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A review of drug use and driving: epidemiology, impairment, risk factors and risk perceptions

ERIN KELLY, SHANE DARKE & JOANNE ROSS

National Drug and Alcohol Research Centre, University of New South Wales, Australia

Abstract

The existing literature on the prevalence of drug driving, the effects of drugs on driving performance, risk factors and risk perceptions associated with drug driving was reviewed. The 12-month prevalence of drug driving among the general population is approximately 4%. Drugs are detected commonly among those involved in motor vehicle accidents, with studies reporting up to 25% of accident-involved drivers positive for drugs. Cannabis is generally the most common drug detected in accident-involved drivers, followed by benzodiazepines, cocaine, amphetamines and opioids. Polydrug use is common among accident-involved drivers. Studies of impairment indicate an undeniable association between alcohol and driving impairment. There is also evidence that cannabis and benzodiazepines increase accident risk. The most equivocal evidence surrounds opioids and stimulants. It is apparent that drugs in combination with alcohol, and multiple drugs, present an even greater risk. Demographically, young males are over-represented among drug drivers. Although there is an association between alcohol use problems and drink driving, it is unclear whether such an association exists between drug use problems and drug driving. Evidence surrounding psychosocial factors and driving behaviour is also equivocal at this stage. While most drivers perceive drug driving to be dangerous and unacceptable, there is less concern about impaired driving among drug drivers and drink drivers than from those who have not engaged in impaired driving. Risk perceptions differ according to drug type, with certain drugs (e.g. cannabis) seen as producing less impairment than others (e.g. alcohol). It is concluded that drug driving is a significant problem, both in terms of a general public health issue and as a specific concern for drug users. [Kelly E, Darke S, Ross J. A review of drug use and driving: epidemiology, impairment, risk factors and risk perceptions. *Drug Alcohol Rev* 2004;23:319 – 344]

Key words: driving, drugs, harm, risk.

Introduction

Motor vehicle accidents (MVAs) are a major cause of mortality, resulting in approximately 300 000 deaths throughout the world each year [1]. In 1999, the median fatalities of OECD countries was 10.4 per 100 000 population [2]. Although the association between alcohol and MVA risk has long been acknowledged, little research has been conducted on drug driving (defined as driving shortly after using drugs), even though drugs also appear to be of concern to traffic safety. In addition to the concern for general traffic safety, drug driving presents a serious health concern for drug users. In an examination of heroin-related deaths in Italy, Quaglio *et al*. [3] found that road accidents were the third most common cause of death for injecting drug users (IDUs), accounting for 10% of deaths.

The current review examined the existing literature in the area of drug driving, with reference to drink driving where appropriate. Specifically the aims of this review were to:

(i) Examine the prevalence of drug driving in a range of populations;
(ii) Examine the effect of drugs on driving performance;
(iii) Identify the risk factors associated with drug driving;

Erin Kelly BPsych (Hons), Research Officer, National Drug and Alcohol Research Centre, Shane Darke PhD, Associate Professor, National Drug and Alcohol Research Centre, Joanne Ross PhD, Lecturer, National Drug and Alcohol Research Centre, University of New South Wales, Australia. Correspondence to Erin Kelly, National Drug and Alcohol Research Centre, University of New South Wales, NSW, 2052, Australia. E-mail: e.kelly@unsw.edu.au

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(iv) Discuss the risk perceptions related to drug driving.

Comprehensive database searches were conducted, including Medline, Psyclit and Embase databases. Search terms included automobile driving, traffic accidents, psychomotor performance, street drugs, heroin, cannabis, amphetamines and cocaine. No exclusion criteria were used for the articles on epidemiology, risk factors or risk perceptions. Due to the extensive nature of the literature on pharmacology, articles published prior to 1970 were excluded from the present review.

For the purpose of this review a distinction will be made between drugs and alcohol. Clearly, alcohol is a drug. As both the law and the literature distinguish between 'drink' and 'drug' driving, this distinction will be maintained within the present review in order to allay possible confusion.

Prevalence of drug driving

While there is limited research on the prevalence of drug driving among the general population, a substantial amount of research has been conducted on accident-involved drivers and drivers suspected of impaired driving. There have also been a number of studies examining drug driving among high-risk populations, such as illicit drug users.

Prevalence of drug driving among the general population

Evidence from surveys indicate that drug driving is not common among the general population (Table 1). Due to the large volume of literature on drug driving prevalence, Table 1 presents drug driving prevalence studies published from 1990 to present. In the 2001 National Household Survey on Drug Abuse 4% of American residents reported drug driving in the preceding 12 months, compared to 10% reporting drink driving over this period. Three-quarters of respondents who reported having drug driven had also driven soon after drinking alcohol, indicating there is an overlap between drink driving and drug driving [4]. Drink driving is also a more common behaviour than drug driving among the Australian population. According to the 2001 National Household Survey [5], 13% of Australian residents reported having driven a motor vehicle while under the influence of alcohol in the previous 12 months compared to 4% who reported having driven under the influence of other drugs during this period.

Prevalence of drug driving among the driving population

The majority of studies on the prevalence of driving under the influence (DUI) of drugs (DUID) or alcohol (DUIA) have examined drivers involved (uninjured, injured, killed) in MVAs (Table 1). In the majority of studies, 5–25% of accident-involved drivers were positive for drugs, all confirmed by blood samples [6–19]. It appears that drugs are an increasing problem in vehicle accident risk. In a recent Australian study, the frequency of alcohol in drivers killed in MVAs had decreased from 33% to 28%, whereas the frequency of drugs increased from 20% in 1990–1993 to 27% in 1997–1999 [20].

Generally, the drugs detected in impaired drivers reflect the general drug use patterns of the community in which the studies are performed. Therefore the drugs that pose the greatest risks for traffic safety will, in all probability, be determined by the use patterns within each community. At present, cannabis is generally the most commonly detected drug in drivers involved in MVAs (2–32%) [7,8,11–14,16,18,21–30]. The next most commonly detected drugs after cannabis are currently benzodiazepines (2–15%), followed by cocaine (4–11%), amphetamines (2–6%) and opioids (3–5%) [7,9,11–13,15,16,18,19,21,22,25,27,28,30–37].

Polydrug use is evident among accident-involved drivers, with more than one drug frequently detected among this population [8,13,14,18,24]. In addition, alcohol and drugs are often detected in combination, with both present in approximately 5–20% of killed or injured drivers [8,10,11,16,19,21,22,24,38,39]. This is not surprising due to the high prevalence of polydrug use among illicit drug users [40,41].

A number of studies have examined drug driving prevalence among 'impaired' drivers; that is, via the analysis of blood and/or urine samples taken from individuals suspected of or arrested for driving DUI. Although studies of drivers arrested for or suspected of DUI do not provide information on the prevalence of DUI among drivers, they do provide information on the *types* of drugs (or drug combinations) used by drivers. Similar to the results of studies of accident-involved drivers, the most common drug detected in studies of impaired drivers is cannabis. Figures as high as 25–55% have been detected in Norway, Switzerland, the Netherlands, Scotland, Slovenia, the United States, Australia and Sweden [9,10,42–57]. In contrast, lower figures have been reported in Finland, Italy and Sweden (3–14%) [58–62]. The next most frequently detected drugs in drivers suspected of DUI are generally the benzodiazepines. High levels of benzodiazepines were detected in Denmark, Norway, Switzerland, Scotland and the Netherlands, at approximately 30–65% [10,47–51]. However, such high levels are not universal, with benzodiazepines detected in approximately 5–20% of suspected or arrested drivers in Australia, Switzerland, Finland, Slovenia, Northern Ireland, Sweden and the United States [42,44,45,52,53,58,60,63].

