one hour of cannabis use and who believed that DUIC on its own either reduced or did not affect their risk of accident (n=133) were asked to indicate on a visual analogue scale their likelihood of driving if they could be convinced that cannabis-intoxicated drivers were "about three to seven times more likely to be responsible for their crash than drivers who have not used drugs or alcohol"	Cannabis	26% indicated that they would be highly likely to continue to drug-drive despite the facts about risks Most participants would be more likely than not to continue to drug-drive despite the facts about risks Very few (7.5%) indicated that they would be unlikely to drive if they could be convinced of the facts about risks	
Lenné et al (2001) Melbourne, Australia	Convenience sample 67 18–25-year-olds who had driven under the influence of cannabis and had used cannabis within last month	Perceptions of risk of crash when driving under the influence of cannabis	Cannabis and alcohol	57% thought that driving under the influence of cannabis did not increase their risk of car crash	

Studies Addressing Perception of Crash-Risk Associated with Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Matthews et al (2009) Australia	573 regular ecstasy users (REU) in Australian capital territories participating in the Ecstasy & Related Drugs Reporting System (EDRS) who reported driving a vehicle in the 6 months prior to interview	Perceived likelihood of having an accident while DUI (very unlikely – very likely) - all participants Perceived likelihood of having an accident while DUI (participants who had driven under the influence of specific substance in question)	Ecstasy, alcohol, cannabis, methamphetamine	Alcohol – 76% likely or very likely Ecstasy, cannabis, methamphetamine – 35 - 45% likely or very likely Proportion who perceived having an accident was likely or very likely was significantly higher for alcohol relative to all other substances and lower for methamphetamine compared to ecstasy, with cannabis falling in between For each drug type, a significantly greater proportion of those who had not driven under the influence perceived that having an accident was 'likely' or 'very likely' compared to those who had recently driven under the influence. Recent users: alcohol 67%, ecstasy 30%, cannabis 23%, methamphetamine 14%	
Matthews et al (2014)	Two groups regular ecstasy users (REU) in Australian capital territories participating in the Ecstasy & Related Drugs Reporting System (EDRS) 573 in 2007 and 429 in 2011 Participants in each group were not the same and all had driven a car and taken ecstasy regularly in the last six months	Perception of likelihood of having a crash if DUI of alcohol (over legal limit), ecstasy, cannabis, and methamphetamine on a five-point Likert scale ranging from 1 (very unlikely) to 5 (very likely) (participants who had used each drug) Assessment of any changes in perceptions between 2007 and 2011	Ecstasy, alcohol, cannabis, methamphetamine, cocaine and LSD	Significant increase in proportion who believed it was likely or very likely that they would have a crash if DUI of ecstasy (44% v 53%) and methamphetamine (27% v 37%) No changes were apparent in perceived risk for cannabis (36% v 34%) or alcohol (76% v 74%), although perceived crash risk associated with DUI alcohol was substantially greater than for illicit drugs	Cannot ascertain that drivers were under the influence of drugs/alcohol at the time/s they had been driving

Studies Addressing Perception of Crash-Risk Associated with Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Porath-Waller (2008)	812 year 9-12 students	Perceived period of time following drug or alcohol use after which it is safe to drive Comparisons by gender and patterns of use	Marijuana	Youth perceived that driving following the use of marijuana or alcohol was significantly less dangerous and detectable by police as compared to driving after using both substances together In terms of substance-related accident involvement, students indicated that the greatest likelihood was associated when the driving occurred after using marijuana combined with alcohol, followed by marijuana use, and then alcohol As students' perceptions of the danger associated with substance use and driving increased, so did their perceived likelihood of being involved in an accident and being detected by police	
Stevenson et al (2001) Western Australia	Convenience sample of 286 university students, 57 (26%) of whom had driven under the influence of alcohol whilst the designated 'skipper' and 39 of whom (18%) had driven the influence of illicit drugs as the designated skipper	Perceptions of risk of crash when driving under the influence of drugs or alcohol	Alcohol, cannabis, ecstasy and amphetamines	95% of respondents thought that driving under the influence of alcohol would increase their likelihood of crashing 10% believed cannabis reduced the risk of crashing, while 8% were unsure	Responses based on all participants including those who did and did not drive under the influence of drugs and or alcohol Results not given for perceptions relating to ecstasy and amphetamines

Studies Addressing Perception of Crash-Risk Associated with Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Findings	Limitations / Notes
Swift, Jones & Donnelly (2010) NSW, Australia	Survey using purposive sampling framework 320 who had used cannabis in the last 12 m and had driven they a car within this period Drug-driving defined as driving within one hour of drug use	Level of agreement with the statement that driving under the influence of alcohol alone and alcohol and cannabis in combination increases crash risk for self and others Level of agreement with the statement that 'you are more at risk of having an accident if you drive while feeling intoxicated by alcohol than if you drive while feeling intoxicated by cannabis'	Cannabis, alcohol	Universal agreement (>97%) that driving under the influence of alcohol alone and alcohol and cannabis in combination increased both own and others' crash risk 53% believed driving under the influence of cannabis alone increased personal accident risk; 36% believed it had no effect and 10% believed it decreased risk Cannabis dependent participants were half as likely as their non-dependent peers to believe their personal risk of a driving under the influence of cannabis crash was increased (45% v 61%) 68% believed driving under the influence of cannabis increased others' risk of an accident, 24% believed it had no impact and only 5% believed risk was decreased Most (87%) agreed/strongly agreed with the statement that accident risk is greater under the influence of alcohol alone than cannabis alone	Were the questions tailored to the specific user groups? Not evident from study – it appears that these percent (%) values reflect all participants in the study including those who had and had not driven under the influence of drugs or alcohol

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TABLE D.6 SUMMARY OF STUDIES ADDRESSING PERCEIVED RISK OF BEING CAUGHT FOR DRUG-DRIVING

Studies Addressing Perception of Being Caught Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Barrie et al (2011) ACT, Australia	Six focus groups with 6-8 young drivers (aged 18-25)	Perception of risk of getting caught by police for drug-driving	Cannabis, speed, ecstasy, alcohol (but key focus was on cannabis)	Most participants did not expect to be tested by police and thus were not worried about losing their licence (the only factor they believed would deter them from drug-driving). This perception appeared to stem from the fact that most were unaware of current drug-driving laws in the ACT and what the penalties were for drug-driving	Perceptions appear to be based on their own as well as others' experiences of drug-driving and so not all participants were drug-drivers
Darke, Kelly & Ross (2004) Sydney, Australia	Cross-sectional structured interview survey of 300 regular injecting drug users, 88% of whom had driven soon after using drug in the last 12 months	Perceptions of the risk of getting caught by police for driving under the influence of drugs	Most common drugs used before driving in last 12 months were cannabis, heroin, amphetamines and cocaine	42% thought it likely they would be caught if they drug drove Recent drug-drivers believed they were less likely to be caught for drug-driving than non-drug-drivers (35% v 54%	
Davey et al (2008) QLD, Australia	516 motorists, 143 of whom had drug-driven at least once	Perception of certainty, severity and swiftness of being apprehended for drug-driving Compared between convicted drug-drivers (n=49) and demographically matched motorists from general driving population	Cannabis, amphetamines, heroin, cocaine	49.9% perceived the certainty of being apprehended as high; 47.8% perceived the severity of apprehension as high and 32.7% perceived the swiftness of apprehension as high Convicted drug-driving offenders significantly more likely to report a greater frequency of drug-driving in the last 6 months; perceived the chances of being apprehended for drug-driving to be significantly higher and swifter than general motorists; and reported a much higher expected frequency of intending to drug-drive in future	

