# Drugs of Abuse, Driving and Traffic Safety

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**Abstract:** Roadside studies indicate that 1-15% of drivers drive under the influence of one or more drugs of abuse. After drug use, drivers are more often culpable for an accident than non-users.

Information on drugs and traffic safety comes from roadside studies, epidemiological research, experimental studies on driving-related skills, and on-the-road driving tests.

Roadside studies show that drivers most frequently test positive for the use of alcohol and/or cannabis. These two drugs affect driving ability in a dose-dependent matter and result in poor vehicle control, especially when used in combination. Drivers on cocaine, ecstasy and amphetamine show no impairment on basic driving skills, but often overestimate their driving skills. In combination with impaired decision making, this increases risk taking during driving. Only few studies looked at the effects on driving of other drugs of abuse, such as ketamine, inhalants and anabolic steroids, but suggest a negative effect on driving performance.

In conclusion, most drugs of abuse negatively affect driving ability, especially when used in combination with alcohol or another drug. It is of concern that a substantial number of drug users are not aware that their driving is impaired.

**Keywords:** Traffic safety, driving, alcohol, nicotine, cannabis, cocaine, ecstasy, LSD, ketamine, amphetamine, inhalants, anabolic steroids.

## INTRODUCTION

In the Western world, traffic death rates have declined over the past years, including those caused by alcohol-related traffic accidents. Public health campaigns and vigorous law enforcement both have contributed to this decline. In contrast to alcohol impaired driving, drug impaired driving is in the increase. Roadside studies showed that 1 to 15 % of the driving population tested positive for one or more drugs of abuse. There is also an increase in drivers who combine drugs and alcohol [1]. A recent report of the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) [2] estimated that 0.3 to 1.3% of the general driving population drives a car under the influence of a combination of alcohol and drugs of abuse. This is of concern, since drivers who have used drugs are significantly more likely to be culpable for a fatal accident than non-users [3, 4], especially after multiple drug use.

Although roadside testing for drugs of abuse is permitted in a growing number of countries, alcohol is still the most commonly detected substance in drivers. This is primarily due to the fact that alcohol is still the most commonly used substance. Furthermore, when alcohol is detected (often by using a breath alcohol test), the impaired driver is usually not further tested for other drugs. In contrast to standard procedures for alcohol testing, there is currently no uniform procedure for testing drugs of abuse. Legal limits are absent or set at zero, because the use of these drugs is illegal. Furthermore, uncertainty exists about the reliability and validity of drug testing devices. As a result, the number of drug-impaired drivers is often underestimated.

## DETERMINING DRUG EFFECTS ON DRIVING

Information on traffic safety related to drugs of abuse comes from various sources including roadside studies, epidemiological research, and experimental studies testing driving related skills. The latter are often used, but it is unsure to what extend these test actually predict real driving [5]. This is caused by the fact that individual skills and abilities such as reaction speed or divided attention are often tested in isolation, whereas during driving these skills are applied simultaneously. Fig. (**1**) summarizes data from 122 experimental studies [6] and shows that performance on various tests is impaired at a different blood alcohol concentration (BAC). This makes it difficult to predict actual driving performance from laboratory test results.

One of the most appealing real life tests is the on-the-road driving test. This standardized test was developed in the 1980s and since it is performed on a public highway in real traffic, it has a high ecological validity [7]. Currently, the on-the-road driving test is considered the gold standard driving test. Subjects are instructed to drive a specially prepared car on a primary highway, while maintaining a steady lateral position and a constant speed (usually 95 km/h). A camera mounted on the roof of the car measures the lateral position of the car relative to the left lane boundary. The duration of

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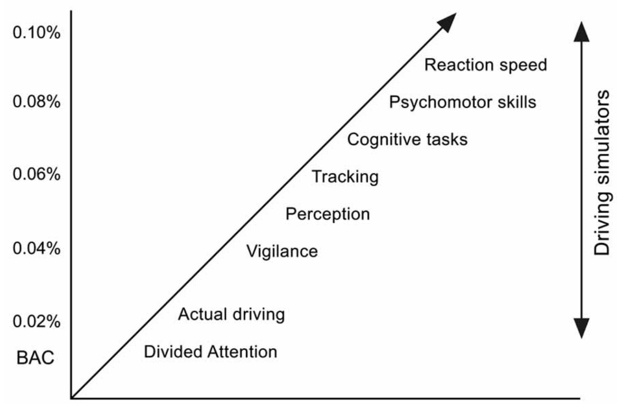


**Fig. (1).** Skills and abilities related to driving and their sensitivity to alcohol-induced impairment. BAC values correspond to those at which more than 50% of tests show significant impairment. Adapted with permission from reference [6].

the 100 km test is approximately one hour. The primary outcome measure of the driving test is the standard deviation of the lateral position (SDLP), i.e. the weaving of the car. Subjects are allowed to take over slower vehicles and are accompanied by a driving instructor with dual controls. In more than 60 on-the-road driving studies, dose-dependent impairment has been shown for various psychoactive drugs including alcohol, hypnotics, anxiolytics, antidepressants, and antihistamines [5, 8].

