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A Report to Congress

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16. Abstract

This report was prepared in accordance with Section 4008 (Marijuana-Impaired Driving) of the Fixing America's Surface Transportation Act (FAST Act), Pub. L. 114-94. The report summarizes what is known about marijuana use and driving.

The report describes the absorption, distribution and elimination of delta-9-tetrahydrocannabinal (THC) the primary psychoactive substance in marijuana, in the body. It contrasts this process with the absorption, distribution and elimination of alcohol in the body, as they are very different processes. The poor correlation of THC concentrations in the blood with impairment is discussed, along with the implication that setting per se levels is not meaningful. Some of the challenges of measuring driving impairment resulting from marijuana use are reviewed. State laws relating to marijuana and driving are presented. What is known about the prevalence of marijuana-impaired driving and the crash risk associated with marijuana-impaired driving is reviewed.

Finally, the report presents information on training for law enforcement to detect marijuana impairment in drivers, the feasibility of developing an impairment standard for driving under the influence of marijuana and recommendations for increasing data collection regarding the prevalence and effects of marijuana-impaired driving.

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Table of Contents

List of Tables and Figures

Tables

Figures

Marijuana-Impaired Driving

A Report to Congress

Introduction

This report has been prepared in response to a requirement in Section 4008 (Marijuana-Impaired Driving) of the Fixing America's Surface Transportation Act (FAST Act), Pub. L. 114-94. This section states:

SEC. 4008. MARIJUANA-IMPAIRED DRIVING.
(a) STUDY.—The Secretary, in consultation with the heads of other Federal agencies as appropriate, shall conduct a study on marijuana-impaired driving.

(b) ISSUES TO BE EXAMINED.—In conducting the study, the Secretary shall examine, at a minimum, the following:

(1) Methods to detect marijuana-impaired driving, including devices capable of measuring marijuana levels in motor vehicle operators.
(2) A review of impairment standard research for driving under the influence of marijuana.
(3) Methods to differentiate the cause of a driving impairment between alcohol and marijuana.
(4) State-based policies on marijuana-impaired driving.
(5) The role and extent of marijuana impairment in motor vehicle accidents.

(c) REPORT.—

(1) IN GENERAL.—Not later than 1 year after the date of enactment of this Act, the Secretary, in cooperation with other Federal agencies as appropriate, shall submit to the Committee on Transportation and Infrastructure of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a report on the results of the study.
(2) CONTENTS.—The report shall include, at a minimum, the following:

(A) FINDINGS.—The findings of the Secretary based on the study, including, at a minimum, the following:

(i) An assessment of methodologies and technologies for measuring driver impairment resulting from the use of marijuana, including the use of marijuana in combination with alcohol.
(ii) A description and assessment of the role of marijuana as a causal factor in traffic crashes and the extent of the problem of marijuana-impaired driving.
(iii) A description and assessment of current State laws relating to marijuana -impaired driving.
(iv) A determination whether an impairment standard for drivers under the influence of marijuana is feasible and could reduce vehicle accidents and save lives.

(B) RECOMMENDATIONS.—The recommendations of the Secretary based on the study, including, at a minimum, the following:

i) Effective and efficient methods for training law enforcement personnel, including drug recognition experts, to detect or measure the level of impairment of a motor vehicle operator who is under the influence of

marijuana by the use of technology or otherwise.

(ii) If feasible, an impairment standard for driving under the influence of marijuana.

(iii) Methodologies for increased data collection regarding the prevalence and effects of marijuana impaired driving.

(d) MARIJUANA DEFINED.—In this section, the term ''marijuana'' includes all substances containing tetrahydrocannabinol.

This report also is in response the Senate Report #114-243, pg.56-57, that accompanied the Consolidated Appropriations Act, 2017 (Public Law 115-31) dated May 5, 2017 which required the Secretary to "develop standards for impairment and assess technologies for measuring driver impairment…[and] develop criteria for roadside drug testing."

This report is organized to respond to the requirements stated above in Section 4008 and in the amendment to Section 4008 contained in the report accompanying the Consolidated Appropriations Act of 2017. It addresses the five issues to be examined, the four topics for which findings are to be provided, and concludes with the three areas where recommendations were required (if feasible). It also addresses the development of standards for impairment, examines the technology available for measuring impairment and the criteria for roadside drug testing.