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Studies Addressing Perception of Being Caught Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Dietze et al (2015) Victoria and other Australian states	Data from the survey of Regular Ecstasy Users (REU) conducted as part of the EDRS for the period 2007-2013 About 100 participants per state who had driven within the past 6 months	Perceptions of risk of being caught if driving after taking drugs and how this might influence their driving behaviour 'Out of the next 100 people in this state who drive after taking drugs, how many do you think will be caught?' 'Has the introduction of random roadside testing in this state changed your driving behaviour?'	Ecstasy, alcohol, cannabis, methamphetamine, cocaine and LSD	The median number of people out of 100 who participants believed would be caught while driving after taking drugs was 5 (IQR: 1-10) In Victoria and other jurisdictions, half of participants reported that the introduction of random roadside drug testing had not changed their drug-related driving behaviour (43% of Victorians and 52% of participants in other jurisdictions) The most commonly reported changes in behaviour among those who reported that roadside testing had changed their behaviour were not driving after using drugs (33% Vic, 53% other states), waiting longer before driving (33% Vic, 26% other states), taking a taxi (19% Vic, 33% other states) and arranging an alternative driver (2% Vic, 15% other states)	Not known whether participants had been under the influence of the drug when driving (presumably most were as they were regular drug users, all of whom had driven)
Donald et al (2006) South Australia, Australia	91 participants who had used an illicit drug/s at least once a month and driven a vehicle at least once a month in previous 6 months 89 had drug-driven in last 12 months	Respondents' level of concern regarding the possibility of being caught by police when 'drug-driving' (overall not for specific substance types) Also examined by gender	Alcohol, cannabis, methamphetamine, ecstasy, cocaine, heroin, LSD	Most participants were not particularly concerned about the possibility of being caught by police the last time they drove within an hour or two of using an illicit substance with 46% reporting being not at all concerned	
Freeman et al (2010) QLD, Australia	Survey of 899 motorists, 19.3% of whom had drug-driven in the last 6 months	To determine how motorists perceive the certainty, severity and swiftness and social sanctions of drug-driving related sanctions	Cannabis, amphetamines, cocaine, heroin	Largest proportion of participants were unsure about certainty of apprehension (45.8%); severity of the corresponding sanction (49.2%), or the swiftness of the applied penalties once apprehended. Not surprising and most likely because at time of the study drug testing had only just been just introduced in QLD 51% reported that they would be concerned about their friend's views about their drug-driving behaviour	Responses appear to be from all motorists including those who had not drug-driven

Studies Addressing Perception of Being Caught Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Gavin et al (2008)	Random telephone survey, 10,391 licensed drivers 501 admitted to having taken recreational drugs within the last 3 months 240 admitted to drug-driving NSW, Australia	Drug-drivers Perceived likelihood of getting caught by police for drug-driving Compares perceptions with survey in 2003	Marijuana, ecstasy and cocaine	29% of drug-drivers in 2008 believed that they would be likely to get caught if they drug drove compared 15% in 2003	
Goldsmith et al (2015)	534 interviews with police detainees from the Drug Use Monitoring in Australia (DUMA) program, 285 of whom had driven a vehicle within the last 12 months and agreed to take part	Percentage of detainees who perceived that being tested for drugs while driving is likely (likely, very likely, extremely likely, unlikely, very unlikely, extremely unlikely)	Alcohol, cannabis, methamphetamine, MDMA, cocaine and heroin	59% thought it was likely (results combined for likely to extremely likely) they would be tested by police for alcohol; 38% methamphetamines; 36% cannabis; 31% MDMA; 29% cocaine, 29% heroin	The offending history of the detainees may have impacted on their perceived risk of being tested by police for substance use (it is possible that a history of interactions with police may have increased the perceived risk for some detainees, who may be more likely to be stopped by police than other members of the community)
Hawkins et al (2004)	N= 5074 NSW drivers aged over 17 years – random telephone survey. 429 were licensed drivers who admitted to being drug users (in last 3 months) 205 were drug-drivers (in last 12 months)	Perception of likelihood of getting caught by police for drug-driving Drug-drivers compared to non-drug-drivers 'High risk' compared to 'low knowledge' and 'lower risk' drug-driving clusters	Cannabis, ecstasy, speed, cocaine, LSD and heroin	Drug-drivers were more likely than non-drug-drivers to believe that they were unlikely to get caught for drug-driving 'High risk' drug-drivers were the least likely to think they would get caught for drug-driving with 80% saying it was very or somewhat unlikely that they would get caught compared to 39% of 'lower risk' drug-drivers	%s not specified for all analyses

Studies Addressing Perception of Being Caught Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Jones et al (2006) Sydney and Newcastle, NSW	320 people who had used cannabis in the last 12 months and who had driven a motor vehicle in the last 12 months (but not necessarily drug-driven during this period)	Experimental paradigm in which participants were asked to rate their willingness to drive under the influence of cannabis in one of four different hypothetical scenarios (random allocation) 1) High certainty – Police can randomly drug test drivers at the roadside 2)Low certainty – Police cannot randomly drug test drivers at the roadside 3) High severity – If caught for DUIC they would be fined $1000 and have their licence disqualified for 12 months 4) Low severity - If caught for DUIC they would be fined $500 and have their licence disqualified for 6 months Participants asked to rate 1) their chances of being caught by police given the scenario, and 2) how big a problem the penalties would be if they were caught and convicted (measured on visual analogue scales) All participants asked to indicate driving likelihood if there was no chance of being caught and punished	Cannabis	No significant differences between groups on potential key drug-driving predictors (i.e. age, gender, offending behaviour, cannabis dependence, other drug use, or beliefs about accident and apprehension risks when DUIC Participants in the high certainty condition were significantly less likely to indicate a willingness to drive given the scenario than those in the lower certainty condition No difference between high and low severity groups in their ratings of how problematic the penalties would be if they were to be caught and convicted, suggesting that the introduction of random roadside testing would increase the perceived certainty of apprehension but there would be no difference in perceived sanction severity if fines and licence disqualification in NSW were doubled 75% of participants rated their chances of DUIC as 50% or greater Participants who reported DUIC in last 12 months were more likely than those who did not report DUIC in the last year to report a willingness to drive if there was no chance of being caught and punished	

Studies Addressing Perception of Being Caught Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Matthews et al (2009) Australia	573 regular ecstasy users (REU) in Australian capital territories participating in the Ecstasy & Related Drugs Reporting System (EDRS) who reported driving a vehicle in the 6 months prior to interview	Perceived likelihood of being caught by police while DUI (very unlikely – very likely) - all participants	Ecstasy, alcohol, cannabis, methamphetamine	Alcohol – 73% likely or very likely Ecstasy, cannabis, methamphetamine – 29 - 19% likely or very likely Proportion who perceived being caught by police was likely or very likely was significantly lower for methamphetamine (19%) compared to cannabis (29%), with the perception for ecstasy not differing from either drug (23%) For each drug type, a significantly greater proportion of those who had not driven under the influence perceived that being caught by police was 'likely' or 'very likely' compared to those who had recently driven under the influence	
Matthews et al (2014)	Two groups regular ecstasy users (REU) in Australian capital territories participating in the Ecstasy & Related Drugs Reporting System (EDRS) 573 in 2007 and 429 in 2011 Participants in each group were not the same and all had driven a car and taken ecstasy regularly in the last six months	Perception of likelihood of being apprehended by police if DUI of alcohol (over legal limit), ecstasy, cannabis, and methamphetamine on a five-point Likert scale ranging from 1 (very unlikely) to 5 (very likely) (participants who had used each drug) Assessment of any changes in perceptions between 2007 and 2011	Ecstasy, alcohol, cannabis, methamphetamine, cocaine and LSD	Significant increase in proportion who believed it was likely/very likely that they would be apprehended by police if DUI of ecstasy (23% v 39%) and methamphetamine (14% V 32%) No significant differences in risk perceptions were found for alcohol or cannabis	Cannot ascertain that drivers were under the influence of drugs/alcohol at the time/s they had been driving