Although the on-the-road driving test has proven to be very sensitive to drug induced impairments at an operational level of driving (i.e. basic vehicle control), impairment on tactical and strategic levels of driving (e.g., risk taking and collision avoidance) are not measured in this test. Not testing these aspects of driving may lead to the wrong conclusion that driving is safe when no effects are found in the on-the-road driving test. For example, studies investigating the acute effects of methylenedioxi-methamphetamine (MDMA) on driving performance indicate that MDMA improved driving performance in the on-the-road driving test, whereas impairments were found on other levels of driving behavior (e.g., increased risk taking) [9-11]. Thus, it is important to test driving at the tactical and strategic level as well. Driving simulators are safe ways to examine performance at these levels of driving.

Decreased attention and impaired perception may affect the driver's ability to react properly to other vehicles. Such a situation can occur when a driver has to respond to changes in speed of other cars. To measure this capacity, Brookhuis *et al*. [12] developed the car-following test. This test is also performed on a public highway in real traffic. Two cars are involved; the first driven by a researcher and the other driven by the subject. The subject is instructed to follow the lead car and maintain a distance of 50m. In the lead car the researcher varies his speed a number of times to measure the response of the subject. The standard speed and number of maneuvers can be changed, depending on the road conditions. The primary outcome measured is the amount of time the following car needs to respond to the lead car.

The fact that the on-the-road driving test and car-following test are performed in real traffic limits their worldwide application. Given the restrictive legislation of most countries, measuring the effects of psychoactive drugs in real traffic is only conducted in The Netherlands. In this review, results from these tests will be discussed as key evidence to determine whether or not driving is impaired when using drugs of abuse. These findings will be supported by results from driving simulator studies and epidemiological and roadside data.

## ALCOHOL

Given the fact that the use of alcohol is generally not prohibited, it is not surprising that it is the most commonly detected drug among drivers. Ahlm *et al.* [13] conducted a prospective study on the prevalence of alcohol in injured Swedish drivers. They revealed that 38% of the fatally injured and 21% of the non-fatally injured drivers tested positive for alcohol. In France, Mura *et al.* [14] examined 900 non-fatally injured drivers and 900 non-injured drivers (control subjects). In 26% of the drivers a BAC above the legal limit (0.05%) was found. In comparison with the control subjects the odds ratio for non-fatal accidents after alcohol use was 3.8. A recent Dutch study reported an odds ratio of 5.5 for alcohol-related traffic accident injury [15]. Most studies report alcohol involvement in 20-38% of traffic related deaths [13, 16].

US roadside studies revealed that 17% of the drivers in 1996 had a BAC above the legal limit. This number was significantly lower than in 1973, when it was more than double at 36% [17]. When compared to European roadside studies [18] these percentages are relatively high, especially when taking into account that the legal limit for driving in the USA can be higher than in Europe (0.08% versus 0.05%).

A classic roadside study with great worldwide impact on traffic legislation was performed by Borkenstein *et al*. [19]. His team stopped several thousand drivers and their BAC was determined. The number of traffic accidents was later determined for these drivers. Borkenstein established a dose-response relationship between BAC and the risk of becoming involved in a traffic accident (see Fig. **2**, left panel, adapted from reference [20]). The risk-curve starts to rise at 0.05% and, thus, many countries use BAC 0.05% as legal limit for driving a car.

Louwerens *et al*. [21] conducted an on-the-road study testing driving performance at different BACs and found dose dependent impairment (See Fig. **2**, right panel). SDLP increments corresponding to the most common legal limits for driving were +2.4 cm (0.05%), +4.1 cm (0.08%), and +5.3 cm (0.10%), and are often used as reference values to illustrate driving safety when using psychoactive drugs. SDLP increment for different BACs correlated significantly with Borkenstein's traffic accident risks (r = 0.98), illustrating the strength of the driving test methodology.