Other drugs detected frequently in drivers suspected of DUI of drugs and/or alcohol include cocaine, amphetamines and opioids. Opioid prevalence varied between 10 and 40% [42,44–53], cocaine from 3 to 30% [42,43,45,46,51,52,59,61] and amphetamine typically between 2 and 20% [42,44,46,48,51,52,56,57,64]. Again, in line with the results of studies of accident-involved drivers, polydrug use is widespread among this population, with more than one drug detected in approximately 40–80% of drug-positive samples [42,46,65–67].

Prevalence of drug driving among selected populations

While drug driving is not common among the general population of drivers [68–72], it appears highly prevalent among certain populations. Not surprisingly, drug driving is prevalent among illicit drug users [73–77]. Recently, Albery *et al.* [74] examined illicit drug use and driving behaviour among a sample of out-of-treatment illicit drug users in the United Kingdom. Eighty-two per cent of those who had driven reported having driven immediately after using illicit drugs in the past 12 months, 20% of whom had done so daily. Driving soon after using drugs was also common in Aitken *et al.*'s [75] study of IDUs in Melbourne, Australia. Two-thirds of those who had driven reported having driven immediately after injecting drugs in the preceding week, with more than a quarter of subjects reporting having done this five or more times in the preceding week. Drug driving has been identified as a common behaviour in other populations associated with substance use, including dance party attendees and university students [78–80].

The effects of drugs on driving performance

It is evident from the previous section that drugs are frequently detected in accident-involved drivers. However, the mere presence of drugs does not provide evidence of a causal role for drugs in such accidents. In an attempt to clarify the relationship between drugs and driving impairment, researchers have conducted various studies, including laboratory, simulator, closed-circuit, on-road and field studies (Table 2).

This section focuses on studies conducted from 1980 onwards. Descriptions of earlier studies can be found in other reviews, including those of Austroads [81], Buxton *et al.* [82], Clayton [83], the European Monitoring Centre for Drugs and Drug Addiction [84], Henderson [85], Maes *et al.* [86] and the Road Safety Committee [87].

Alcohol

There is unequivocal evidence that alcohol produces significant impairment in driving performance, as demonstrated through laboratory, simulator and driving studies. Results from laboratory studies demonstrate dose-related deficits in performance after alcohol use in concentration, coordination, tracking, divided attention and reaction time [81,82,84,88–93]. Results from driving simulators, closed circuit and on-road driving studies show evidence of deficits in various skills after alcohol use, including brake reaction time, collision frequency, speed control, indicator use, steering responsiveness and lane control [81,82,84,88,94,95]. Alcohol has also been shown to produce changes in risk-taking behaviour, decision making and planning, and to increase the number of simulated accidents [81,82,84].

There is overwhelming evidence of impairment due to alcohol in case–controlled field studies of MVAs [84,88]. Alcohol is related to an increased risk of accident-involvement and an increased risk of responsibility for the accident [22,38,96–99]. At a BAC of 0.1%, the probability that an accident-involved driver was responsible for that accident is approximately 90% [100]. Christophersen *et al.* [96] reported accident risk to be four times greater for drivers with BACs of 0.05–0.99%, 12 times greater BACs of 0.1–0.15% and 45 times greater for drivers with BACs $> 0.15\%$.

Cannabis

There is evidence from laboratory, simulator and driving studies that the principal psychoactive component of cannabis, delta-9-tetra-hydrocannabinol (THC) significantly impairs driving performance. Although laboratory studies have examined only low doses of THC, impairments have been detected in tracking, attention, reaction time, short-term memory, hand–eye coordination, vigilance, time and distance perception, decision making and concentration [81,84–86,88,101–107]. Performance decrements are generally dose-related and typically persist for 2–4 hours [20,81,99,102]. Results of simulator and driving studies provide evidence of dose-related cannabis-induced impairment in various aspects of vehicle control, including steering, headway control (regulating the distance between one's own vehicle and the vehicle in front), speed variability, car following, reaction time and lateral position variability [85,88,94,95,101–103,108–111].

Although driving does appear to be impaired by cannabis, particularly in high concentrations, the level of impairment in simulator and driving studies does not replicate that evident in laboratory studies. It has been suggested that this is due to the ability of subjects to

Table 1. *Drug driving prevalence studies published from 1990 to present*

Study	Country/period	Methodology	Sample size	Impaired driving reported/ detected
AAMI [72]	Australia 2002	Licensed drivers; telephone survey	1184	36% DUIA (life-time); 9% DUID (life-time)
Aitken *et al.* [194]	Australia 1997	Heroin users (drivers); survey	84	67% drug driven (previous week); 23% DUID (previous week)
Albery & Guppy [160]	UK 1990	Licensed drivers; questionnaire;	1011	20% DUIA (12 months)
Albery *et al.* [74]	U.K. 2000	Non-treatment illicit drug users, driven (12 months) survey	71	82% DUID (12 months); 20% DUID daily (12); most common drugs: heroin (64%), cannabis (62%)
Alvarez *et al.* [69]	Spain 1990	Drivers attending medical traffic centres; questionnaire	675	3% DUID (life-time)
Alvarez *et al.* [175]	Spain 1991 – 1998	Drivers killed in MVAs; blood	3191	Illicit drugs 9%, DUIA 35%, alcohol & illicit drugs 4%
Anderson & Ingram [195]	Scotland 2001	Licensed drivers; household survey	1004	22% DUIA (life-time); 5% DUIA (previous 12 months)
Athanaselis *et al.* [17]	Greece 1995 – 1997	Drivers involved in MVAs (fatal & non-fatal); blood	856	DUIA 33%, drugs 6%; most common drugs: opioids, cannabinoids, benzodiazepines
ATSB [196]	Australia 1998	Drivers involved in road accidents; blood	2269	DUIA 19% of injured drivers, 26% of those killed
Augsburger & Rivier [42]	Switzerland 1982 – 1994	Drivers suspected of DUID; Blood/urine	641	Cannabinoids 57%, opioids 36%, alcohol 36%, benzodiazepines 15%, cocaine 11%, methadone 10%, amphetamines 4%
Begg *et al.* [197]	New Zealand 1972 – 1999	People born 1972 – 1973; follow-up at 21 and 26 years	936	Age 21: 19% DUIA; age 26: 10% DUIA
'Benzodiazepine/Driving' Collaborative Group [34]	France 1989 – 1990	Drivers injured in MVAs; blood	2852	Benzodiazepines 8%, DUIA 18%
Brookoff *et al.* [43]	USA 1993	Arrestees for reckless driving; urine for cannabis & cocaine	150	Cocaine 13%, cannabis 33%, both 12%
Ceder & Jones [53]	Sweden 2000	Drivers suspected of DUID; blood	3808	Amphetamines 63%, THC 29%, diazepam 20%, morphine 10%, methamphetamine 10%
Chikritzhs *et al.* [198]	Australia 1990 – 1997	Drivers & pedestrians killed in MVAs	3068	31% of road fatalities alcohol-related
Christensen *et al.* [47]	Denmark 1981 – 1985	Drivers suspected of DUID; blood/urine	461	Benzodiazepines 65%, opioids 38%

(*continued overleaf*)

Table 1. (*continued*)