First, a background section covers some critical information necessary for the reader to understand some of the complex technical issues that are the basis for the content that follows. This information is designed to provide a basic understanding of the process of absorption, distribution and elimination of alcohol and marijuana in the body, the time course for these processes, the effects these drugs have on driving-related skills, how drug testing is conducted, and the impaired driving detection process.

In 2009 the National Highway Traffic Safety Administration (NHTSA) issued a Report to Congress on Drug-impaired Driving (Compton, Vegega, and Smither, 2009) that addressed some of the same issues covered in this report and some of the material from that report is relevant here and is incorporated in this report.

Background

There is a large group of drugs that have the potential to impair driving and cause crashes. This larger body of drugs with the potential to impair driving consists of all psychoactive substances. Psychoactive substances include alcohol, some over-the-counter drugs, some prescription drugs, and most illegal drugs. The mechanism by which these drugs affect the body and behavior, the extent to which they impair driving, and the time course for the impairment of driving can differ greatly among these drugs.

Since the effects of alcohol on driving performance and crash risk are relatively well understood, it is useful to review and compare what is known about alcohol-impaired driving and marijuana-impaired driving as it clarifies some of the challenges and unknowns that pertain to marijuana-impaired driving. Alcohol-impaired driving has been a subject of intense interest and research for well over 60 years. There have been many studies conducted on the role of alcohol in contributing to traffic crashes starting in the 1950's. This research involved studies of alcohol-impaired driving related skills, primarily through laboratory studies involving subjects dosed on alcohol, using psychomotor tasks (reaction time, tracking, target detection), driving simulators and drivers on closed courses in instrumented vehicles,

epidemiological studies including roadside surveys of alcohol use by drivers, and studies of alcohol use by crash-involved drivers. This research built a persuasive case that alcohol was a significant contributor to traffic crashes. For example, in the 1950's it was estimated that alcohol-positive drivers were involved in approximately 50 percent of fatal crashes (involving over 25,000 fatalities per year), while the latest data available shows that alcohol-related fatal crashes have declined to around 30 percent (involving over 10,000 fatalities per year). In the 1960's research was able to estimate the crash risk of drivers at different alcohol concentration levels.

In the ensuing decades extensive efforts were taken to reduce the harm caused by alcohol use by drivers. These efforts included strengthening laws against alcohol-impaired driving, public education efforts about the dangers of driving after drinking, development of tools to assist law enforcement in detecting and arresting impaired drivers, and the prosecution of alcohol-impaired drivers. This included the development of the Breathalyzer and subsequent more sophisticated methods of measuring alcohol concentration in the breath. Laws were enacted that made specific alcohol concentrations presumptive of impairment; subsequently laws were passed that made it a crime to drive with an alcohol level at, or above a specified level (known as "illegal Per Se" levels). To address the deliberate pace often encountered in the criminal justice system many States adopted "administrative per se" laws that allowed for the almost immediate suspension or revocation of the driver license for persons operating a motor vehicle with an alcohol concentration above a specified level.

Much of this progress in addressing the harm caused by alcohol-impaired driving and the public's understanding of this problem derives from the pharmacokinetics (the absorption, distribution and elimination of a drug from the body) and pharmacodynamics (how a drug affects physiological process and behaviors). These processes differ, often substantially, for other drugs, including marijuana. Understanding these differences is critical to understanding how marijuana-impaired driving differs, and the impact these differences will have on efforts to reduce the harm from drug-impaired driving.

When one consumes alcohol (typically in a drink) it is readily absorbed into the blood system in the gastrointestinal tract. While there are factors that influence this process (e.g., presence of food) it occurs in a fairly regular fashion over time. The peak blood alcohol concentration is generally reached within about 20 minutes after the cessation of drinking. The process of eliminating alcohol from the body starts almost immediately upon its entry into the blood system. This process takes place primarily in the liver. Most doses of alcohol overwhelm the quantity and capacity of the enzymes that break it down, so that alcohol is removed from the bloodstream at an approximately constant rate. The elimination of most other drugs from the body occurs at a rate proportional to the current concentration, so that they exhibit exponential decay. This means the elimination occurs most rapidly when higher concentrations are present and slows down when less of the drug is present.