A simulated driving study [22] reported that a low dose of alcohol may have a protective effect on driving ability. Comparing performance at baseline (no alcohol) with a low BAC (0.04%) showed that participants reduced their average speed. This study illustrates that at low BAC drivers may show successful compensation for awareness of mild alcohol induced impairment. However in the high BAC condition

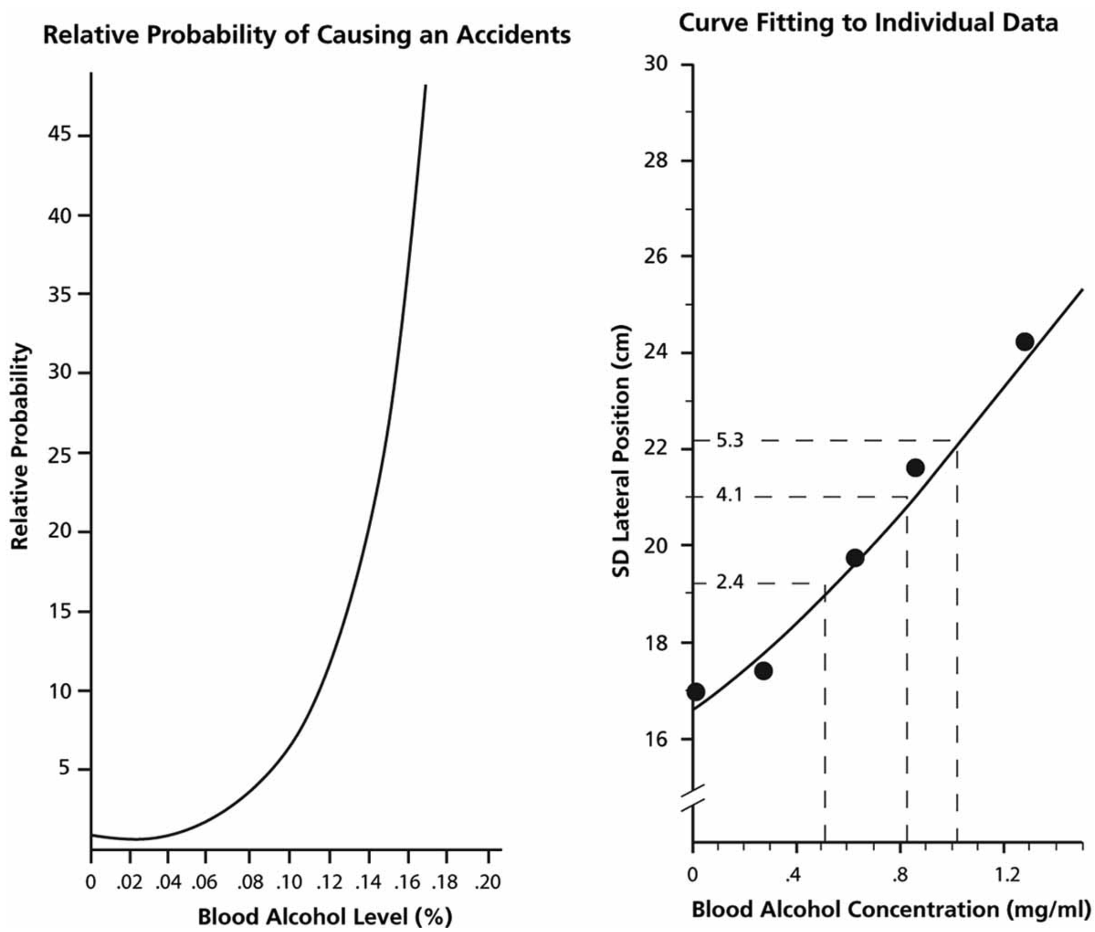


**Fig. (2).** SDLP increment observed for different blood alcohol concentrations (right panel) and corresponding traffic accident risk (left panel). Adapted with permission from reference [20].

(0.08%) this compensation was absent: participant's driving performance deteriorated and speed increased.

Numerous laboratory studies have been conducted on the effects of alcohol. These studies reveal that impairment in critical driving skills begins at BAC levels as low as 0.02% (See Fig. **1**). Although subjects may be able to compensate for these impairments, dose-dependent impairment has been established for most driving related skills including tracking, divided attention, vigilance, information processing, and psychomotor skills. It is not surprising that several countries have lowered their legal BAC limit of 0.05% to 0.02% for novice drivers. Studies investigating the effects of lowering BAC limits consistently found a decrease in car-accidents after lowering the limits [23, 24]. For example, when a zero-tolerance law for drivers under the age of 21 was introduced in Maryland (USA), the percentage of alcohol related car accident decreased by 11% [23]. In conclusion, there is overwhelming evidence that driving after using alcohol should be avoided.

## NICOTINE

No studies have been performed on the prevalence of driving under the influence of nicotine and there is no data on nicotine involvement in traffic accidents. This is surprising, since smoking a cigarette can be regarded as a secondary task that may potentially distract from the primary driving task, or at least causes the driver to divide his attention between both activities when lighting up and extinguishing the cigarette. On the other hand, nicotine is known for its cognitive enhancing effects by reducing reaction time and increasing alertness [25]. Thus, it can be hypothesized that smoking may actually improve driving performance. A few driving studies have focused on the effects of nicotine abstinence on driving performance. Heimstra *et al*. [26] reported no difference in simulated driving performance between those who smoked a cigarette during the test and control subjects. However, when smokers had to refrain from smoking, they performed significantly worse. Sherwood [27] confirmed that driving performance of craving smokers significantly improved to normal (non-smoker) levels after allowing them a cigarette.