Study	Country/period	Methodology	Sample size	Impaired driving reported/ detected
Christophersen *et al.* [64]	Norway1986 – 1988	Drivers suspected of DUID: D-cases, or DUIA: A-cases; blood/ urine	D-cases: 47; A-cases: 223	DUIA 81% A-cases & 40% D-cases; drugs in 38% A-cases & 77% D-cases; most common drugs in A-cases: cannabinoids (26%), benzodiazepines (17%); most common drugs in D-cases: benzodiazepines (53%), cannabinoids (43%)
Christophersen *et al.* [56]	Norway 1991	Drivers suspected of DUID; blood/urine	1514	THC 41%, diazepam 31%, flunitrazepam 17%, amphetamines 14%;
Christophersen *et al.* [65]	Scandinavia 1996	Drivers suspected of DUI; blood	800	DUIA 68 – 99%, drugs 20 – 38%; benzodiazepines detected in 18 – 24% of samples, THC 3 – 15%;
Christophersen *et al.* [57]	Norway 1992	Drivers suspected of DUID; blood	2372	Drugs 60%; THC 32%, diazepam 25%, amphetamines 15%, flunitrazepam 9%
Dawson [172]	USA 1992	National sample; current drinkers	18352	12% DUIA (12 months)
Del Rio & Alvarez [68]	Spain 1993	Randomly selected drivers; questionnaire	1500	3% DUID (12 months); cannabis, cocaine & amphetamines most commonly reported
Del Rio [19]	Spain 1991 – 2000	Drivers killed in MVAs; blood	5745	DUIA 32%, illegal drugs 9%, alcohol & drugs 4%
Drummer [22]	Australia 1990 – 1993	Drivers killed in MVAs; blood	1045	DUIA 33%, drugs 22%, illicit drugs, 13%, drugs & alcohol 9%
Drummer [35]	Australia 1990 – 1999	Drivers killed in MVAs; blood	3398	DUIA 29%; drugs 27%
Dussault *et al.* [71]	Canada 1999	Drivers; questionnaire, breath and urine	Survey: 5507; breath: 5281; urine: 2281	Alcohol 4%, drugs 10%, drugs & alcohol 1%
Everett *et al.* [171]	USA 1995	University students 18 – 24 years	2847	DUIA 28% (months); passenger of DUIA 39% (months)
Fell [199]	USA 1988	Drivers killed in MVAs; blood	42119	Alcohol 49%
Giorgetti *et al.* [61]	Italy 1994	Drivers; roadside survey	1399	DUIA 30%, drugs 16%, alcohol & drugs 5%
Gjerde & Kinn [200]	Norway 1989 – 1990	Drivers suspected of DUID, with BACs $\leqslant$ 0.01%; blood/urine for cannabis	425	THC 56%
Gjerde *et al.* [9]	Norway 1989 – 1990	Drivers killed in MVAs; blood	159	DUIA 27%, drugs 16%; benzodiazepines (15%), THC (5%)
Haworth *et al.* [23]	Australia 1995 – 1996	Blood; drivers in accident in which at least one occupant killed; comparison accident-involved & non-involved drivers	Accident-involved drivers: 127; non-accident-involved drivers: 865	DUIA 36%, cannabis 19%; DUIA and cannabis more frequent in accident-involved drivers

(*continued overleaf*)

Table 1. (*continued*)

Study	Country/period	Methodology	Sample size	Impaired driving reported/ detected
Hingson *et al.* [201]	USA 1992	Drinkers only; household survey	27081	23% DUIA (life-time); 5% DUIA (12 months)
Jonasson *et al.* [67]	Sweden 1992 – 1997	Drivers suspected of DUIA; blood/urine for opioids	4896	Dextropropoxyphene 3%, codeine 8%
Kruger *et al.* [70]	Germany 1992 – 1994	Drivers; roadside survey; interview, breath & saliva	2235	DUIA 1%, benzodiazepines 3%, cannabis 1%
Lenne *et al.* [76]	Australia 2001	Licence holding cannabis users, 18 – 25 years; survey	67	DUI cannabis (6 months) 43% of time they use. DUI cannabis/ alcohol (6 months) 14% of time they use cannabis & alcohol
Lenton & Davidson [79]	Australia 1995	People who had attended a rave within previous 6 months; survey	83	80% drove/were driven to a recent rave, of whom 42% reported the driver had used drugs before driving
Lillsunde *et al.* [18]	Finland 1991	Drivers involved in MVAs; blood	206	Drugs 52%, 'abuse' levels 28%; multiple drugs detected in 75% of drug abuse groups
Lillsunde *et al.* [58]	Finland 1979 & 1993	Drivers suspected of DUI; blood	1979: 298; 1993: 332	DUIA 95% (1993); drugs in 7% from 1979 & 27% from 1993
Longo *et al.* [25]	Australia 1995 – 1996	Drivers injured in MVAs; blood	2500	DUIA 10%, drugs 10%
Longo *et al.* [36]	Australia 1995 – 1996	Drivers injured in MVAs; blood for benzodiazepines	2500	Benzodiazepines 3%
Loxley *et al.* [202]	Australia 1988	Drivers; Household survey	1504	71% DUIA (life-time); 32% DUIA (12 months)
Marzuk *et al.* [27]	USA 1984 – 1987	Drivers & passengers killed in MVAs; blood	Drivers: 449; passengers: 194	Cocaine 18%; alcohol 46%; cocaine/alcohol 10%
Mercer & Jeffery [11]	Canada 1990 – 1991	Drivers killed in MVAs; blood	227	Alcohol 48%, drugs 20%, drugs & alcohol 11%
Morland *et al.* [48]	Norway 1993	Drivers suspected of DUI; blood/ urine	1197	alcohol 69%, drugs 30%; alcohol & drugs 14%,
Perl *et al.* [44]	Australia 1992	Drivers suspected of DUID; blood	417	Drugs 84%, cannabis 38%, minor tranquillizers 12%, heroin 10%, amphetamines 8%
Plaut & Staub [51]	Switzerland 1995 – 1999	Drivers suspected of DUID; urine	311	Drugs 84%, alcohol 60%, cannabis 54%, benzodiazepines 31%, opioids 27%, methadone 22%, cocaine 20%
Reilly *et al.* [77]	Australia 1994 – 1995	Long-term cannabis users; survey	268	DUI cannabis 90%
Ryan [203]	Australia 1999	General drivers/drivers involved in accidents; roadside survey & breath	General drivers: 8616; accident-involved: 1230	DUAI 2% of samples; DUIA accident-involved drivers 33%

(*continued overleaf*)

Table 1. (*continued*)

Study	Country/period	Methodology	Sample size	Impaired driving reported/ detected
Sciwy-Bochat *et al.* [66]	Germany 1987 – 1992	Drivers suspected of DUID; blood/urine	292	Drugs 97%; 87% more than one drug
Seymour & Oliver [10]	Scotland1995 – 1998	Drivers suspected of DUI & drivers killed in road accidents; blood/urine	Suspected drivers: 752; accident drivers: 151	Suspected drivers: drugs 68% of blood samples; benzodiazepines 56%, cannabis in 27%; accident-involved: alcohol 32%, drugs 19%, drugs & alcohol 6%
Seymour & Oliver [50]	Scotland 1999	Drivers suspected of DUID; blood/urine	183	Drugs 81%, diazepam 67%, temazepam 47%, morphine 21%, cannabis 18%
Sjogren *et al.* [6]	Sweden 1991 – 1993	Drivers killed or injured in MVAs; blood	Injured drivers: 130; killed drivers: 247	Drugs 10% of injured drivers, 7% of drivers killed in MVAs ; DUIA 8% of injured drivers, 13% of drivers killed
Smink *et al.* [46]	Netherlands 1995 – 1998	Drivers tested due to conspicuous driving /accident-involvement; blood/urine	1665	Drugs 80%; 42% multiple drugs; cocaine 33%, benzodiazepines 33%, cannabinoids 22%, opioids 19%, amphetamines 14%
Soderstrom *et al.* [31]	USA 1990 – 1991	Injured automobile & motorcycle riders; blood	Tested for THC: 331; tested for alcohol, cocaine:1338	Drivers: alcohol 35%, THC 3%, cocaine 5%. Riders:alcohol 47%, THC 32%, cocaine 8%
Stevenson *et al.* [78]	Australia 2001	University students; survey	286	DUIA 26% , DUID 18%, alcohol/ drugs 14% while designated driver [12months]
Stoduto *et al.* [16]	Canada1986 – 1989	Drivers & passengers injured in motor MVAs; blood	BACs from 769 injured drivers/passengers; drug screens 339 drivers	Alcohol 36%; drugs 41%, alcohol & drugs 17%; most frequently detected drugs: cannabinoids 14%, benzodiazepines 12%, cocaine 5%, morphine 5%
Sugrue *et al.* [30]	Australia 1992 – 1993	Drivers injured in MVAs; urine	164	Alcohol 80%, cannabinoids 15%, benzodiazepines 3%
Swensen [29]	Australia 1992 – 1995	Road users killed in MVAs; blood	829	Alcohol 12%, cannabis 11%, opioids 6%, psychostimulants 3%
Terhune *et al.* [38]	USA 1990 – 1991	Drivers killed in MVAs; blood	1882	Alcohol 52%, drugs 18%, alcohol & drugs 11%
Tunbridge *et al.* [13]	Great Britain 1996 – 1999	Drivers killed in MVAs; blood	516	Drugs 77%, DUIA 20%
U.S.A. Dpt. of Transportation [54]	USA 1998 – 1999	Urine; drivers arrested DUI	800	Drugs 36%, THC 22%, cocaine 16%, amphetamines 5%, morphine 5%
Voas *et al.* [204]	USA 1996	Roadside survey; breath	6028	DUIA 8%