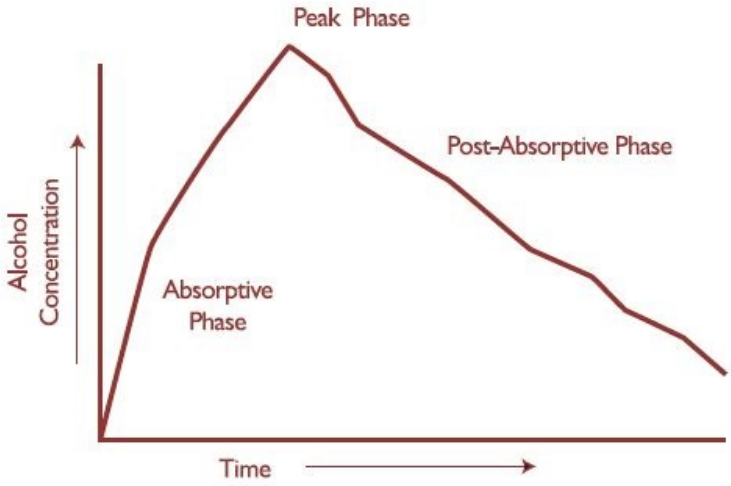
This fairly steady rate of elimination of alcohol occurs regardless of the concentration of alcohol in the blood. The rate is influenced by a number of factors (e.g., the health of the liver, experience consuming alcohol). Thus, the peak BAC reached after consumption of a specific quantity of alcohol depends primarily on the rate and amount of alcohol consumed, as the rate of elimination is fairly constant. It should be noted that alcohol readily passes through the blood-brain barrier (that prevents many harmful substances in the blood from entering the brain). See Figure 1 for a graphic display of this process of absorption and elimination of alcohol (adapted from APRI, 2003).

When one compares the effects of consuming alcohol on behavior (balance, coordination, reaction time), attention (divided attention, vigilance), cognition (decision making), and other propensities like risk taking and judgement, one finds that observed impairment in these functions correlates fairly well with alcohol concentration (in the blood or breath). Impairment increases with rising alcohol concentration

and declines with dropping alcohol concentration. This correlation between alcohol concentration and impairment has allowed the use of alcohol concentration (BAC- blood alcohol concentration or BrAC – breath alcohol concentration) to be used to infer the degree of impairment caused by the consumption of alcohol. The higher the BAC or BrAC the greater the impairment one will find. This well-established relationship has provided the basis for laws prohibiting driving with high BACs.

FIGURE 1

General Alcohol Concentration Curve



In summary, ethyl alcohol is a relatively simple drug whose absorption, distribution and elimination from the body along with the behavioral and cognitive effects are fairly well documented.

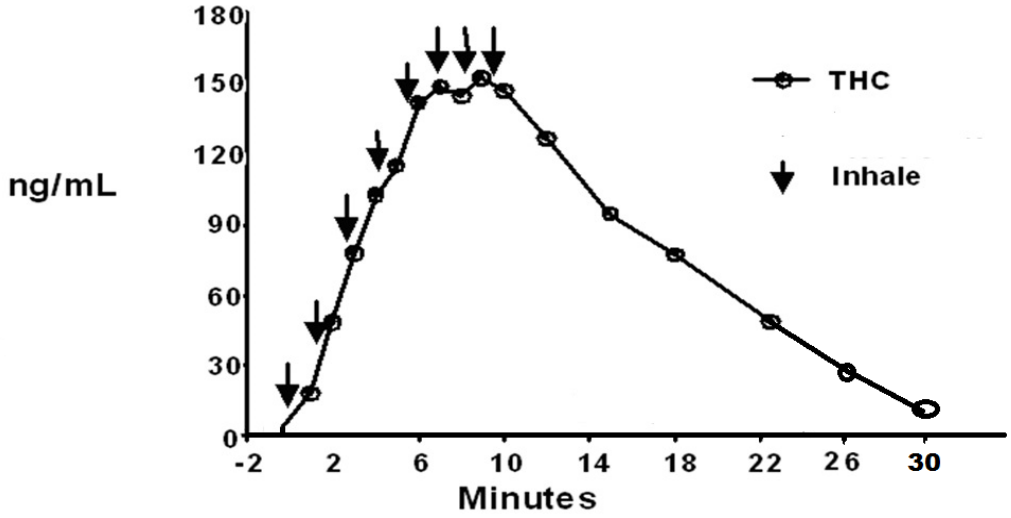
In comparison, the absorption, distribution and elimination from the body of marijuana (and many other drugs), along with the behavioral and cognitive effects is very different from the case with alcohol. The term marijuana refers to the plant known as marijuana (*cannabis sativa*). The typical way in which marijuana is consumed has been through smoking the plant material (leaves, flowers, seeds and stem), though other means of ingestion have been used, like through eating food products laced with an active ingredient of marijuana. The use of edible marijuana products has been increasing in recent years and presents some interesting new challenges that will be discussed briefly later in this report.