Studies Addressing Perception of Being Caught Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Ross et al (2007) Sydney, Australia	419 nightclub attendees, mean age 23.5 years, of whom between 1% and 15% had driven under the influence of drugs or alcohol in the past month	Perceived risks of being caught by random roadside drug testing for driving under the influence of drugs	Alcohol, ecstasy, cannabis, methamphetamine powder, cocaine, crystal methamphetamine	Alcohol – very likely (51%), quite likely (29%) Stimulant drugs: not very likely or very likely for speed (50%), crystal methamphetamine (46%), ecstasy (45%), or cocaine (49%). Just over 50% thought it was not likely or not very likely that persons driving under the influence of cannabis would be caught	No comparison group of non-drug-drivers Responses of drug-drivers appear to be combined with those of non-drug-drivers

Studies Addressing Perception of Being Caught Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Watling et al (2010) QLD	899 members of the public, university students, and individuals referred to a drug diversion program (20% of whom had drug-driven in the past 6 months)	Participants' awareness of the drug-driving legislation and testing techniques Participant experiences of punishment (having been caught and convicted for drug-driving), direct punishment avoidance (having avoided being caught and convicted while drug-driving), vicarious punishment (knowing others who have been caught and convicted for drug-driving) and vicarious punishment avoidance (knowing others who have avoided being caught and convicted while drug-driving) on their perceived likelihood of drug-driving in the next 6 months Measured with the Drug-driving Questionnaire (DDQ)	Cannabis (most prevalent but other drug types were not specified)	44.8% were aware of the drug-driving legislation and 64.2% were aware of the testing methods for drug-driving, 36.2% were aware of the penalty if convicted for drug-driving Punishment dropped from analysis because only 12 participants had been caught for drug-driving Direct punishment avoidance and vicarious punishment avoidance were significant predictors of reported intentions to drug-drive in future, and punishment avoidance was related to reduced perceptions of certainty (of punishment) and severity (of punishment) Vicarious punishment was not a significant predictor of drug-driving intentions (may reflect that the penalties were not perceived to be severe enough or that drivers have compensatory strategies and or can drive safely on drugs) Vicarious punishment avoidance was a significant predictor of intentions to drug-drive in future and was negatively related to perceptions of certainty Vicarious punishment avoidance was a more influential predictor of drug-driving than personal experiences of punishment avoidance Gender and criminal record were the most influential predictors of future intentions to drug-drive Vicarious punishment avoidance reduced perceptions of certainty more than personal experiences of punishment avoidance	
Wilson (2010) Melbourne, Victoria	40 current drug users recruited through snowball sampling techniques, 32 of whom had engaged in drug-driving	Perceptions of the likelihood of detection by police Drug-drivers and passengers of drug-drivers	Cannabis, ecstasy, methamphetamine	Participants believed that prior to the introduction of random roadside drug testing the likelihood of detection by police was non-existent. Since the introduction of random roadside drug testing participants believed that the threat of detection was possible but still low (based on anecdotal evidence) Some participants believed that random roadside drug testing had been introduced for moral reasons (i.e. to reduce drug use in general) rather than because drug use impairs driving performance Most participants supported random roadside drug testing as a necessary measure for general road safety.	No use of %s to indicate size of agreement with various attitudes/ beliefs

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TABLE D.7 SUMMARY OF STUDIES ADDRESSING SELF-REPORTED KNOWLEDGE ABOUT DRUG-DRIVING

Studies Addressing Self-Reported Knowledge of Caught Drug-Driving

Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Hammond et al (2009) New Zealand	Internet survey n=1,166 drug users of which 1,124 had driven a vehicle Drug-driving defined as driving within 3 hours after use	All drug users "How much do you know about the following drugs in relation to their effect on driving ability?" Rating scale 'nothing', 'very little', 'some', 'quite a lot', and 'a lot'	Alcohol, cannabis, meth(amphetamine), LSD, ecstasy, cocaine, heroin, benzos, BZP party pills, legal party pills	With the exception of alcohol, knowledge of drug effects was poor Alcohol only substance for which the majority knew 'a lot' (52.2%) or 'quite a lot' (37.5%) about its effects on driving ability. Relative to other drugs, somewhat more known about cannabis (31.7% 'some' and 28.5% 'quite a lot') Respondents reported knowing less about the effects of other substances Respondents knew 'some' (28.8%) or 'very little' (27.4%) about amphetamines/methamphetamines, Most knew 'very little' about ecstasy (31.5%), cocaine (34.3%), heroin (33.0%). Most knew 'nothing' about prescription stimulants 37.0%, benzodiazepines 32.8%, and legal party pills 38.8%	
As above	As above	All drug users "How long after consuming enough to feel under the influence of the following drugs would it be safe to drive?" ('within 1 hour', '1 to 2 hours', '2 to 4 hours', '4 to 6 hours', '6 to 10 hours', 'more than 10 hours', and 'don't know')	Alcohol, cannabis, meth(amphetamine), LSD, ecstasy, cocaine, heroin, benzos, BZP party pills, legal party pills	Most respondents said they did not know what timeframe is appropriate for most drugs. Alcohol only substance for which most reported knowing how long they should wait (97.1%), with most nominating waiting 10 + hours (32.9%) Most common response for cannabis was 'don't know' (26.0%) 74.0% did select a timeframe, with 51.6% selecting a timeframe for LSD/hallucinogen consumption, while the other half (48.4%) did not know what timeframe was appropriate. For all other substances, most did not know how long to wait (amphetamine/methamphetamine 51.7%, ecstasy 52.2%, cocaine 57.1%, heroin 62.4%, prescription stimulants 66.6%, benzodiazepines 62.2%, BZP party pills 59.3%, and legal party pills 67.0%	The 'don't know' response was likely the most appropriate for many substances as there was not enough information given for participants to make a safe assessment Variables such as amount of substance consumed, body mass of user, food and water intake, health status of user, fatigue and level of intoxication make it impossible for even an expert to nominate a safe delay between intoxication and unimpaired driving

Studies Addressing Self-Reported Knowledge of Caught Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Mallick et al (2007) Australia	Internet survey of 6,801 Australian drivers, 16.9% of whom had driven under the influence of any illicit drug other than alcohol and 12.6% of whom had driven under the influence of alcohol (i.e. over 0.05)	"How much do you know about the following drugs in relation to their effect on driving ability?" Rating scale 'nothing', 'very little', 'some', 'quite a lot', and 'a lot' All respondents (n=6,801)	Alcohol, cannabis, cocaine, methamphetamine, ecstasy	High levels of knowledge in relation to alcohol and driving (79.5% 'a lot', 20.1% 'a little' and 0.5% 'nothing' With the exception of cannabis, more than two thirds of respondents reported that they knew nothing or a little about the effects of each of the illicit drugs on driving ability For cannabis, 51.1% knew a little and 33.2% knew a lot	
As above	As above	"How long after consuming enough to feel under the influence of the following drugs would it be safe to drive?" ('within 1 hour', '1 to 2 hours', '2 to 4 hours', '4 to 6 hours', '6 to 10 hours', 'more than 10 hours', and 'don't know') All respondents (n=6,801)	As above	With the exception of cannabis, more than one third of respondents reported that it would be necessary to wait more than 10 hours after consuming all types of illicit drugs before driving With the exception of cannabis, more than one third of respondents reported that they did not know how long after consuming each of the drugs it would be safe to drive With respect to cannabis, 8% reported that it would be safe to drive within one hour, 9% 1-2 hours, 13% 2-4 hours, 4-6 hours 11.7%, 6-10 hours 8.2%). 21% reported that it would be necessary to wait more than 10 hours and 29.2% were unable to specify a time	