(*continued overleaf*)

Table 1. (*continued*)

Study	Country/period	Methodology	Sample size	Impaired driving reported/ detected
Vollrath & Widera [80]	Germany 1998	Drivers attending discotheques; survey; breath & urine or blood	Survey: 2779; breath samples: 2555; urine or blood samples: 324	Alcohol 30%, drugs 13%
Waller *et al.* [39]	USA 1992–1994	Road users injured in MVAs; blood	894	Alcohol 21%, drugs 14%, drugs & alcohol 7%
Walsh & Mann [153]	Canada 1996–1997	Licensed drivers; random digit dialling	4735	DUI cannabis (12 months) 2%
Zancaner *et al.* [59]	Italy 1994	Drivers suspected of DUID; Blood/urine	265	DUIA 31%, drugs 10%; cannabis 6%, cocaine 3%
Zorec-Karlovsek & Susanj [52]	Slovenia 1998–1999	Drivers suspected of DUID; blood/urine	636	Drugs 58%, cannabinoids 53%, opioids 31%, methadone 29%, amphetamines 18%, benzodiazepines 17%, cocaine 8%

compensate for the impairments, for example, by driving more slowly and by avoiding risky driving manoeuvres [81,88,109,110].

There is inconsistent evidence regarding the impairing effects of cannabis in field studies. The results of Drummer's [22] early work indicate that cannabis does not significantly increase the likelihood of accident-involvement. However, in this study only an *inactive* component of cannabis (THC-COOH), which would not be expected to impair performance, was measured [20,112]. In a more recent study in which THC, the active component of cannabis, was tested for, the risk of culpability in a fatal vehicle accident was twice as high for a THC-positive driver than for a drug/alcohol-free driver [20,112]. In contrast, Longo *et al.* [97], controlling for driver age, found THC-positive drivers were no more likely to be judged culpable for an accident than drug/alcohol-free drivers. Also, there was no significant dose-dependent relationship between THC and culpability, indicating that Drummer's results may have been confounded by driver age. However, Longo *et al.* [99] studied *injured* drivers, as opposed to Drummer's [35] study of drivers *killed* in MVAs. Further, the average THC concentration in Longo's study was lower than in Drummer's study. In line with the results of Longo *et al.* [97], Terhune *et al.* [38] reported that fatally injured THC-positive drivers were no more likely to be responsible for MVAs than THC-free drivers.

In summary, laboratory studies suggest that THC significantly impairs driving performance. Consistent with laboratory studies, THC has been reported as increasing the risk of accident-involvement in fatally injured drivers [35]. In contrast, other studies have reported no association between THC and accident-involvement among injured drivers [97] and fatally injured drivers [38]. The relationship between THC and street driving performance is equivocal, and more research is needed in order to determine whether or not there is an association between THC and risk of accident-involvement.

Benzodiazepines

Laboratory studies have generally found decreased performance due to benzodiazepines in visual and speed perception, information processing, coordination, reaction time, memory and attention [81–83,91,92,113–124], frequently in a dose-dependent relationship [118,120,122]. There are, however, inconsistencies in the literature, with some benzodiazepines producing impairment while others have not [114,119]. It appears that the inconsistent results regarding the effects of benzodiazepines are not due entirely to differences between the types of benzodiazepine used, with contradictory results found in studies which have

Table 2. *Studies of drug impairment*

Study	Country/period	Methodology	Sample size	Performance impairment
'Benzodiazepine/Driving' Collaborative Group [34]	France 1989 – 1990	Field study; responsibility; drivers injured in MVAs	2852	Relative risk of accident 2.1 times for BACs of 0.02 – 0.08% & 6.2 for BACs > 0.08%
Berghaus *et al.* [205]	Germany 1993	Laboratory study; comparison methadone maintenance patients and non-drug users	26	Control subjects performed better than MM subjects in all psychophysical tests
Busto *et al.* [119]	Canada 2000	Laboratory study: alprazolam, lorazepam, bromazepam, placebo	13	Lorazepam & alprazolam significantly impaired performance
Chesher *et al.* [92]	Australia 1989	Laboratory study; methadone clients, non-user controls	64	No evidence for acute effects of methadone for methadone clients; alcohol & diazepam produced performance decrements for all subjects
Christophersen *et al.* [96]	Norway 1993	Field study; calculation of accident risk; accident-involved drivers, suspected of DUI	394	Accident risk for BACs of 0 – 0.05% = 1, 0.051 – 0.99% = 4, 0.1 – – 0.149% = 12, > 0.15% = 45; benzodiazepines = 19, cannabis = 10, amphetamines = 10
de Gier *et al.* [114]	Netherlands 1986	Laboratory study and on-road driving; outpatients receiving lorazepam or bromazepam	18	Decrease in attention of lorazepam patients; correlations between serum levels of both drugs & level of performance impairment
Drummer [22]	Australia 1990 – 1993	Field study; culpability analysis; drivers killed in MVAs	1045	Increased culpability compared to alcohol/drug free: alcohol-only drivers (culpability increased with BACs); alcohol/drug drivers; opiate-only; cannabis/alcohol
Drummer [35]	Australia 1990 – 1999	Field study; culpability analysis; drivers killed in MVAs	3398	Alcohol-positive drivers 6 × more likely to be culpable than drug/alcohol-free drivers. Psychoactive drug-positive (2), THC-positive (3)
Fant *et al.* [107]	USA 1998	Laboratory study; current cannabis users	10	Smooth pursuit eye tracking significantly impaired
Hendler *et al.* [123]	USA 1980	Laboratory study; in-patients receiving narcotics or benzodiazepines for chronic pain	106	Significant impairment in cognitive functioning among patients receiving benzodiazepines

(*continued overleaf*)

Table 2. (*continued*)