The primary psychoactive substance in marijuana is delta-9-tetrahydrocannabinal (THC). THC is one of over 500 known compounds in the cannabis plant, including more than 80 other cannabinoids. THC is associated with the psychoactive effects of ingesting marijuana plant material. THC has been shown to bind with receptors in the brain (and to a lesser extent in other parts of the body) and it is likely that this process underlies some of the psychoactive (behavioral and cognitive) effects of marijuana use.

While ethyl alcohol is readily soluble in water, and hence blood, THC is fat soluble. This means that once ingested, THC is stored in fatty tissues in the body and can be released back into the blood sometimes long after ingestion. Some studies have detected THC in the blood at 30 days post ingestion (Heustis, 2007). Thus, while THC can be detected in the blood long after ingestion, the acute psychoactive effects of marijuana ingestion last for mere hours, not days or weeks. Also, unlike alcohol, which is metabolized at a steady rate, the metabolism of THC occurs in a different fashion such that

THC blood levels decline exponentially. Some studies have reported a fairly wide variability that is affected by the means of ingestion (smoking, oil, and edibles), potency, and user characteristics. Most research on the effects of marijuana has used smoking and often do not measure the concentration of THC in the blood.

Figure 2
Absorption of THC in Plasma after Smoking



Note: Whole Blood THC is less than Plasma THC

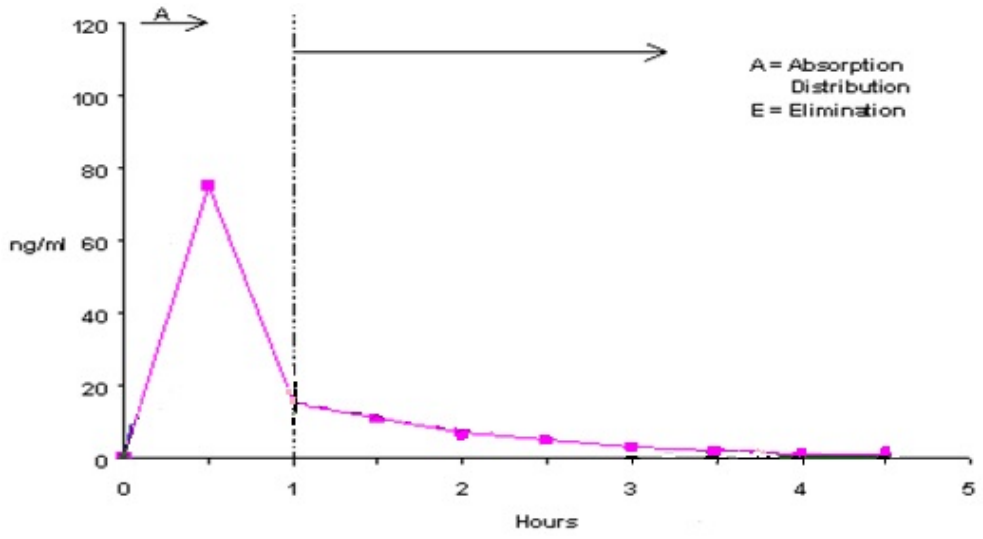
Figure 2 (above) shows a generalized example of the absorption of THC in the blood (plasma) after smoking a marijuana cigarette (Heustis, 2007, Huestis, Hemmingfield, Cone, 1992). Blood plasma is whole blood with the blood cells removed, in other words just the liquid portion of whole blood (serum is plasma without clotting factors). Note that THC is detectable in the blood within a minute or so after the initiation of smoking. The peak THC level occurs at the end of smoking or immediately after cessation (depending on the rate and duration of inhalations). THC levels drop rapidly after cessation of smoking. In contrast to alcohol, which is metabolized at a relatively steady rate, THC is metabolized at an exponentially declining rate where the THC blood level first drops rapidly, followed by a slower decline as lower THC levels are reached. As seen in Figure 2, within 30 minutes the THC level has dropped to 80 – 90 percent of the peak level. After a few hours only low or no THC can be detected in the blood. Very low THC levels may persist in the blood from a single administration for more than six hours.