## CANNABIS

After alcohol, cannabis is the most common drug of abuse found in drivers. A longitudinal study from New Zealand reported that almost 21% of young drivers admitted that they had driven at least once after smoking cannabis [28]. Around 60% of the interviewed Australian nightclub attendees reported that they were driven home by someone under the influence of $\Delta^9$-tetrahydrocannabinol (THC) or that they drove themselves after smoking cannabis [29].

A Norwegian roadside study randomly stopped drivers and revealed that 0.6% of the 10,835 drivers tested positive for the use of THC [18]. An Australian study also showed that 87 out of 13,176 drivers (0.6%) tested positive for THC [30]. The prevalence of THC in (fatal) car accidents ranges from 4-14% [31]. In 50-80% of these cases the drivers also tested positive for alcohol. Several epidemiological studies [3, 14, 32-36], but not all [15], revealed that THC usage significantly elevates the chance to be involved in car accidents. When looking at whether the driver was actually at fault of the accident various epidemiological studies concluded that cannabis use alone did not have an effect on culpability rates [4, 37-39].

A number of studies have examined the effect of THC on actual driving performance. Of these studies only two have been carried out in real traffic, the others were performed on closed roads. Klonoff tested driving after administration of THC or placebo [40]. Subjects drove under supervision of a professional driving instructor who evaluated their driving performance. Subjects smoked either one standardized cigarette containing 4.9 mg or 8.4 mg THC. Klonoff concluded that driving skills were only affected by the THC intake in the highest dosage group. Sutton [41] conducted an on-the-road test on a closed course, investigating the effects of cannabis and alcohol (combined and alone). The same dosages of cannabis as in Klonoff's study were used and BAC equaled to 0.06%. This study showed significant driving impairment when both substances were combined, but not when used alone. These results could be due to the relatively small course that was used for the driving test. Sutton used official driver examination statutes to evaluate driving performance, which make these result more reliable when compared to those of Klonoff. In real traffic, Robbe [42] performed various driving tests examining the effects of THC (alone and combined with alcohol). Subjects performed a car-following test, a highway driving test and a city-driving test. In the car-following test and the city-driving test, no significant effects of THC usage on driving performance were found. In the on-the-road driving test, significant dose-related impairment was found. When THC was combined with alcohol, driving impairment was greater than when alcohol or THC were administered alone [43, 44]. The results from these studies are summarized in Fig. (**3**, adapted from reference [45]).

The results summarized in Fig. (**3**) show that THC alone impairs driving performance to some extend, whereas the combination of THC with alcohol has a more pronounced effect on driving performance. Drivers seem aware of the impairing effects of THC and often compensate this impairment by a more conservative driving style (e.g., reducing speed or not overtaking) [31, 46, 47]. Unfortunately, compensation is not possible when events are unexpected [46]. Also, compensation fails when cannabis is used in combination with alcohol. This is illustrated by significantly increased culpability rates for drivers who combine alcohol and cannabis use [4]. In conclusion, driving after cannabis use is unsafe, especially when combined with alcohol.

## COCAINE

A Swedish study revealed that 3% of 26,567 suspected drivers were under the influence of cocaine. Several of these drivers were stopped because of their dangerous driving style: pronounced weaving of the car, speeding, and ignoring red-traffic lights [48]. In Switzerland, 13% of 440 of drug-