Studies Addressing Self-Reported Knowledge of Caught Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Hawkins et al (2004) NSW, Australia	N= 5074 drivers aged over 17 years – random telephone survey. 429 were licensed drivers who admitted to being drug users (in last 3 months) 205 were drug-drivers (in last 12 months)	*'High risk' compared to 'low knowledge' and 'lower risk' drug-driving clusters Impact of knowledge about the impairing effects of drug-driving on drug-driving behaviour Knowledge about the impairing effects of drugs on driving	Cannabis, ecstasy, speed, cocaine, LSD and heroin	'High risk' drug-drivers were the least likely to say that information about how drugs affect driving would change their behaviour compared with more than half of 'low knowledge' drug-drivers 'Low knowledge' drug-drivers were more likely than other group members to either believe that the higher risk drugs (such as speed and ecstasy) were safe for driving or to say that they did not know whether they were safe The 'lower risk' group were the most aware of the three groups that drugs affect driving skills; were more informed about the risks of drug-driving and said they were receptive to information about the dangers of drug-driving *Comparing the clusters of 2003 (see Hawkins et al (2004) with 2008 showed the following main differences: the moderate risk cluster increased in size while the more conservative lower risk cluster decreased in size. This likely explained by the high-risk cluster's views in 2003 tending toward the more moderate group in 2008, with increasing tendencies to consider the social consequences of getting caught and increasing beliefs in the likelihood of getting caught.	%s not specified for all analyses
Mabbott & Hartley (1999) 3 truck stops in Western Australia	Interviews with 236 truck drivers aged 21-69 (mix of short and long-haul operations)	Knowledge of stimulants and their side effects and whether this differs according to trip length and number of known peers who use stimulants All respondents	Stimulants (illicit and prescription)	Of the 158 drivers who responded, 81% knew less than 3 side effects to drugs which they had listed as being commonly used within the industry Intrastate drivers were more likely to report that they did not know the side effects of stimulant drugs compared to those who were interstate drivers Those who knew no drivers using stimulants were less likely to report knowing the side effects of stimulants than those who knew more than 10 drivers who use stimulants	% who had drug-driven not known but 27% reported using stimulants as a countermeasure for fatigue

Studies Addressing Self-Reported Knowledge of Caught Drug-Driving					
Author/s, Year, Location	Methodology & Sample	Focus of Analysis	Substances Examined (Of relevance to our review)	Key Findings	Limitations / Notes
Porath-Waller (2008)	812 year 9-12 students	Perceived period of time following drug or alcohol use after which it is safe to drive Comparisons by gender and patterns of use	Marijuana	Participants believed their driving performance to be affected for about five hours after drinking their last alcoholic drink, compared to four hours after using their last marijuana joint As adolescents' past-year frequency of using marijuana increased, their perceptions of how long marijuana affects their driving decreased. When differences in the perceived length of time that driving is affected following the use of either marijuana or alcohol were examined according to adolescents' past-year frequency of alcohol use, non-drinkers were found to perceive significantly longer periods of time as compared to infrequent and regular drinkers	

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TABLE D.8 SUMMARY OF STUDIES EXAMINING PREDICTORS OF DRUG-DRIVING

Studies Examining Predictors of Drug-Driving					
Author/s, Year, Location	Method & Sample	Substances Examined (Of relevance to our review)	Predictors Examined	Key Findings	Limitations / Notes
Adams et al (2008) Australia	1,714 police detainees who provided information about their drug-driving experiences, of which 1,215 had driven a vehicle in the last 12 months, 65% of whom 789 had driven after using drugs and or alcohol and agreed to participate in an interview	Alcohol, cannabis, amphetamine, methamphetamine, benzodiazepines, cocaine and heroin	Comparisons in terms of demographics between detainees who reported driving after using drugs in the last 12 months and detainees who had not drug-driven in the same period	Detainees who reported driving after using drugs were significantly more likely to: have an education of year ten or less, be unemployed, receive government benefits, self-report dependency on drugs, have been arrested or imprisoned in last 12 months. Detainees who self-reported heroin dependence in the last 12 months were more likely to drive multiple times per week after using heroin than non-dependent detainees (70% v 44%)	

Studies Examining Predictors of Drug-Driving					
Author/s, Year, Location	Method & Sample	Substances Examined (Of relevance to our review)	Predictors Examined	Key Findings	Limitations / Notes
Agic et al (2013) Ontario, Canada	22,106 respondents who held a driving licence - derived from an annual repeated cross-sectional survey of Ontario adults	Alcohol and cannabis	Comparisons between four groups: No driving under the influence of alcohol or drugs in last 12 months, driving after alcohol only in last 12 months, driving after using cannabis only in last 12 months, driving after using alcohol and cannabis in last 12 months on gender, age, substance use, substance problems, and mental health: current smoker, weekly binge drinking, cannabis use, cannabis use problems, psychological distress, poor mental health	Statistically significant differences between groups were found on the following: drivers in the 3 groups that report substance use and driving were much more likely to be male and younger than drivers who do not report driving post substance use Driving under the influence of cannabis and the driving under the influence of alcohol plus cannabis groups were much more likely to be tobacco smokers and cannabis users than the other two groups There was a strong association of cannabis problems with driving after using cannabis: over 80% of both the driving under the influence of cannabis and the driving under the influence of alcohol plus cannabis groups scored in the problem range on cannabis use, compared to 7.2% among driving under the influence of alcohol and 3.3% among those who reported no driving after substance use. Alcohol use and problem measures appeared to differentiate between the driving under the influence of cannabis and driving under the influence of alcohol plus cannabis groups, 57% of the latter compared to 28% of the former reported weekly binge drinking, and 82% of the latter compared to 44% of the former fell into the harmful/hazardous drinking range on the hazardous drinking measures Similar differences were observed on mental health measures although the differences were less pronounced. The three groups reporting substance use and driving showed more evidence of mental health problems than those who did not report any driving after substance use The driving under the influence of cannabis plus alcohol group demonstrated the highest levels of psychological distress and were more likely to report fair or poor mental health	Findings are exploratory Not possible to determine whether those who reported driving after drinking and taking cannabis combined both of these substances on individual driving occasions