While peak THC levels occur right after smoking ends, when alcohol is ingested by drinking, a peak BAC level in the blood or breath does not occur until sometime after the last drink is consumed. As mentioned above, alcohol primarily is absorbed into the blood (and hence into the lungs) through the gastrointestinal tract. Depending on a variety of factors it can take 20 minutes or more before alcohol is detectable in the blood or breath. The peak BAC level is dependent on the rate of intake and the rate of elimination. For the average person BAC is eliminated at a steady rate of approximately .015 BAC per hour. Thus, someone with a peak BAC of .16 would still have detectable alcohol in their blood ten hours later.

Figure 3 (below) shows the time course for THC in plasma after smoking over a longer period of time (Berghaus 1998; Chester 1995). When a driver's blood sample is collected, either because of a crash or if they are stopped by police for suspicion of impaired driving, the collection almost always occurs hours after ingestion has ceased. Often, time passes between the cessation of smoking and the beginning of driving, and more time passes between the beginning of driving and the encounter with law enforcement officials. Yet more time passes between the beginning of this encounter and point in time when blood is drawn (often after a search warrant is obtained for driving under the influence of drugs or

Figure 3

Time Course of THC Concentration in Plasma after Smoking Marijuana
[15mg THC in a 70kg person]
(Adapted from Berghaus et. al. 1998 and Chester 1995)



after the driver has been transported to a hospital post-crash). Thus, the likely THC level detectable in such a blood sample will be relatively low.

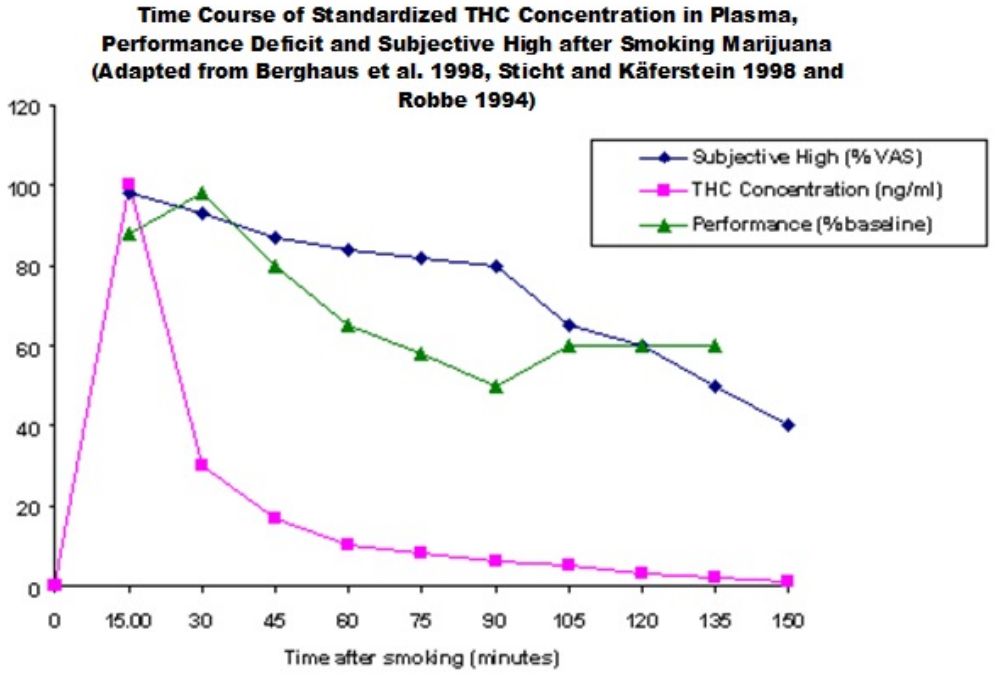
It was mentioned above that the effects of alcohol consumption on behavior, judgement, cognition and emotions all correlate fairly well with the rise and fall of alcohol concentration in the body as measured by blood alcohol concentration and breath alcohol concentration. This has been well established through a large number of carefully controlled studies in which subjects were dosed with alcohol and had their BAC or BrAC measured repeatedly while they performed a variety of tasks over time (see US DOT, 1991). The higher the alcohol concentration the greater the impairment that was observed. As alcohol concentration rose so did the degree of impairment; as alcohol concentration declined so did the degree of impairment.

Unlike alcohol, marijuana is classified as a Schedule I substance under the Controlled Substances Act. A much smaller number of studies have looked at the impairing effects of marijuana use on driving-related skills. Less is known about these effects due in part to the typical differences in research methods, tasks, subjects and dosing that are used. A clearer understanding of the effects of marijuana use will take additional time as more research is conducted. The extra precautions associated with

conducting research on a Schedule I drug may contribute to this relative lack of research. For example, these include the need for a government license to obtain, store and use marijuana, the security requirements for storage, and documentation requirements and disposal requirements.