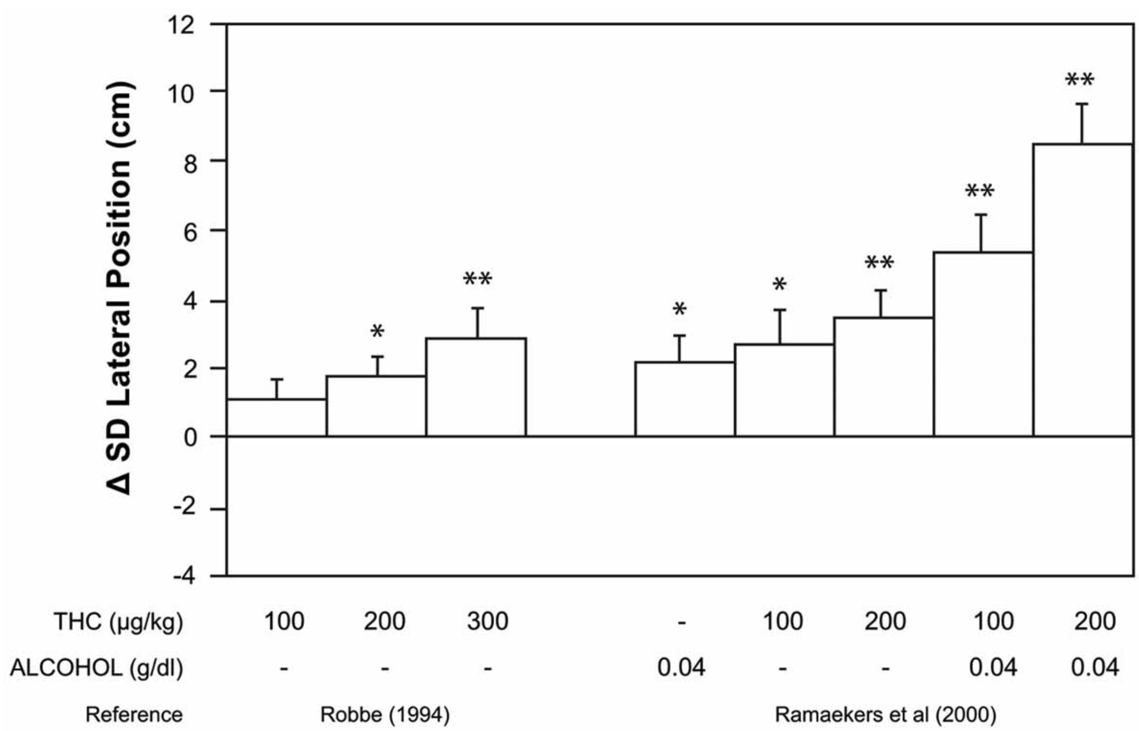


**Fig. (3).** Mean Δ SDLP (+SE) for different dosages of THC, with or without alcohol. Significant differences from placebo are indicated by: * p<.05; **, p<.01. Mean (range) plasma THC concentrations after 100, 200 and 300 µg/kg were 7.9 (0.8-17.2), 12.0 (1.5-27.1) and 16.1 (4.7-30.9) ng/mL. Adapted with permission from reference [45].

driving suspects had taken cocaine before driving [49]. A Norwegian road-side study reported that cocaine or its metabolite benzoylecgonine was found in 0.12% of drivers [19], comparable to 1% found in Irish drivers [50]. These studies and others [51], show that the prevalence of cocaine-using drivers differs between studies, ranging from less than 1% to 13%. This wide range is probably caused by the fact that cocaine use is much more prevalent among specific subgroups (e.g. partygoers) when compared to the general population. The percentage of reported cocaine-impaired drivers therefore depends on where and when a roadside study has been conducted.

Among those who use cocaine regularly, driving episodes under the influence of cocaine are more common. A telephone interview among cocaine abusers indicated that 16% had ever driven within an hour after cocaine intake [52]. An interview with 300 injecting drug users in Australia revealed that 39% of frequent cocaine users had ever driven after using cocaine, with 9% admitting that they drove weekly after cocaine use. Only one third of all subjects indicated that they felt driving after cocaine use is dangerous [53]. The idea of unimpaired or even improved driving is caused by the fact that cocaine reduces reaction time and improves vigilance performance [54, 55]. Taking these effects of cocaine into account it is likely that performance in highway driving tests will actually improve after using cocaine. However, cocaine users also reported being more alert and euphoric when using cocaine [55]. This may result in overconfidence in driving skills, speeding and dangerous take-over maneuvers, which is consistent with police records [48, 55]. Laboratory tests have confirmed that cocaine impairs complex decision making and increases risk taking on tests such as the Iowa Gambling Task [56, 57]. Misjudgment of driving ability and increased risk taking make driving after using cocaine unsafe.

## ECSTASY AND MDMA

Ecstasy and ±3,4-,ethelenedioxymethamphetamine (MDMA) are popular recreational drugs that are frequently used at parties and festivals [58]. It is likely that after such events some people will drive home under the influence of MDMA or ecstasy. Several studies have confirmed this assumption [29, 59-62]. Interviews performed in Australia and Scotland revealed that 8-33% of the MDMA users reported that they would either drive themselves while under the influence of drugs, or were passengers of drugged drivers. MDMA and ecstasy were frequently used in combination with alcohol and other drugs [29, 60-62].

Road-side studies show that 1-2% of the general population drives under the influence of ecstasy (MDMA) [30, 63]. Research shows that only a small percentage of drivers, who had a car accident, are under the influence of MDMA. Research in Australia, Hong Kong and France reveal that less than 5% of injured drivers tested positive for the use of MDMA [14, 64, 65].