Study	Country/period	Methodology	Sample size	Performance impairment
Hill & Zacny [137]	USA 2000	Laboratory study; recreational/ non-dependent drug users; hydromorphone, morphine & placebo	12	Highest dose of hydromorphine produced psychomotor impairment
Hindmarch & Gudgeon [132]	UK 1980	On-road driving test; clobazam, lorazepam, placebo	12	Significant difference between groups:lorazepam < placebo < clobazam
Hindmarch *et al.* [90]	UK 1991	Laboratory study; alcohol vs. placebo	18	Significant impairment in performance at moderate to high doses
Longo *et al.* [36]	Australia 1995–1996	Field study; culpability analysis; drivers injured in MVAs	2500	Higher levels of culpability compared to drug/alcohol-free drivers for: benzodiazepine-positive drivers and benzodiazepine/alcohol-positive drivers; linear relationship between benzodiazepine concentration & culpability
Longo *et al.* [97]	Australia 1995–1996	Field study; culpability analysis; drivers injured in MVAs	2500	Drug/alcohol-free drivers significantly less likely be culpable than alcohol-positive drivers, alcohol/THC positive drivers, benzodiazepine-positive drivers & alcohol/benzodiazepine-positive drivers. Concentration-dependent relationship between alcohol & culpability, benzodiazepines & culpability
Lucki *et al.* [124]	USA 1985	Laboratory study; benzodiazepine users & drug-free controls	48	Performance of chronic benzodiazepine users did not differ from controls in any of performance measures
Mercer *et al.* [122]	UK 1998	Laboratory study; double-blind randomised placebo-controlled six-limb crossover design; subjects received 2 mg lorazepam	13	Lorazepam significantly impaired performance on all psychometric tests: choice reaction time, stroop test, visual analogue scales, logical reasoning & adaptive tracking
Mintzer & Griffiths [120]	USA 1999	Laboratory study; triazolam vs. placebo	18	Triazolam significantly impaired psychomotor performance and memory

(*continued overleaf*)

Table 2. (*continued*)

Study	Country/period	Methodology	Sample size	Performance impairment
Mintzer *et al.* [117]	USA 2001	Laboratory study; triazolam vs. placebo	6	Triazolam significantly impaired recognition memory performance
Mortimer & Howat [94]	USA 1986	On-road driving test; alcohol, diazepam, alcohol/diazepam, placebo	14	Steering performance significantly impaired in alcohol, diazepam & alcohol/diazepam conditions
Moskowitz & Smiley [129]	USA 1982	Simulator study; diazepam vs. placebo	48	Diazepam group significantly impaired on tracking control, target detection & speed control
Neutel [206]	Canada 1979 – 1986	Field study; risk of hospitalization for injuries from MVAs: benzodiazepine users vs. non-benzodiazepine users	323658	Two weeks after filling benzodiazepine prescription risk of hospitalization 6.5 for hypnotics, 5.6 for anxiolytics
O'Neill *et al.* [116]	UK 2000	Laboratory study; dextropropoxyphene, morphine, lorazepam & placebo	10	Lorazepam, dextropropoxyphene and morphine impaired psychomotor performance
Peck *et al.* [109]	USA 1986	Closed-course driving test; alcohol , cannabis, cannabis/alcohol, placebo	80	Significant impairment in driving performance for cannabis subjects & alcohol subjects; Impairment alcohol > cannabis
Robbe & O'Hanlon [110]	Netherlands 1993	Closed circuit & on-road driving tests; recreational cannabis users; THC, alcohol, placebo	56	Closed circuit test: THC subjects significantly impaired; highway test: dose-related impairment of THC subjects in road-tracking; urban traffic test: modest dose of alcohol produced impairment in driving; cannabis did not impair
Robbe & O'Hanlon [95]	Netherlands 1995	On-road driving study; regular users of cannabis & alcohol; THC, placebo	18	Impairments in road tracking & car following performance after alcohol & THC
Robertson & Drummer [98]	Australia 1989 – 1991	Field study; culpability analysis: drivers killed in MVAs	341	Alcohol-positive drivers over-represented in culpable group; dose-related response
Roset *et al.* [118]	Spain 2001	Laboratory study; placebo vs. flunitrazepam	36	Flunitrazepam significantly decreased psychomotor performance; dose-related response
Seppala *et al.* [91]	Finland 1986	Laboratory study; placebo, alcohol, diazepam, lorazepam	42	Diazepam, alcohol/diazepam, lorazepam impaired psychomotor performance
Smiley *et al.* [101]	USA 1985	Simulator study; diazepam, THC, alcohol	92	THC, alcohol & diazepam impaired performance

(*continued overleaf*)

Table 2. (*continued*)

Study	Country/period	Methodology	Sample size	Performance impairment
Stoller *et al.* [134]	USA 2001	Laboratory study; subjects opioid-dependent; buprenorphine/naloxone, hydromorphone, placebo	8	Hydromorphone impaired circular lights task; buprenorphine/naloxone impaired circular lights task & trail-making test performance
Terhune *et al.* [38]	USA 1990 – 1991	Field study; responsibility analysis; drivers killed in MVAs	1882	Relative accident risk for drivers with BACs $> 0.10\% = 7$, alcohol/THC = 12, alcohol/cocaine = 5, alcohol/multiple drugs = 16
Troy *et al.* [121]	USA 2000	Laboratory study; triazolam vs. placebo	24	Triazolam impaired memory & executive functioning
van Laar *et al.* [131]	Netherlands 2001	On-road driving test; lorazepam vs. placebo	18	Lorazepam significantly impaired lateral position control
Verster *et al.* [115]	USA 2002	Laboratory study and simulator test; placebo vs. alprazolam	20	Alprazolam significantly impaired performance in laboratory and simulator
Walker & Zacny [135]	USA 1998	Laboratory study; morphine, codeine, placebo	12	No significant impairment produced by morphine or codeine
Walker *et al.* [136]	USA 2001	Laboratory study; placebo (saline), butorphanol, nalbuphine, pentazocine	15	High dose morphine decreased performance in executive functioning; butorphanol impaired Maddox-wing test, hand-eye coordination & logical reasoning test
Williams *et al.* [14]	USA 1982 – 1983	Field study; responsibility analysis; killed in MVAs	427	Accident responsibility increased with number of drugs detected; alcohol-positive more likely to be responsible than drug/alcohol-free drivers; accident responsibility increased with BAC

examined the same dose of particular drugs [84,125–128]. Impairment may be limited to the early stages of benzodiazepine intake, with the general clinical suggestion that tolerance develops within a few days of benzodiazepine use [81,82,119,124]. In line with this proposition, long-term studies of benzodiazepine therapy indicate that chronic use of benzodiazepines does not produce any significant impairment [124,128].

Driving and simulator studies have also generally found evidence of benzodiazepine-induced impairment in driving performance, in areas such as steering, emergency decision making, lane position, attention, braking, speed control and reaction time [81,94,101,115,126,129–131]. However, as with laboratory studies, there are inconsistencies according to the type of benzodiazepine used [114,132].

The results from epidemiological studies in regards to benzodiazepines and accident risk are inconclusive [22,34,36,84,96]. Longo *et al*. [36] found that significantly more benzodiazepine-positive drivers were deemed culpable than drug/alcohol-free drivers, with a significant linear dose relationship between benzodiazepine-concentration and culpability. However, Drummer [22] found no significant difference between the culpability ratios of drug/alcohol-free drivers and benzodiazepine-only drivers. Similarly, in a study of injured drivers in France the benzodiazepine-positive drivers were no more likely than the benzodiazepine-negative drivers to be responsible for the vehicle accident [34].

Opioids

Experiments involving both opioid-dependent and non-opioid-dependent patients have generally shown evidence of mood effects after administration of opioids, including 'mental clouding', calmness and drowsiness [116,133–136]. However, there is inconsistent evidence as to whether opioids produce psychomotor impairment, which can be attributed to such factors as the type of opioid administered, the route of administration and tolerance [92,133,134,136,137]. For example, methadone has been shown to influence performance in non-opioid users, in areas such as reaction time, information processing and visual acuity [84,92,133]. However, few studies have found any evidence of methadone-induced performance decrements in methadone maintenance (MM) patients, presumably due to their opioid tolerance [84,92,133,138]. There is some evidence of a dose-related response for methadone and other opioids, indicating that the lack of evidence for significant opioid-induced impairment may be due to the low doses of opioids administered in the majority of laboratory studies [118,136,137].