While fewer studies have examined the relationship between THC blood levels and degree of impairment, in those studies that have been conducted the consistent finding is that the level of THC in the blood and the degree of impairment do not appear to be closely related. Peak impairment does not occur when THC concentration in the blood is at or near peak levels. Peak THC level can occur when low impairment is measured, and high impairment can be measured when THC level is low. Thus, in contrast to the situation with alcohol, someone can show little or no impairment at a THC level at which someone else may show a greater degree of impairment.

Figure 4



While high levels of THC are detected in the blood (and oral fluid) during and right after smoking, they are not typically observed an hour or two later. In cases of traffic crashes or arrests for impaired driving, it is most likely that only relatively low levels of THC will be found by the time an oral fluid or blood sample is obtained. Low THC levels of a few nanograms per milliliter (ng/ml) in blood can result from relatively recent use (e.g., smoking within 1 – 3 hours) when some slight or even moderate impairment is likely to be present, or it can result from chronic use where no recent ingestion has occurred and no impairment is present.

Figure 4 above shows this lack of clear correspondence between THC level in plasma and impairment (also subjective reports of being "high") in subjects who ingested marijuana through smoking (Ward, N.J. and Dye, L. 1999). As expected, the peak THC level is reached soon after smoking ends. However, peak performance deficits are observed long after the peak THC level occurs. In fact, peak impairment occurs at 90 minutes after smoking while the THC level has declined over 80 percent from

the peak level at that point in time. Notice also that the subjectively reported "high" also does not correspond well with blood plasma THC concentration. THC level in blood (or oral fluid) does not appear to be an accurate and reliable predictor of impairment from THC. Also, when low levels of THC are found in the blood, the presence of THC is not a reliable indicator of recent marijuana use.

The next two sections provide a brief overview of the impaired driving detection process and the drug testing process.

The Impaired Driving Detection Process

The detection of driver drug impairment typically takes place as a result of a law enforcement officer observing inappropriate driving behavior. The officer will stop the vehicle and engage the driver in conversation while the driver is inside the vehicle. The officer at this time may form a suspicion that the driver is impaired. This suspicion can be based on observations of driving behavior, the appearance of the driver (e.g., face flushed, speech slurred, odor of alcoholic beverages on breath), the behavior of the driver, and any statements the driver has made about alcohol or drug use. If the officer suspects that the driver is impaired, the officer will request that the driver exit the vehicle, and the officer will proceed to conduct pre-arrest screening tests. This phase can include the use of the Standardized Field Sobriety Test (SFST), which helps the officer determine whether the driver is impaired by alcohol and if the driver's BAC or BrAC is likely to be above the legal limit (Compton, et. al., 2009; Jones, et. al., 2003).

Based on this information, the officer may place the driver under arrest for suspicion of impaired driving. At this point, the officer will request a breath or blood sample for alcohol concentration testing – most typically a breath sample, but blood or urine samples could also be requested. If the suspect agrees to take an alcohol concentration test the officer will, in a jurisdiction that uses breath alcohol testing, take the offender to a booking location where the sample will be requested, for example, for an evidential breath test. However in many instances, the officer may obtain the sample at roadside in the patrol vehicle or in a mobile testing van or similar setting, if an evidential breath test device is available in the field. In a jurisdiction in which blood alcohol testing is used, the officer will typically obtain a search warrant and transport the driver to a medicinal facility where a blood sample can be drawn. In some cases the driver may be transported to a booking facility if a nurse or phlebotomist is available. In a few jurisdictions law enforcement officers are trained and licensed as phlebotomists and can draw the blood sample themselves. A recent U.S. Supreme Court case decision said that warrantless blood tests of alcohol concentration are not generally allowed (Missouri v. McNeely, No. 11–1425, decided April 17, 2013), although warrantless breath alcohol tests are generally permissible as they are less intrusive than blood tests of alcohol concentration (Birchfield v. North Dakota, No. 14–1468, decided June 23, 2016).