In contrast, driving after using ecstasy or MDMA is common among recreational users and various studies have been performed to examine their effects on driving. Ramaekers *et al*. examined the effects of MDMA (with and without alcohol) in on-the-road driving tests in real traffic [10-11]. Two studies concluded that MDMA improved performance in the on-the-road driving test, by significantly decreasing the weaving of the car. When combined with alcohol, MDMA partly counteracted the impairing effect of alcohol. In the car-following test MDMA impaired performance in one study, but not in another [10, 11]. In the car-following test, the impairing effects of alcohol were not counteracted by MDMA.

A driving simulator study of Brookhuis *et al.* [9] investigated driving performance in self-administering MDMA users before and after they visited a rave-party. The results indicate that driving ability decreases during the night after (multiple) drug usage. The data confirmed more pronounced driving impairment when MDMA was used in combination with other drugs when compared to using the drug alone. The results of this naturalistic study can be influenced by the effects of sleep deprivation and exhaustion from dancing as the tested subjects did not sleep during the night. Almost all of the subjects view that their driving is improved after intake of MDMA. Although basic driving skills (lane keeping and reaction speed) seem improved after MDMA use [10, 11], other researchers reported increased risk taking behavior and impulsivity (e.g., speeding, ignoring stop signs) after intake of MDMA [66, 67]. Similar to driving after cocaine use, MDMA may result in overconfidence that in combination with impaired decision making may result in unsafe driving.

## LSD

The prevalence of driving under the influence of lysergic acid diethylamide (LSD) is low [19, 68, 69]. Tomaszewski *et al.* reported that of 242 US drivers detained for driving under influence of drugs 0.4% tested positive for the use of LSD [69]. Davey *et al.* interviewed 211 illicit drug users of which 2% admitted to have driven after using LSD or another hallucinogen at least once in the year before the interview [70]. Neal questioned 61 Scottish nightclub attendees about their drug usage and driving experiences [62]. Ten of the attendees indicated that they had consumed LSD and 5 of them admitted to have driven after LSD intake. All drivers were negative about driving after LSD intake, and they all stated it was very dangerous. Hallucinations and visual impairments were reported as the most dangerous effects of LSD on driving performance. Nevertheless, in specific populations, LSD use among drivers is high. For example, Riley *et al.* interviewed 122 partygoers, of which 30.3% confirmed using LSD in the past year. More than one third (36%) admitted to drive after LSD use on one or more occasions [60]. There are no driving simulator tests or actual driving tests conducted with LSD. Little is known about the LSD effects on psychomotor function, besides that LSD significantly decreases reaction time [71]. In addition, visual hallucinations, depersonalization, tremors, and severe panic attacks are common adverse effects of LSD use [71, 72]. If one or more of these effects are present, it can be assumed that driving is dangerous.

## KETAMINE

Researchers suspect that driving under the influence of ketamine is common among partygoers [73]. In Scotland, 15% of 122 partygoers admitted to use ketamine and 36% of them confirmed driving after using ketamine [60]. A study conducted in Hong Kong examining the prevalence of ketamine use in fatal car-crash victims found that 9% of drivers tested positive for ketamine [65]. Although there are no studies which tested the effects of ketamine in driving tests or driving simulators, several studies did investigate the effect of ketamine on psychomotor functioning. These studies showed that ketamine had an impairing effect on executive cognitive functions, decreased attention, and impaired memory functioning [74, 75]. In other studies researchers reported prolonged reaction time in choice reaction time tests [76]. Subjects were often aware of these effects, as they indicate feeling more tired and clumsy after ketamine use [77]. In addition, ketamine may cause abnormal psychic sensations such as "out of body" experiences, illusions and sometimes hallucinations. Also, ketamine may cause misinterpretation of auditory and visual stimuli [78, 79]. These effects make driving after using ketamine unsafe.

## AMPHETAMINES

In the general driver population, methamphetamine use is detected in up to 2% of stopped drivers [19, 30]. The incidence of methamphetamine in victims of traffic accidents ranges from 2% to 5% [64, 65, 80, 81]. Long distance drivers, i.e. truck drivers, are known to use stimulant drugs such as methamphetamines to stay awake during prolonged driving. Crouch *et al.* [82] reported that 7% of fatally injured truck drivers had used methamphetamines, when compared to 13% who had used cannabis or alcohol. Although some studies reported very high percentages of truck drivers who use amphetamines (e.g., 66% in Brazilian truck drivers) [83], European data report that much less truck drivers test positive for amphetamines (e.g., 0.3% in France) [84]. Since these are professional drivers, methamphetamine use among this group of drivers is of great concern.