No studies were found examining the effects of opioids in simulator, closed-circuit or on-road driving studies. There is limited information from field studies, and the existing literature is contradictory. In his earlier study, Drummer [22] reported a significant difference between the culpability ratios of drug/alcohol-free drivers and opioid-only drivers; however, in his more recent work there was no significant difference between the groups [35]. The numbers of opioid-positive drivers in other field studies have generally been too low to be able to undertake responsibility analyses [85].

Stimulants

There are inconsistent results from laboratory studies regarding stimulants and performance impairment. Low doses of amphetamine produce few deleterious effects on cognitive functioning, and may enhance performance in some psychomotor tasks, though generally only in fatigued subjects performing reasonably simple tasks [84,86,139,140]. As with other drugs, it is not possible to assess the effects of high 'abuse' levels of amphetamines on driving performance in the laboratory due to ethical limitations. There is some evidence of psychomotor and cognitive impairment after administration of ecstasy (MDMA) in areas such as attention, perception and memory [139,141]. There is inconsistent evidence regarding cocaine and performance, with some studies finding evidence of decreased performance [93], some increased performance [142,143] and some no effect [144].

As with opioids, no studies were found that have examined the relationship between stimulants and driving impairment through simulator or driving studies. There is no substantial evidence of increased accident risk due to stimulants from field studies. Although Christophersen *et al*. [96] reported the risk of accident involvement for Norwegian amphetamine-positive drivers as 10 times greater than expected [96], Drummer [22,35] reported no significant difference between stimulant-positive and drug/alcohol-free drivers in either his recent or his earlier work. Similarly, Longo *et al*. [97] found no significant difference between the culpability rate of drivers positive for stimulants and those negative for drugs and alcohol, and Terhune [38] reported no significant difference between amphetamine-only or cocaine-only drivers and drug/alcohol-free drivers in culpability.

Drug combinations

Laboratory studies have generally shown evidence of greater impairment in psychomotor performance when alcohol is combined with other drugs [36,85,88,91,92,134,145]. For example, there is evidence of an additive effect on performance when

alcohol and cannabis are administered in combination [85,88,145]. Benzodiazepines generally extenuate the impairment produced by alcohol, although this is most evident with small doses of alcohol [36,91,145]. There is also some evidence of greater impairment when multiple drugs are administered [92,134].

Impairment in driving performance has been shown to increase when alcohol is combined with other drugs, as assessed by simulator and driving studies. The combination of benzodiazepines with alcohol has generally produced an additive effect on performance [81,101]. Similarly, the combined effects of alcohol and cannabis appear to be additive [95,101,109,111].

Results of field studies indicate that drivers who have used multiple drugs, or drugs combined with alcohol, prior to driving, experience greater impairment than drivers who have used one substance [22,81,99]. In Drummer's recent study [99], drivers positive for multiple drugs were five times more likely to be culpable for an accident. Also, the risk of accident for drivers positive for both cannabis and alcohol was 15 times higher, an increase from 12 times for drivers positive for alcohol alone.

In summary, there is an undeniable association between alcohol and driving impairment. There is also considerable evidence that cannabis and benzodiazepines increase accident risk. The most equivocal evidence surrounds opioids and stimulants which, not surprisingly, are the drugs least often studied. Although the evidence regarding drugs and accident risk is sparse, it can be assumed that all drugs in high doses are likely to increase accident risk. Further, it is apparent that drugs in combination with alcohol and multiple drugs present an even greater risk to traffic safety. This is of particular concern, due to the high incidence of polydrug use evident in drug using populations [40,41].

Risk factors associated with drug driving

Research has been conducted in order to establish whether particular factors are related to drug driving. While there is evidence that young drivers are the most likely group to engage in drug driving (excluding driving after using benzodiazepines), research around other factors, such as sex, psychological characteristics, social factors, substance use and driving behaviour is more equivocal.

Age

There is a well-established association between younger drivers and increased driving risk, due to factors such as limited driving experience and a greater propensity to risk-taking behaviour [146–149]. The majority of studies on drug driving have revealed a higher incidence of drug driving among young people, generally defined as those aged under 35 [17,18,25,44,65,67,69,150–154] (Table 3). However, this is not the case with all drug groups, as DUI of benzodiazepines has been found to be more common in middle-aged to older drivers [24,25,64], due presumably to the high rates of benzodiazepine prescription among this age group [155].

Sex

Males have been found to be over-represented among illicit drug users and more likely to engage in risky driving behaviours [156,157]. Although it would be presumed, therefore, that males would be over-represented among drug drivers, there is equivocal evidence for this proposition [154] (Table 3). While, in the majority of studies, males are more likely to report drug driving [151–153,156,158] and to be found positive for drugs due to suspicion of impaired driving [10,44,58,67] or after accident-involvement [16,17,24,25,27,159], a number of studies have failed to find evidence of sex differences in drug driving prevalence [19,68,69,160–162]. There is also evidence that drug driving prevalence among females has increased in recent years [163]. Further, sex differences in drug driving prevalence vary according to the type of drug studied. For example, females are frequently more likely to test positive for benzodiazepines [152,163]. These results reflect the typical usage of such drugs, which are prescribed more frequently to females than to males [155].

Substance use

While individuals who drive while impaired by alcohol have often been found to consume high levels of alcohol and/or experience alcohol-related problems [149,160,164–175], there have been few studies on the association between drug use and drug driving and what has been found is contradictory (Table 3). Lobmann & Kruger [162] found that the association between impaired driving and amount of substance consumption was greater for drug driving than for drink driving. Begg *et al.* [174] found a relationship between cannabis dependence and DUI of cannabis. In contrast, Albery *et al.* [74] found no association between drug driving frequency with frequency of drug use, or severity of dependence.

Psychosocial

Drivers who drug drive have been found to have lower constraint and high levels of sensation seeking, psychoticism, extraversion, negative emotionality and aggression [162,174,176] (Table 3). However, Begg *et al.*

[174] found that low constraint was the only characteristic that predicted persistent DUI of cannabis that was not directly associated with cannabis use. This is in line with the results of Macdonald & Mann [177], who found that although drink driving has been associated with a range of psychological characteristics, including antisocial behaviour, aggression, sensation seeking, risk taking, anxiety and poor self-control [164,167,169, 170,176–178], many of these variables are actually related to problem drinking, and are therefore only indirectly related to drink driving. In fact, the authors stated that the predictive value of these variables disappeared when alcohol consumption was controlled for.

The majority of research on the association between impaired driving and social characteristics have examined drink driving, with those convicted of DUIA generally over-represented in terms of lower socio-economic background, unemployment and limited education [149,161,177,179] (Table 3). While there is some evidence that drug driving is associated with limited education [153,162], no studies were found that have examined the association between drug driving and other social factors, such as unemployment or socio-economic status. It seems likely that, as with psychological characteristics, any association between impaired driving and social factors would actually be due to a relationship between poor social functioning and substance use, and only indirectly related to impaired driving.

Driving behaviour

There is some evidence of an association between impaired driving and other risky driving behaviours [180,181] (Table 3). Horwood & Fergusson [180] found drink driving to be associated with speeding, running red lights and unlicensed driving. Similarly, Longo [181] reported a significant relationship between DUIA convictions and other traffic offences. In contrast, drug driving frequency was not associated with driving convictions in Albery *et al.*'s [74] study of dependent illicit drug users.

No studies were found that have examined the relationship between driving frequency and drug driving, and there are conflicting results from studies of drink driving and driving frequency. Macdonald [177] found that distance driven predicts DUIA, while Wilson [149] and Macdonald & Dooley [166] found no significant difference between DUIA and non-DUIA drivers for either driving frequency or distance driven.

In summary, it appears that young males are over-represented among drug drivers. Although there is an association between alcohol use problems and drink driving, it is unclear whether such an association exists between drug use problems and drug driving, due to a lack of research in this area. Evidence surrounding psychosocial factors and driving behaviour is also equivocal at this stage.