While there are cases where an impaired driver exhibits signs and symptoms not indicative of alcohol consumption, most often driver impairment is from alcohol, and thus the officer will typically begin by testing this possibility. When the BAC test results are incompatible with the observed impairment, then the officer will consider drugs other than alcohol as the likely cause of the observed impairment. Typically, if the suspect is found to be under the influence of alcohol, especially when the BAC is at, or above, the legal limit, the investigation stops at that point, even if the officer has reason to suspect that the use of other drugs is contributing to the suspect's impairment.

There are several disincentives for investigating potential impairment due to drugs other than alcohol when BAC evidence clearly shows an illegal alcohol level. Generally, the alcohol charge meets the

burden of proof and State laws typically do not have additional penalties for multiple substance impairment.

However, if impairment is observed and BAC tests are negative, officers can seek additional evidence to support a drug-impaired driving charge. In jurisdictions that participate in the Drug Evaluation and Classification (DEC) Program, the arresting officer may request an evaluation by a Drug Recognition Expert (DRE). This program, originally developed by the Los Angeles Police Department in the 1970's, trains officers to recognize the signs and symptoms of drug use as an aid to investigating suspected drug-impaired driving cases. The program is now managed nationally by the International Association of Chiefs of Police (IACP), with technical assistance from NHTSA. The DRE performs a drug influence evaluation (DIE) on the suspected impaired driver in order to determine whether the observed impairment is likely to be due to drug use (and if so, what specific type of drug(s)) or whether the observed impairment is due to neurological conditions, illness, or disease. The DRE, or arresting officer in cases where no DRE is available, gathers a biological sample (blood or urine) to be analyzed by a toxicology lab to confirm the suspect had used a drug or drugs. Currently all fifty States and the District of Columbia participate in the DEC program with over 8,000 certified DREs.

Drug Testing Process

Generally, prosecution on a drug-impaired driving offense will include evidence that the driver had used a specific potentially impairing drug, and that an observed impairment likely resulted from that drug use. It is difficult, though not impossible, to obtain a conviction for drug-impaired driving without evidence of drug use by the suspect. For example, a suspect may refuse to provide a specimen for testing and/or the officer may be unable to obtain a search warrant in a timely fashion.

Evidence of drug use is typically obtained by the investigating law enforcement officer (physical evidence, odor of marijuana use, etc.), but most often comes from forensic testing conducted in a laboratory of a biological specimen taken from the suspect. Laboratory testing of biological specimens can be time consuming and expensive.

Laboratory Testing

Because of the large number of potentially impairing drugs the standard process is to conduct a screening test that will give an indication which of a number of drug categories might be present in the specimen. Screening tests are easier to conduct, cheaper, and can test for a number of drug categories simultaneously. For marijuana, it is common to use an immunoassay test designed to detect cannabinoids. However, a positive screening test cannot be taken as evidence that the drug is present in the specimen, as these tests lack high specificity, are subject to cross-reactivity, and may on occasion produce a false positive result. Many of the THC immunoassay screening tests can give a positive response to the presence of THC metabolites, even though THC is not present in the sample.

Following a positive screening test indicating that a type of drug appears to be present in the specimen, a more accurate, sensitive and specific test will be conducted for the drugs in the category indicated by the screening test. These tests are more complicated to conduct, require expensive equipment, and are time consuming. Many laboratories have backlogs of samples waiting for testing that are many months or longer.

The testing methods used will often depend on the suspect drug class. Most common are techniques combining a gas chromatograph (GC) with mass spectrometry (MS), often referred to as gas chromatography–mass spectrometry (GC/MS). Liquid chromatography is also used in combination with mass spectrometry, often referred to as liquid chromatography–mass spectrometry (LC-MS).

Often, this process involves further ionization with a second pass through the mass spectrometer or LC/MS/MS. Not only are these methods highly specific in detecting a specific molecule (based on atomic weight and molecular structure) they allow the quantification of the amount of the drug present.

Specimen Collection

Evidence that a suspected impaired driver has actually used a drug can be provided by a test that definitively shows that it is present in a biological specimen. Typically urine or blood specimens are taken for this purpose and then sent to a laboratory for analysis. There may be a delay of days, weeks, or months before the results are known. Thus, an officer will not know the test result prior to the time the suspect is charged. Different biological specimens have advantages and disadvantages, depending on the purpose of the testing. Biological specimens for drug testing include the following:

- Blood Testing – Blood testing is considered the "gold standard" for testing for the presence of drugs in impaired driving cases. However, as described in the background section to this report, currently there is limited ability to relate the amount of a drug or metabolite in blood to the presence and amount of impairment. Collecting a blood sample is an invasive procedure typically requiring a search warrant and a nurse or licensed phlebotomist.