Miller *et al.* [85] examined the effects of methamphetamine in narcoleptic patients and healthy subjects. Methamphetamine improved performance of narcoleptic patients in the driving simulator in a dose dependent manner. Silber *et al.* [86] tested the effects of dexamphetamine, a drug with similar effects as methamphetamine. Dexamphetamine significantly impaired simulated driving performance during daytime testing. During night-time testing no significant differences from placebo were found. Gustavsen *et al.* [87] reviewed literature on amphetamine and methamphetamine and concluded that low dosages of amphetamine significantly improve psychomotor performance of fatigued subjects towards baseline levels. However, after reviewing data of the impaired driver registry of the Norwegian Institute of Public Health, they also concluded that there was a positive relationship between amphetamine concentration and driving impairment.

Logan [88, 89] concluded that most studies that examined the behavioral effects of stimulant drugs report an increase in risk taking behavior and impaired decision making. After reviewing 28 cases in which drivers were arrested or killed after methamphetamine intake, Logan [89] concluded that both low and high dosages of methamphetamine may have an effect on driving performance. Logan illustrated the key effects of methamphetamine on driving in a model which is shown in Fig. (**4**).

As is evident from Fig. (**4**), low doses of methamphetamine increase alertness and reduce sleepiness and reaction time. These effects may actually improve driving performance. Higher dosages, which are more commonly used by drivers, result in euphoria, rapid flow of ideas, feelings of great mental capacity and physical strength, and sometimes hallucinations and delusions. When blood methamphetamine concentrations are declining agitation replaces feelings of euphoria, concentration problems occur, and subject become fatigued again. The sequence of effects depicted in Fig. (**4**) illustrate that it is unsafe to drive after using methamphetamine, especially in the withdrawal phase after using the drug.

## INHALANTS

Inhalants are less commonly abused drugs. Del Rio [90] reported that out of 1500 Spanish drivers only 0.1% admitted to have driven at least once after nonmedical use of inhalants. In Australia researchers revealed that 5% of 300 interviewed drug users had ever driven after the nonmedical use of an inhalant [53]. A study among US students showed that 5.2 % had abused inhalants before their $18^{th}$ birthday, whereas 61.7% of them had driven a car while under the influence of alcohol or drugs [91].

Some laboratory studies examined the psychomotor effects of inhalants. Beckman *et al.* [92] investigated the effects of three inhalants ($N_2O$, isoflurane and sevoflurane) on psychomotor functioning. They found that all three substances significantly impaired auditory reaction time, hand-eye coordination, and time estimation. In addition, memory function was also affected. The investigators also observed that the subjects were much more tired after using isoflurane and sevoflurane. Dinwiddie [93] reported that abusing inhalants can cause hallucinations, delusions and distortions in perception of size, color and time. Also, impaired muscle coordination and body balance may lead to hospitalization due to traffic accidents or falling. Kurtzman *et al.* [94] confirmed these findings and added tremors, slurred speech, euphoria and decreased reflexes as commonly reported side effects of inhalant abuse. Although these adverse effects are likely to impair driving ability, no research has been conducted that tested the effects of inhalants on driving performance. The adverse effects observed after abuse of inhalants are not likely to be present after normal use.

## ANABOLIC STEROIDS

Anabolic steroids are primarily used by athletes to enhance their performance in sports, but they are also used as recreational drugs [95]. Little is known about the effects of anabolic steroids on traffic safety. One driving simulator study [96] compared driving performance of 6 subjects in a driving simulator after administration of placebo and testosterone cypionate. The drug was taken daily for three weeks to achieve a steady-state concentration. There was no significant effect on driving performance, and testosterone cypionate did not provoke aggressive behavior. Besides this