Risk perceptions related to drug driving

The majority of studies on risk perceptions related to impaired driving have been conducted on drink driving. It appears that risk perceptions do have an influence on impaired driving behaviour.

General perceptions of impaired driving

It is apparent that there is a negative perception of impaired driving among the general population, both for alcohol and drugs, with impaired driving viewed as dangerous and unacceptable [152,182–185]. There appears to be a perception among the general population of drivers that drug driving presents a greater threat to road safety than drink driving [152,184]. In an Australian study, 93% of drivers perceived it was safer to drive after drinking than to drive after using recreational drugs [184]. However, it appears that there are a minority of drivers with more permissive attitudes [152,184,185].

Perceptions of drug driving among illicit drug users

While there is a negative perception of drug driving among the general population, there is evidence of a lack of concern regarding drug driving among the drug using population [75,186]. In Davey & French's [186] recent study, most respondents stated that their driving skills were not affected by drugs. The two main dangers associated with drug driving were reported to be 'hanging out', or withdrawing from drugs, and going 'on the nod' (falling in and out of a sleeping state). Similarly, in a study of heroin users, respondents believed it was more dangerous to drive while 'hanging out' than immediately after injecting or while 'stoned', due to feelings of anxiety and irritation [75].

Perceptions according to frequency of impaired driving

Risk perceptions have been found to differ according to DUI experience or frequency (both drug driving and drink driving) [74,149,162,166,182,187]. Albery *et al.* [74] found that illicit drug users who reported never having drug driven believed that alcohol impairs driving performance as much as heroin and methadone, whereas subjects who reported drug driving believed that alcohol diminishes driving performance more than any other drug. Similarly, Lobmann & Kruger [162] found that drug drivers had more permissive views of drug driving than non-drug drivers.

Table 3. *Risk factors associated with impaired driving*

Study	Country/ period	Methodology	Sample size	Factors associated with DUI
Albery *et al.* [74]	UK 2000	Survey; out-of-treatment illicit drug users	71	DUID not associated with frequency of heroin, methadone, cannabis or alcohol use
Albery & Guppy [160]	UK 1990	Questionnaire; representative sample of driver's license holders	1172	Age negatively associated with DUIA; alcohol consumption positively associated with DUIA
Alvarez *et al.* [69]	Spain 1990	Questionnaire; drivers attending medical traffic centres	675	DUID highest for those aged 18–24 ; DUID prevalence increased with academic level
Anderson & Ingram [198]	Scotland 2001	Household survey; licensed drivers	1004	Males more likely to DUIA (ever/12 months) 17–29-year-olds most likely to DUID (12 months)
Athanaselis *et al.* [17]	Greece 1995–1997	Blood analysis; drivers involved in MVAs	856	DUID/DUIA accident-involved drivers highest in 21–30 age group & in males
Augsburger & Rivier [42]	Switzerland 1982–1994	Blood/urine; drivers suspected of DUID	641	Males represented 86% of DIUD suspects; Majority 18–34 years
Australian Institute of Health & Welfare [151]	Australia 1998	Household survey	10 030	DUIA and DUID (12 months) most common among males and 20–29 year
Australian Institute of Health & Welfare [156]	Australia 2001	Household survey	27 000	DUIA and DUID (12 months) more common in males
Beerman *et al.* [207]	US 1973–1982 & 1984–1985	Survey & court records; drivers arrested for DUIA	397	No sex difference in DUIA arrests; unemployment , BACs, major criminal offences increased with DUIA arrests
Begg *et al.* [200]	New Zealand 1972–1999	Longitudinal study; follow-up at 21 & 26 years	936	Males and younger age associated with DUIA
Begg *et al.* [174]	New Zealand 1972–1999	Longitudinal study; people born between 1972 & 1973 in Dunedin	933	DUIA: males, aggressive behaviour at age 18 & alcohol dependence at age 21; DUID: males, low constraint at age 18, a non-traffic conviction < 18, traffic conviction < 21, cannabis dependence at 21
Bradstock *et al.* [208]	USA 1981–1983	Telephone survey; randomly selected	22236	DUIA: males, 18–24 age group, heavy smokers, binge drinkers, chronic heavy drinkers
Brinkmann *et al.* [173]	Germany 1996	Blood; drivers convicted of DUIA; randomly selected	327	Alcohol dependence

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Table 3. (*continued*)

Study	Country/ period	Methodology	Sample size	Factors associated with DUI
Chikritzhs *et al.* [201]	Australia 1990 – 1997	Blood; drivers & pedestrians killed in MVAs	3068	Alcohol-related road injuries three times greater in males; significantly more 15 – 24 years
Christophersen *et al.* [65]	Scandinavia 1996	Blood: drivers suspected DUI	800	Males; drugs most frequently 20 – 29-year-olds
Christophersen *et al.* [64]	Norway 1986 – 1988	Blood/urine; drivers suspected of DUID or DUIA	DUID: 47; DUIA: 223	Males; benzodiazepines and cannabinoids more frequently in 25 – 34-year-olds
Christophersen *et al.* [56]	Norway 1991	Blood/urine; DUID suspects	1514	Males; most common age group 25 – 35-year-olds
Dawson [172]	USA 1992	Household survey	18 352	DUID: frequent, dependent drinkers
Del Rio & Alvarez [68]	Spain 1993	Questionnaire	1500	DUID prevalence greatest in 16 – 30 year-olds
Drummer [22]	Australia 1990 – 1993	Blood; drivers killed in MVAs	1045	Culpability of drug-only group highest in 60 + age, followed by < 25 age
Elliot [158]	USA 1983	National household survey; 18 – 24-year-olds	1725	DUIA/ DUID: males; criminality
Everest & Tunbridge [7]	UK 1985	Body fluid & tissue; road users killed in MVAs	1273 (including 520 drivers)	Drug-positive drivers more likely to be male, younger
Everett *et al.* [171]	USA 1995	Questionnaire; undergraduates	2847	DUIA: episodic heavy drinking, marijuana use, using illegal drugs in combination with alcohol
Fell [202]	USA 1988	Blood; drivers killed in MVAs	42 119	Drivers aged 20 – 25
Haworth *et al.* [159]	Australia 1995 – 1996	Blood; drivers involved in single vehicle road accidents	127	Males, < 25 years
Hendtlass [209]	Australia & Northern Ireland 1981 – 1982	Roadside survey	Melbourne: 3503; Belfast: 11987; rural Victoria: 301	Melbourne: alcohol use highest < 20 years. Rural Victoria: alcohol highest highest 30 – 39 years
Hendtlass [24]	Australia 1980 – 1982	Body fluid; drivers/pedestrians involved in road accidents	402	DUID: females; cannabinoids most frequent in 25 – 44-year-olds. Psycholeptics most frequent in 45 – 64-year-olds
Holubowycz *et al.* [210]	Australia 1985 – 1992	Blood; vehicle occupants & motorcyclists killed /injured in MVAs	Killed: 1389; injured: 1573	Males: BACs significantly higher
Homel [211]	Australia 1983	Household survey; licence holders; drinkers only	400	DUID: males
Horwood & Fergusson [180]	New Zealand 1998	Questionnaire; aged 21 years	907	DUIA: males; risky driving histories

(*continued overleaf*)

Table 3. (*continued*)