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Studies Examining Predictors of Drug-Driving					
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Armstrong et al (2005) QLD, Australia	331 young university students, of which 82 (25.7%) reported drug-driving at some time, 27 (8.2%) reported drug-driving in the last 12 months and 18 (5.7%) reported drug-driving within the previous four weeks	Marijuana, speed/amphetamines, heroin, ecstasy, LSD, cocaine	Vicarious punishment avoidance Vicarious punishment Perceived risk of apprehension Punishment avoidance (direct) Perceived social rewards Perceived social punishments Attitudes Sensation-seeking Willingness to drug-drive Dirven (alcohol and drugs) Willingness to drive over the legal BAC limit	Drug-driving was significantly correlated with vicarious punishment avoidance (the deterrent effect of an individual's vicarious experiences of punishment and punishment avoidance through association with others – Starr and Warr's 1993 expanded model of deterrence theory) and direct punishment avoidance, suggesting an important link between young people's perceptions about detection and punishment and their own propensity to drug-drive. In other words, when younger drivers (or their peers) successfully evade detection whilst driving under the influence of drugs, this may encourage them to engage in future driving due to a perceived lack of punishment Those who scored high on the measure of sensation-seeking were more likely to report drug-driving than low sensation-seeking participants. Sensation seekers were more likely to anticipate social reinforcements and less likely to anticipate social punishments for drug-driving. Attitudes was strongly correlated to participants' willingness to drug-drive and sensation-seeking was positively correlated with attitudes towards drug-driving and willingness to drug-drive indicating that sensation seekers held more positive attitudes towards drug-driving and were more prepared to engage in the behaviour in the future	The overrepresentation of females in the sample may underestimate current behaviour in this sample given that males tend to use drugs more frequently than females The sample of university students may not be representative of the wider population of drug users
Armstrong et al (2014) ACT, Australia	Telephone interviews with 801 motorists, 10.74% of whom indicated that they had ever driven within 24 hours of taking an illicit drug	Cannabis, ecstasy, meth/amphetamine	The impact of perceptions of certainty of apprehension, severity and swiftness of sanctions (the classical deterrence theory variables); direct and vicarious effects of punishment and punishment avoidance (the reconceptualised deterrence theory variables); and demographic factors (age, sex) on drug-driving and intentions to drug-drive in future	Males were more likely to have driven within 24 hours of using drugs Younger individuals were more likely to likely to have driven within 24 hours of using drugs since the introduction of roadside testing Future intentions to drive within 4 hours of drug use were correlated with younger age, unawareness of roadside oral fluid testing, having previously avoided punishment, not knowing someone else who has been punished, and knowing someone who has avoided punishment The classical deterrence theory variables of certainty of apprehension, severity and swiftness of sanctions were not predictive of future intentions to drug-drive. However, age, having avoided apprehension and knowing of others that have avoided apprehension were predictive of intentions to drug-drive in the future.	

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Begg et al (2003) Dunedin, New Zealand	931 young people aged 15-26. Assessments included information on the number of times they had driven a car within 2 hours of using marijuana. Those who engaged in this behaviour at both 21 and 26 years were classified as "persistent" and compared with others who did not engage in these behaviours	Cannabis	Demographic characteristics, personality measures, mental health measures, anti-social behaviour, early driving related behaviours	Univariate results showed that males were more likely to report low constraint (i.e., impulsive, incautious behaviour), high levels of negative emotionality, high substance use at age 18, alcohol dependence at age 21, juvenile arrest, non-traffic related police conviction before age 18, a traffic conviction before age 21, an alcohol traffic conviction, aggressive behaviour at age 18, able to drive a car at age 15, motorcycle licence at age 18, and to have been involved in a traffic crash between ages 13 and 26 Univariate results showed that females were more likely to have been a parent at age 21, had high substance use at age 18, cannabis dependent at age 21, been arrested as a juvenile between age 10-16 years Multivariate results for males showed low constraint at age 18, a non-traffic police conviction before age 18, and a traffic conviction before age 21 predicted persistent driving after using cannabis. Cannabis dependence at age 21 was shown to be the most powerful predictor associated with persistent driving after using cannabis but after adjusting for cannabis dependence, only a police conviction (traffic and non-traffic – these appear to have been related to cannabis use) and low constraint remained significant predictors There was little similarity between the persistent drink-driver and the persistent cannabis using driver	Participants were analogous to a community sample and the results may be generalizable to young adults in other communities, whereas in other studies the participants are analogous to a clinical sample and thus the results may not be generalizable to the community No multivariate analyses for females due to too few numbers who drove after using cannabis

Studies Examining Predictors of Drug-Driving					
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Bergeron et al (2014) Canada	48 young male cannabis users (18-26 years) who drove at least once per week of whom 19% had never driven under the influence of cannabis	Cannabis	Cannabis use patterns and their relationship with self-reported and objectively measured (in a driving simulator) risk-taking behaviour while driving Levels of risk-taking behaviour and their relationship with different levels of cannabis consumption	Those who consumed cannabis several times per week reported taking significantly more risks while driving than those who only consume cannabis once per month The more users of cannabis reported or showed risky driving behaviours in the simulator, the greater the likelihood that they were susceptible to driving after smoking cannabis or after drinking alcohol. Participants more frequently reported having driven in the hour immediately following cannabis consumption relative to having driven immediately after drinking alcohol	Use of other substances was not controlled for Use of speed only as a measure of risk-taking in the simulator without assessing the intention behind this behaviour Sample size was small, only included males and was not likely to be representative of the population Note, participants in this study were not under the influence of cannabis when driving in the simulator

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Bergeron & Paquette (2014) Canada	72 young male cannabis users (18-25 years) who drove at least twice per week, of whom 12.5% had never driven under the influence of cannabis	Cannabis	Examine the relationship between reckless driving and frequency of driving under the influence of cannabis Examine the contribution of sensation-seeking, impulsivity, age and driving exposure in the prediction of driving under the influence of cannabis Examine the association between driving under the influence of cannabis and involvement in traffic violations and crashes	The frequency of cannabis consumption was found to be significantly correlated with driving under the influence of cannabis The frequency of cannabis consumption was found to be significantly correlated with sensation-seeking and with risky driving Beyond age and driving exposure, sensation-seeking was a significant predictor of driving under the influence of cannabis (so, individuals scoring high on sensation-seeking show a higher risk of driving under the influence of cannabis) Neither age nor driving exposure was found to be a significant predictor of driving under the influence of cannabis The frequency of cannabis use and frequency of driving under the influence of cannabis were related to maximum speed (in the simulator) Driving under the influence of cannabis was significantly associated with an increased risk of traffic tickets (e.g., for excessive speed or omitting to stop) and with self-report risky behaviours	Use of other substances was not controlled for Sample size was small, only included males and was not likely to be representative of the population No subjective assessment of the intention behind behaviours exhibited in the simulator Note, participants in this study were not under the influence of cannabis when driving in the simulator
Bingham et al (2008) Michigan, USA	Telephone survey data and state driver history records for a sample of 5,244 young adults	Cannabis Other drugs Alcohol	Environment system, personality system, driving behaviours, traffic offences on driving under the influence of cannabis and driving under the influence of other drugs	Psychosocial characteristics associated with degree of substance-involved driving Degree of SID predicted having a traffic offense States: “Interventions could have enhanced effectiveness if they also targeted individual psychosocial and behavioural characteristics, either to alter these behaviours or by tailoring the intervention or program for these characteristic”.	

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Studies Examining Predictors of Drug-Driving					
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Calaft et al (2009) 9 European cities	Survey of 1,363 regular nightlife users aged 16-35 using respondent driven sampling technique	Alcohol, cannabis, ecstasy, cocaine	Examined the associations between driving under the influence of drugs or alcohol and patterns of substance use, age and sex	Driving under the influence of drugs in the last 30 days was not independently related to either age or sex but it was strongly related to the use of cannabis, cocaine and number of times drunk; the odds of having driven under the influence of drugs were more than 15 times higher for those using cannabis twice or more a week compared to those who did not use cannabis at all; more than 9 times higher for those who used cocaine twice or more a week compared to those who did not use cocaine at all, and more than 6 times higher for those who were drunk 5 or more times in the past 30 days compared to those who never drank at all during this period 35% respondents who used cannabis 2 or more times per week had driven under the influence of drugs in last 30 days compared to 29% who had used cannabis once per week and 15% who had used it less than once per week. Similar pattern for ecstasy and cocaine and number of times drunk Drug-driving was also related to 'usual choice of transport mode' to get to night life settings with those using a private vehicle to travel being over 5 times at greater risk of drug-driving than those who used public transport While those using substances at high frequencies experience the greatest drink/drug-driving related risks, even lower frequencies of drug use and drunkenness still result in significantly higher levels of risk behaviours than those who abstain from drugs or who have never drunk in the last 30 days	
Darke, Kelly & Ross (2004) Sydney, Australia	Cross-sectional structured interview survey of 300 regular injecting drug users, 88% of whom had driven soon after using drug in the last 12 months	Most common drugs used before driving in last 12 months were cannabis, heroin, amphetamines and cocaine	To examine factors associated with drug-driving by comparing drug-drivers with drug users who did not drive in terms of demographics (age, sex, employment, treatment status), geographical location, driving frequency, drug use, and psychopathology	Drug-drivers had driven significantly more frequently over the preceding 12 months than nondrug-drivers with 49% having drug-driven at least weekly compared to 17% of non-drug-drivers) Drug-drivers had significantly higher levels of dependence on their drug of choice, higher frequency of use of their drug of choice, and more extensive polydrug use Drug-drivers were significantly more likely to have used a drug in a car and to have injected a drug in a car in the previous 12 months	