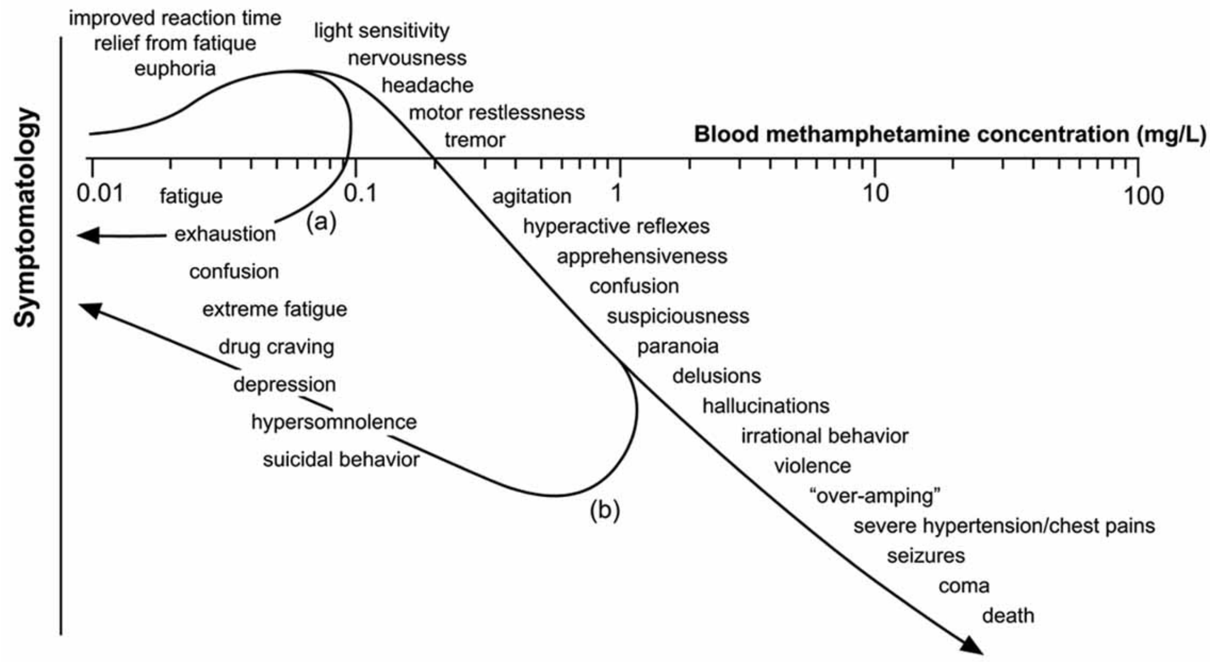


**Fig. (4).** Dose and time dependent effects of methamphetamine. Adapted with permission from reference [90].

driving simulator study human studies on cognitive and psychomotor performance after using anabolic steroids are scarce. Several studies show that people who use anabolic steroids are more often involved in risk taking behavior. For example, McGabe *et al*. [97] reported a positive association between anabolic steroid usage and risk taking behavior, such as combining drinking and driving. A study in Massachusetts (USA) revealed that students who used steroids showed significantly more risk-taking in traffic than non-users, as they drove more frequently after drinking and did not use seatbelts and helmets [98]. Petersson *et al*. [99] investigated the use of anabolic steroids in patients that received medical care in Sweden. In total 248 patients tested positive for anabolic steroids, of which 12 died during the study. Among them, two patients died in a traffic accident, but this was not significantly different from the control group. A review of Thiblin *et al*. [100] concluded that steroid users report increased confidence, self-esteem, motivation, energy and enthusiasm. However, prolonged anabolic steroid abuse could cause enhanced aggressive behavior which may be reflected in driving behavior. Hall *et al*. [101] also reported an increase in aggression and adverse effects such as rage, depression, delirium, mania and psychosis. More research is needed on the effects of anabolic steroids on driving performance and related skills and abilities.

## CONCLUSION

Many drivers who use drugs of abuse underestimate the risk of traffic accidents and participate in traffic after drug use [102]. For example, three million Europeans use cannabis daily and 80% of them drive after use [103]. Therefore, it is important to inform drivers about the potential risks of driving after alcohol and drugs of abuse.

This review discussed the effects of drugs of abuse drug use on driving ability and traffic safety. It can be concluded that many of these drugs have a negative effect on driving performance, most commonly by producing sedation or increasing risk taking behavior. Drugs such as alcohol, ecstasy and cannabis have been extensively investigated. In contrast, much less scientific evidence is available on other drugs such as cocaine, amphetamines, nicotine, steroids and inhalants. Future research should focus on these drugs, because particularly cocaine, amphetamines and nicotine are commonly used among certain groups of drivers.

It is important to note that drugs may not affect all aspects of driving performance. For example, ecstasy improves driving performance on an operational level of driving (i.e. less weaving on a highway driving test). However, higher levels of driving may be affected leading to increased risk taking and impaired decision making. Furthermore, the subjective feeling produced by some drugs may make drivers feel unimpaired while actual measurements of driving performance show otherwise. This presumed unimpaired driving may lead to overconfidence and unsafe driving. Moreover, this unawareness prevents drivers from compensating for the impairments by adjusting their driving behavior (e.g., slowing their speed). Future studies should examine driving ability at all levels of performance. Future studies should also address the effects of combined drug use. Current research shows that, especially the common combination of drugs with alcohol, significantly impairs driving performance.

**Learning Objectives:**

- Alcohol and drugs of abuse may significantly impair driving ability
- Sedative effects may impair basic vehicle control
- Increased risk taking and overconfidence makes driving unsafe
- Drivers are not always aware of driving impairment after using drugs of abuse

**Further Research:**

- Effects of various drugs of abuse need to be examined more thoroughly
- Insight in dose response effects and the relationship with driving performance
- Examine gender and age differences
- Effects of long term drug use on driving performance
- Study the effect of combined drug use on driving performance; including drug-alcohol interactions

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Received: July 13, 2009 Revised: August 2, 2009 Accepted: November 2, 2009