Study	Country/ period	Methodology	Sample size	Factors associated with DUI
Jonasson *et al.* [67]	Sweden 1992 – 1997	Blood/urine for opioids; drivers suspected of DUIA	4896	Males, 25 – 34-year-olds
Karlsson *et al.* [212]	Sweden 1996	Questionnaire; random sample	3064	DUIA: males; 25 – 34-year-olds
Klepp *et al.* [213]	USA 1986	Questionnaire; high school students	1700	DUIA: males
Lapham *et al.* [167]	USA 1994 – 1997	Questionnaire; individuals convicted of DUIA, aged 23 – 54	1105	Significant difference between DUIA; compared to general population, offenders had higher levels of alcohol and drug dependence, major depression, post-traumatic stress disorder, antisocial personality disorder
Lillsunde *et al.* [58]	Finland 1979 & 1993	Blood; drivers suspected DUI	630	Males
Lillsunde *et al.* [18]	Finland 1991	Blood; drivers involved in car accidents	206	DUID: 20 – 29-year-olds
Liu *et al.* [168]	US 1993	Telephone survey	102 263	DUIA: males, < 35-year-olds; binge drinkers
Lobmann & Kruger [162]	Germany 1998	Survey & investigation, involving driving simulator & medical examination	Survey: 2779; investigation: 483	DUIA & DUID drivers: high psychoticism, little concern for health, permissive attitudes towards DUI
Longo [181]	Australia 1995 – 1996	Examination of traffic offences; drivers injured in MVAs; blood	2420	DUIA convictions: males; convictions for other traffic offences
Longo *et al.* [25]	Australia 1995 – 1996	Blood; drivers injured in MVAs	2500	Cannabis: younger; benzodiazepines: older; alcohol: males, younger
Macdonald & Dooley [177]	Canada 1988	Household survey; individuals with convictions for DUIA matched with controls	Total sample: 9943; DUIA cases: 78; controls: 78	Cases more likely than controls to have other driving convictions
Marzuk *et al.* [27]	USA 1984 – 1987	Blood analysis (cocaine); drivers & passengers killed in MVAs	Drivers: 449; passengers: 194	Males; 31 – 45-year-olds
McLean *et al.* [26]	Australia 1983 – 1984	Blood; road users killed or injured in MVAs, traffic offenders	Accident fatalities: 42; accident survivors: 37; breath-tested drivers/riders: 115	DUIA: younger
Mcleod *et al.* [152]	Australia 1997	Questionnaire	807	DUIA/DUID: males; younger
McMillen *et al.* [169]	USA 1992	Questionnaire	132	DUIA: more traffic violations, accidents, drinks per week, sensation seeking, hostility; less social responsibility
NHTSA [214]	USA 1997	Telephone survey	4010	DUIA: males, 21 – 29-year-olds
Perl *et al.* [44]	Australia 1992	Blood; DUID suspects	417	DUID: male; 20 – 40-year-olds
Seymour & Oliver [10]	Scotland 1995 – 1998	Blood/urine; DUI suspects	752	Males
Shinar *et al.* [148]	USA 1994 – 1995	Telephone survey	188	DUIA: males

(*continued overleaf*)

Table 3. (*continued*)

Study	Country/ period	Methodology	Sample size	Factors associated with DUI
Sjogren *et al.* [6]	Sweden 1991 – 1993	Blood; drivers killed or injured in MVAs	377	Drivers killed in MVAs: alcohol-positive drivers significantly younger vs. alcohol-negative drivers
Skurtveit *et al.* [163]	Norway 1992 – 1993	Blood/urine; drivers suspected of DUIA or DUID	DUID: 5642; DUIA: 11970	DUIA: male; DUID: male; younger; females more likely benzodiazepines
Stoduto *et al.* [16]	Canada 1986 – 1989	Blood; drivers & passengers injured in MVAs	BACs obtained from 769 injured drivers/passengers; drug screens available for 339 drivers	DUIA/DUID: males
Vine & Watson [37]	Australia 1980 – 1982	Blood; drivers, motorcyclists & pedestrians killed in MVAs	425 (including 405 drivers)	DUIA/DUID: males
Voas *et al.* [207]	USA 1996	Roadside survey; breath test	6028	DUIA: male; 21 – 34-year-olds
Walsh & Mann [153]	Canada 1996 – 1997	Telephone survey	Sample: 4735; cannabis users: 367	DUI cannabis: males; < 25 years, unmarried, less education
Wilson [149]	Canada 1992	Survey; driving record	Drivers convicted of DUIA: 238; high-risk drivers: 285; control: 374	DUIA: younger, less education; heavier drinking; higher levels of cannabis, amphetamine, cocaine use
Yu & Willford [165]	USA 1989	Survey; individuals in alcohol treatment centres, drink driving programmes, jails & on probation	878	DUIA: males; problem drinking; high-risk driving

Perceptions according to drug type

There is evidence that risk perceptions differ according to drug type. As described above, in Albery *et al.*'s [74] study, participants perceived certain drugs to be more impairing than others. Similarly, Lobmann & Kruger [162] reported that drug drivers perceived opiates, hallucinogens and alcohol to be more impairing than cannabis and stimulants. Other studies have also found evidence of a lack of concern regarding cannabis and driving impairment [76,77,79,152]. However, there is evidence of a concern about driving after using multiple drugs, such as the combination of cannabis and alcohol [76].

Influence of perceptions on drug driving

It appears that drink driving is influenced by risk perceptions. Drivers are more likely to drink drive if they perceive that being arrested for DUIA or being involved in an accident is unlikely [78,162,185,188–193]. However, there has been very little research on the association between drug driving and risk perceptions. The only study found that examined this association was that of Lobmann & Kruger [162]. The authors found no difference between drug drivers and non-drug drivers in terms of the possibility of detection for drug driving or the severity of punishment for drug driving. However, this may be due to the general perception that being caught for drug driving is unlikely [76,152,186].

Conclusions

It is clear that impaired driving is a significant cause of human trauma. Although the majority of drivers do not drive while impaired by drugs and/or alcohol, impaired driving is prevalent in populations associated with risky behaviour, such as illicit drug users. Drug driving has long been overshadowed by research into drink driving. This is despite evidence that the prevalence of alcohol in road trauma is decreasing and the incidence of drugs in accident-involved drivers is increasing, and that there appears to be an overlap between drug driving and drink driving.

Interestingly, there appears to be an overlap between drug driving and drink driving as evidenced by the prevalence of accident-involved drivers positive for both drugs and alcohol. This reflects general drug use patterns, with polydrug use and the combined use of drugs and alcohol common occurrences. Typically, the types of drugs detected in impaired drivers also reflect general use patterns, indicating that the drugs most likely to present a significant threat to traffic safety are those prevalent within the particular population.

Results from laboratory, simulator, driving and field studies provide unequivocal evidence that alcohol produces driving impairment and consequently increases MVA risk. Studies also indicate that cannabis and benzodiazepines are likely to produce impaired driving performance. There are equivocal results from studies of the performance impairment produced by stimulants and opioids, which is not surprising, being the drugs least often studied. It is also not of surprise that the substances most commonly detected in drivers, alcohol, cannabis and benzodiazepines are the drugs with most evidence of impairment. Overall, while differences arise due to the type of drug in consideration, it is apparent that high doses of drugs, multiple drug use and drugs used in combination with alcohol are all likely to produce a significant threat to traffic safety.

There is evidence that risk perceptions influence impaired driving behaviour. Those who perceive that there is a strong possibility of being caught or being involved in an accident are less likely to drive while impaired. The general perception that one is unlikely to be caught for drug driving undoubtedly contributes to the problem. Another contributing factor is the perception of illicit drug users that drugs do not significantly impair driving performance. The more permissive attitudes towards impaired driving of those who drive while impaired may be due to a lack of negative consequences resulting from this behaviour or perhaps are rationalisations to justify the behaviour.

Drug driving is a significant problem, both in terms of a general public health issue, and as a specific concern for illicit drug users. This area is worthy of attention not only with regard to further research, but also interventions. As drug driving is not common in the general population of drivers, it would seem appropriate to focus research, and ultimately interventions, on high-risk populations such as illicit drug users. Particular areas in need of further research include clarification of drug-induced driving impairment and risk perceptions related to drug driving. The latter is especially relevant for drug driving interventions which, in addition to more general efforts to reduce drug and/or alcohol dependence, might reduce drug driving-related harm.

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