Studies Examining Predictors of Drug-Driving

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Davey, Davey & Obst (2005) QLD, Australia	Undergraduate university cohort (n=275, aged 18-55) 25% of sample had drug-driven ever (n=68) and 15% had drug-driven in last 12 months (n=41)	Marijuana, speed, ecstasy, LSD, benzos, heroin, cocaine	Predictors of drug-driving examined: Age, gender, drug use patterns, attitudes towards drug-driving and attitudes towards drink-driving	Age was a significant predictor of drug-driving with older participants more likely to report having drug-driven than younger participants. Actual drug use was the strongest predictor of drug-driving with those using drugs recently being more likely to drug-drive than others. The greater and the more frequent the drug taking behaviour, the more likely participants were to have drug-driven Attitudes towards drug-driving were significant predictors of drug-driving behaviour, meaning that more favourable attitudes towards drug-driving lead to increased likelihood of drug-driving behaviour. The attitudes most strongly linked to drug-driving behaviour were those relating to what the participant's peers thought about drug-driving and the perceived harms, or risks (it's OK to drive if you're not too high) Drink-driving was a significant predictor of drug-driving with those reporting drink-driving being more likely to drug-drive than those who did not drink-drive	
Davey et al (2008) QLD, Australia	516 motorists, 143 of whom had drug-driven at least once	Cannabis, amphetamines, heroin, cocaine	Examination of predictors: legal sanctions: perception of certainty, severity and swiftness of being apprehended for drug-driving; non-legal sanctions: perception of social, internal, and physical; and drug consumption on intentions to drug-drive in the next 6 months	Previous drug-driving behaviour was a significant predictor of intentions to drug-drive in future, with those who reported drug-driving in last 6 months more than twice as likely to report intentions to reoffend Certainty of apprehension was a significant predictor, with those reporting lower perceptions of apprehension more likely to offend in the next 6 months. Thus, those who reported a low perceived certainty of apprehension were more likely to drug-drive than those who perceived the probability of being caught for drug-driving to be high Drug consumption levels were a significant predictor, with those who reported frequently using drugs being over 3 times as likely to drug-drive in the next 6 months Perceptions regarding the severity and swiftness of sanctions, in addition to the 3 non-legal sanctions did not contribute to the prediction of intentions to offend Previous drug-driving convictions, perceptions of drug testing effectiveness and socio-demographic characteristics did not increase the predictive value of the model	

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Thomas Dols et al. (2010) Valencia, Spain	Cross-sectional survey of 11,239 students aged 14-18 years from 252 private and public schools 20% of students reported driving, 45% of whom drove after alcohol or drug use	Drugs and alcohol (but only results for cannabis reported (n=30) here due to the authors' combining driving under the influence of alcohol and drug use in most of the analyses)	Gender, age, number of standard drinks per week, starting age for alcohol consumption, number of cannabis cigarettes smoked per week, perceived degree of danger for alcohol and cannabis consumption, any alcohol or drug related problems reported during their lifetime, if they repeated an academic year, how well they thought they were doing in their studies, and family relationships with the dependent variable driving after substance use Logistic regression: dependent variable was driving a vehicle after use of alcohol, alcohol and drugs, or drugs on a night out during the last 6 months	The higher the number of cannabis cigarettes smoked per week and the lower the awareness of the dangers of cannabis, the higher the likelihood of driving after consuming drugs Any substance use associated with driving during a night out was associated with being male, consuming more drinks per week, smoking more cannabis cigarettes per week, having a lower awareness of the dangers of cannabis, having a worse family relationship and reporting alcohol and or drug related problems in their lifetime	Potential underestimation of the 16–18-year age group since attendance at school is mandatory until age 16 Potential underestimation of car drivers since the majority are permitted to ride Driving or riding behaviour among the sample may be sporadic given the potential for limited access to a vehicle for some drivers in this age group
Dietze et al (2015) Victoria and other Australian states	Data from the survey of Regular Ecstasy Users (REU) conducted as part of the EDRS for the period 2007-2013 About 100 participants per state who had driven within the past 6 months	Ecstasy, alcohol, cannabis, methamphetamine, cocaine and LSD	Year of interview, sex, age, accommodation type, identify as Aboriginal or Torres Strait Islander (ATSI), completed high school, employment status, arrested, drug of choice (ecstasy or other), no. drug types used past month, ever injected any drug, binged past 6 months associated with driving under the influence of drugs stratified by whether participants believed they were impaired at the time of driving	Year of interview, male gender, reporting a drug choice other than ecstasy, having ever injected any drugs and having binged on stimulants in the past 6 months and greater number of drug types used in the past 6 months (in a dose-response manner) were significantly associated with driving under the influence of drugs were participants believed they were not impaired Year of interview, male gender, having binged on stimulants in the past 6 months and greater number of drug types used in the past 6 months (in a dose-response manner) were significantly associated with driving under the influence of drugs were participants believed they were impaired	

Studies Examining Predictors of Drug-Driving

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Duff & Rowland (2006) Melbourne, Australia	455 semi structured interview surveys with night club patrons, 281 of whom reported driving within 4 hours of consuming an illicit substance in the past year Recruited through convenience sampling	Cannabis, ecstasy, speed, LSD, cocaine, heroin	Predicting drug-driving by setting (bar/pub, club, party, rave, friend's home, own home), controlling for age and gender Predicting drug-driving by drug type (cannabis, ecstasy, LSD, speed/crystal/ice), controlling for age and gender Predicting drug-driving by marital status, employment status, attitude towards driving under the influence and the extent to which it is common for friends to drive under the influence (controlled for age and gender)	Permissive attitudes towards drug-driving, higher than average prevalence of drug-driving in one's peer group, frequency of use of cannabis and ecstasy, and propensity to use these substances in rave and party settings significantly predicted drug-driving The less concerned participants were about the effects of drug use on driving, the more likely they were to drive under the influence of an illicit drug. Similarly, the less common it was for a participant's friends to drive under the influence of an illicit drug, the less likely it was for the participant to drive under the influence of an illicit drug	Use of a convenience sample means the findings are unlikely to be representative of the general population of young people in Victoria Settings were assessed with proxy measures and thus did not directly assess whether a respondent used drugs in a particular setting
Fischer et al (2006) Canada	45 18–28-year-old university students who had driven within four hours of cannabis use in the past year	Cannabis	Not specified	Median split analysis suggested that 'high' frequency of cannabis use (i.e. multiple times a week or more) was significantly associated with both 'high' frequency (i.e. six or more episodes) of driving under the influence of cannabis in the past year as well as a high level of anticipated likelihood of driving under the influence of cannabis in the coming year	Data was collected from a convenience sample without controls

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Fischer et al (2014) Canada (Toronto, Ottawa, Ontario)	272 university students (18-28) who had identified as having driven a car within 4 hours of cannabis use in the last year, final sample = 248 Snowball recruitment technique	Cannabis	Age, sex, daily driving, owning a car, non-medical drug use, cannabis use frequency and setting, cannabis use and driving in conjunction with other drugs, checked by police for impaired driving, previous MVA involvement, perceptions of cannabis' effects on driving in general and for oneself, and expectations regarding traffic related offences and cannabis driving activities in future	High (i.e.,> 12 times) (compared to low i.e., <12 times) frequency cannabis use and driving was associated with frequent (i.e. at least weekly) cannabis use, daily driving, perception of own ability to drive not being impaired by cannabis use, expectations of driving under the influence of cannabis in the next 12 months	
Freeman et al (2010) QLD, Australia	Survey of 899 motorists, 19.3% of whom had drug-driven in the last 6 months	Cannabis, amphetamines, cocaine, heroin	To determine what perceptual (i.e., certainty, severity, swiftness and social sanctions) and behavioural (i.e. criminal record, previous drug-driving, being a passenger of a drug-driver, and overall drug consumption) based factors predict intentions to drug-drive in the future	Only certainty of apprehension was predictive of future intentions to drug-drive as was social sanctions. Specifically, those with low apprehension certainty were significantly more likely to report future intentions of drug-driving as were individuals who were least concerned about the possible social sanctions associated with the behaviour. Certainty of apprehension and social sanctions remained significant predictors of future intentions to drug-drive over and above the inclusion of behavioural factors. But these two were less influential predictors than the behavioural variables of having drug-driven in last 6 months or overall drug consumption	

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Author/s, Year, Location	Method & Sample	Substances Examined (Of relevance to our review)	Predictors Examined	Key Findings	Limitations / Notes
Jones et al (2007) Australia	Cross sectional sample of 320 cannabis users	Cannabis	Age, gender, whether participants identified as indigenous Australians, country of birth, employment, education, peer drug-driving, cannabis dependence, age of first cannabis use, previous injecting behaviour and the number of drugs used, risky alcohol use, prior licence disqualifications, average weekly distance driven in the last year, perceived risk of accident, risk of apprehension, and severity of fines associated with driving under the influence of cannabis in the past year	Use of multiple drugs, believing that cannabis use does not increase accident risk and cannabis dependence predicted likelihood of driving under the influence of cannabis Earlier onset cannabis use predicted driving under the influence of cannabis but only in women	The purposive sampling framework does not allow generalisation of the results to all cannabis users. However, the large proportion of the sample that could be described as an entrenched subgroup of users is potentially useful for targeting countermeasures since this group is most at risk of drug-driving
Kohn et al (2014) US	Surveys of 675 of young college students, 444 of whom replied and 97 of whom drove under the influence of drugs	Cannabinoids, stimulants, depressants, hallucinogens, alcohol	Demographics (age, sex, race ethnicity), college status (year, major, grade point average), housing information (on- versus off-campus), hometown, lifestyle information (number of roommates, close friends, involvement in Greek life, athletics or honour program, presence of faculty confidant), amount of time spent in various activities (studying, socialising, watching tv), the importance of academics, parties, arts, community services, athletics, religion and best friends in high school and or college use of drugs, beliefs about drug impairment when driving	Drug-driving was more likely among males versus females, those living off campus, those reporting that parties are important, those reporting that community service is not important, those reporting that religion is not important, those reporting that personal drug use in high school as well as that their best friends used drugs in high school and college. Those factors most associated with drug-driving included using drugs in high school and best friends in college used drugs regularly	Sample limited to one university and may not be representative of university students in general population No information collected on non-respondents. Non-respondents may have been more likely to drug-drive and this may underestimate the proportion of drug users in this sample

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Lasebikan (2010) Nigeria, South Africa	Interviews with 422 commercial drivers	Cannabis	Age, education status, DSM cannabis abuse, DSM cannabis dependence, hire car driver status (compare with owner driver status), mean distance travelled, unfavourable attitudes toward policies, critical comments from passengers about driving under the influence of cannabis, previous driving under the influence of cannabis accidents	Cannabis abuse, cannabis dependence, and being a hire car driver were associated with driving under the influence of cannabis	Other drug use was not controlled for
Lobmann & Krueger, 2000 Bavaria, Germany	2,779 drivers visiting discos briefly interviewed, 483 of whom participated in detailed interviews (17.4% response rate)	Cannabis, ecstasy, amphetamines, cocaine, hallucinogens, opiates, and alcohol	Sociodemographic data, personality data, health concern, drug and alcohol consumption, drug and alcohol consumption by network, social integration, attitude towards driving and psychoactive substances, attitude of network towards driving and psychoactive substances, perception and knowledge of deterrence	Drug and drunk driving was predicted by a high consumption of drugs, a permissive attitude towards driving whilst intoxicated as well as a permissive attitude within the social network, low rating of own health concern, drug use and alcohol by friends and being non-conformist Drug-driving was predicted by still being at school, low education, preference for techno music, being an extrovert and a sensation seeker, identifying as politically left, high yearly driving mileage Drink-driving was predicted by being employed, high education, no preference for techno music, going out often, high peer orientation, low perceived probability of detection by police, low perceived severity of penalty if detected	Unclear whether low education means poor performance at school or did not complete all of schooling. Similar for high education

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Author/s, Year, Location	Method & Sample	Substances Examined (Of relevance to our review)	Predictors Examined	Key Findings	Limitations / Notes
Matthews et al (2009) Australia	Face-to-face interviews with 573 regular ecstasy users (REU) in Australian capital territories participating in the Ecstasy & Related Drugs Reporting System (EDRS) who reported driving a vehicle in the 6 months prior to interview, 72% of whom had driven under the influence of illicit drugs (within one hour) in the last 6 months	Ecstasy, alcohol, cannabis, methamphetamine	Investigated potential factors associated with driving under the influence of each illicit substance within the last 6 months: number of days used substance, risk perception (accident and legal), frequency of drug use, age and sex	**Driving under the influence of alcohol (n=521)** - more frequent alcohol use, lower perceptions of accident risk, male sex, and younger age were associated with increased risk of DUI of alcohol **Driving under the influence of ecstasy (n=533)** - lower perceptions of the likelihood of having an accident or being apprehended by police, a greater frequency of ecstasy use, and male sex contributed to an increase of DUI of ecstasy **Driving under the influence of cannabis (n=434**) - more frequent cannabis use, and lower perceptions of accident risk were associated with DUI cannabis. **Driving under the influence of methamphetamine (n=434)** - more frequent methamphetamine use and lower perceptions of the likelihood of having an accident or being apprehended by police while DUI methamphetamine were associated with increased risk of DUI methamphetamine **Summary**: Driving under the influence of each substance was most strongly associated with frequency of use and risk perceptions (both accident and legal) and to a lesser extent, demographic characteristics such as age and sex	

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Matthews et al (2014)	Two groups regular ecstasy users (REU) in Australian capital territories participating in the Ecstasy & Related Drugs Reporting System (EDRS) 573 in 2007 and 429 in 2011 Participants in each group were not the same and all had driven a car and taken ecstasy regularly in the last six months	Ecstasy, alcohol, cannabis, methamphetamine, cocaine and LSD	Examined the associations between driving under the influence of various substances and crash and legal risk perceptions associated with drug-driving	**Driving under the influence of alcohol (n=935)** – significantly associated with male sex, younger age, a greater number of days of alcohol use in past 6 months, and lower crash risk perceptions **Driving under the influence of cannabis (n=779)** – significantly associated with a greater number of days of cannabis use in last 6 months and lower crash risk perceptions **Driving under the influence of ecstasy (n=932)** – significantly associated with a greater number of days of ecstasy use in last 6 months and lower legal risk perceptions **Driving under the influence of methamphetamine (n=614)** – significantly associated with a greater number of days of methamphetamine use in last 6 months and lower crash risk perceptions **Lower crash risk perceptions were found to be associated with** engagement in driving under the influence of alcohol, cannabis, ecstasy and methamphetamine in the last six months • Higher perception of risk was associated with a lower likelihood of driving under the influence. **Lower legal risk perceptions** were associated with driving under the influence of ecstasy. The relationship between driving under the influence and crash risk • Perceptions were stronger than for legal risk perceptions for alcohol, methamphetamine and cannabis. For meth, like cannabis, the **risk of police apprehension** was rated as relatively low, which may account for the lower strength of this relationship.	Cannot ascertain that drivers were under the influence of drugs/alcohol at the time/s they had been driving

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Payne et al (2013) Australia	857 police detainees who provided information about their drug-driving experiences, of whom 562 had driven a vehicle in the last 12 months, of whom 159 had driven at least once after taking cannabis in the last 12 months	Cannabis	Comparison of demographics within drug-drivers Comparison between drug and non-drug-drivers on risky driving (failing to stop for police) Frequency of drug-driving according to frequency of use of drug	• Male detainees (20%) were more likely than female detainees (11%) to self-report a history of driving under the influence of cannabis – a finding that held true even when estimated only for those male and female detainees who had used cannabis in the past 30 days. (39% v 24%). • Detainees aged 36 or more were significantly less likely to drive after using cannabis than younger detainees • Drug-driving is unlikely to be an isolated practice but one that occurs largely within the context of other risky driving behaviours: 35% v 18% of drug vs non-drug-drivers (in past 12 m) had failed to stop their vehicle when requested by police. • Among very recent cannabis users, the prevalence of drug-driving was higher among those who used cannabis more than 3 times per week 51%) compared to those who used it less frequently i.e. 1-3 times per week (31%) and less than once per week (13%)	
Pilkington et al (2013) Mississippi, USA	6,339 persons enrolled in a court mandated alcohol safety education program who were arrested for a driving under the influence offence, of whom 18.8% were using cannabis on the day of their arrest	Alcohol, cannabis and other drugs	Compared characteristics of offenders between different drug types being used on the day of arrest (including polydrug use)	Cannabis users tended to be: • Male, younger, less educated, more likely to be African American, and more likely to be unemployed than those who did not use cannabis. • Had significantly lower scores on the Alcohol Use Disorders Identification Test (AUDIT), • Reported significantly more substance use related consequences • Twice as likely as those who did not use cannabis to have been arrested for crimes other than driving under the influence. • Cannabis users also had a significantly higher number of traffic citations for moving violations such as speeding or running a red light, than non-cannabis users	

Studies Examining Predictors of Drug-Driving					
Author/s, Year, Location	Method & Sample	Substances Examined (Of relevance to our review)	Predictors Examined	Key Findings	Limitations / Notes
Richer & Bergeron (2009) Quebec, Canada	72 young males aged 17-45 years who drove at least once per week, of whom 30 were cannabis users. 80% of users had driven under the influence of cannabis in the previous 12 months	Cannabis	Potential predictors of driving under the influence of cannabis: age, driving exposure, sensation-seeking, impulsivity	• Age was negatively correlated with driving under the influence of cannabis, supporting the fact that younger drivers will drive after consuming cannabis more often than do older drivers (but neither age nor driving exposure is a significant predictor of driving under the influence of cannabis) • Driving under the influence of cannabis was significantly and positively linked to: ○ risky driving, negative emotional driving, dangerous driving, driving under the influence of alcohol, sensation-seeking and impulsivity • Driving under the influence of cannabis was predicted by sensation-seeking and impulsivity ○ those who score high on either of these personality factors drove more frequently under the influence of cannabis than those who report lower scores on sensation-seeking and impulsivity, with sensation-seeking being the more important predictor	Use of other substances was not controlled for Sample size was small, only included males and was not likely to be representative of the population Note, participants in this study were not under the influence of cannabis when driving in the simulator
Scott-Parker et al (2014) QLD, Australia	1,077 young drivers 18-20 years, 30 of whom had at least occasionally driven under the influence of drugs	Illicit drugs (such as marijuana and ecstasy). Note, the specific drug types were not reported	Compared self-reported risky driving behaviours between drug and non-drug-drivers: speeding, driving errors, general risky driving, carrying passengers in risky circumstances	• No difference between the two groups in terms of education level and age • Drug-drivers significantly more likely to speed, commit driving errors, engage in general risky driving behaviours, carry passengers in risky situations, drink-drive, and report stronger risky driving intentions and to report having had an offence detected	Very small sample of participants who drove after taking drugs (n=30; 20 males and 10 females)

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Sutherland and Burns (2011)
South Australia
	Interviews with 597 regular injecting drug users (PWID) (2006-2011) from the Illicit Drugs Reporting System (IDRS)
	Drug users who had driven within an hour of consuming one or more drugs in the last 6 months (n=58)
		Heroin, cannabis, methamphetamine	Examination of predictors (not specified) of driving under the influence of drugs	• Significantly more likely to have reported drug-driving within the last 6 month
				  ○ Those who had a higher frequency of heroin use
				  ○ Those who had completed any courses after leaving school
				• Inversely, those who reported suffering from drug induced psychosis within the past 12 months were significantly less likely to have driven after consuming drugs	

Swift, Jones & Donnelly (2010) NSW, Australia	Survey using purposive sampling framework 320 who had used cannabis in the last 12 m and had driven a car within this period Drug-driving defined as driving with one hour of drug use	Cannabis alone or cannabis combined with alcohol	Examination of independent predictors (not specified) of reporting at least weekly compared to less frequent driving under the influence of cannabis (DUIC)	• Being cannabis dependent (versus non-dependent) and driving more than 60 km per week (versus less than 60 km per week) were associated with increased odds of driving under the influence of cannabis • Believing driving under the influence of cannabis increased accident risk discouraged this behaviour (versus believing driving under the influence of cannabis had no impact or decreased accident risk). • No independent effect of gender, age, alcohol, or other drug use, having had previous cannabis related accidents or beliefs about the likelihood of being caught by the police for DUIC.	

Studies Examining Predictors of Drug-Driving					
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Watling and Freeman (2010) QLD, Australia	Survey of 922 members of the general public	Cannabis, meth/amphetamines, cocaine, heroin	Examined the relative contribution that deterrence (i.e., certainty, severity, swiftness of sanctions), defiance (feelings of shame and legitimacy of sanctioning authority) and deviance (moral attachment to the norm) had for predicting the samples' intentions to drug-drive in the future after controlling for overall drug consumption.	Overall drug consumption was a strong predictor of **intentions to drug-drive** – that is, the more drug use the individual reported the more likely they were to drug-drive. **Deterrence theory –** neither the certainty, severity, nor swiftness were significantly predictive of intentions to drug-drive. **Defiance theory –** feelings of shame and legitimacy of sanctioning authority were significant predictors of intentions to drug-drive. More specifically, decreases in both reported feelings of shame and in the legitimacy of the sanctioning authority resulted in an increased likelihood of drug-driving, although it is noted that feelings of shame was the more influential of the two predictors. **Deviance –** the variable of moral attachment to the norm was found to be a significant predictor of intentions to drug-drive.	Not known what % had drug-driven

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Further information

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