- Oral Fluid Testing — The collection of oral fluid is minimally invasive and effective in detecting many types of drugs, though it may require a search warrant under the same conditions that pertain to blood sample collection. Devices that collect oral fluid for laboratory testing appear to be a reliable means of testing for recent drug use. The technology to rapidly, accurately and reliably collect oral fluid at the point of arrest is quickly evolving. Some companies market self-contained test kits that can be used by law enforcement; however, these point-of-arrest screening devices have not been shown to be completely accurate and reliable. Marijuana (THC) is readily detected in oral fluid, however, there are issues associated with distinguishing use versus environmental exposure, that have not been fully addressed.

- Sweat Testing — The collection of sweat over time can produce a cumulative record of prior drug use. However, a positive sweat test result cannot be regarded as evidence of impairment at the time of an arrest or crash. Sweat testing has no advantages over oral fluid testing, and is susceptible to contamination.

- Hair Testing — Although it is possible to test samples of hair for drug usage, the results are of limited utility for drug-impaired driving cases. Positive hair test results cannot be used to demonstrate drug use at the time of driving. In addition, variations in hair growth and the addition of substances to the hair, such as coloring products, make it difficult to extrapolate when drug usage occurred and may also affect the results. While THC can be detected in hair it can result from environmental exposure (e.g., from marijuana smoke) that can produce a positive hair test result.

- Urine Testing — The drug testing methodology for urinalysis is well established. Drugs and drug metabolites are detectable in urine for several days after the drug has been used (and sometimes for weeks). Urine test results cannot be used to prove that a driver was under the influence of the drug at the time of arrest or testing. Detection of THC or other cannabinoids in urine does not necessarily reflect recent use.

Measuring Driver Impairment Due to Marijuana Use

Review of Research on the Effects of Marijuana use on Driving

Smoking marijuana has been shown to affect a number of driving-related skills. Laboratory, simulator and instrumented vehicle studies have shown that marijuana can impair critical abilities necessary for safe driving, such as:

- slow reaction time, for example, responding to unexpected events - emergency braking (Casswell, 1977; Smiley et. al., 1981; Lenné, M.G., et al., 2010);
- cause problems with road tracking - lane position variability (Smiley, et. al., 1981; Robbe and O'Hanlon, 1993; Ramaekers, 2004);
- decrease divided attention - target recognition (Smiley, 1999; Menetrey, et. al., 2005), impair cognitive performance - attention maintenance (Ramaekers, et. al., 2004); and impair executive functions - route planning, decision making, and risk taking (Dott, 1972, Ellingstad et al, 1973; Menetrey, et al., 2005).

It should be noted that this type of research typically does not involve measurement of blood THC levels; rather, subjects' performance between non-dosed trials (placebo condition) and dosed trials (when administered marijuana) are compared. As a result of differences in how subjects conduct the smoking regime (inhalation rate, depth of inhalation, and time between inhalation and exhalation), fairly wide differences in blood THC levels are likely between subjects.

An example of this type of research on the effects of marijuana on driving related skills is a recent study conducted by the National Institute on Drug Abuse, the National Highway Traffic Safety Administration and the Office of National Drug Control Policy using the National Advanced Driving Simulator at the University of Iowa. Volunteer subjects were dosed on marijuana, alcohol or both marijuana and alcohol. They then drove a full motion driving simulator over a predetermined route. One of the effects of marijuana use was to cause an increase in the variability of their vehicle's lane position (the ability to maintain their vehicle in the center of the lane). Both alcohol and marijuana alone increased lane position variability and when combined the effects were additive. However, only alcohol increased lane departures (Hartman, et al 2015).

The same study looked at the speed at which the driver drove relative to the speed limit as a result of marijuana and alcohol use by the drivers. Subjects dosed on marijuana showed reduced mean speeds, increased time driving below the speed limit and increased following distance during a car following task. Alcohol, in contrast was associated with higher mean speeds (over the speed limit), greater variability in speed, and spent a greater percent of time driving above the speed limit. Marijuana had no effect on variability of speed. In the combined alcohol and marijuana condition it appeared that marijuana mitigated some of the effects found with alcohol by reducing the time spent above the speed limit (Hartman, et al., 2016).

It should also be noted that many studies have not shown impairment on these psychomotor tasks, cognitive and executive functions as have shown statistically significant impairments. It is not clear why this is the case. It may stem from different THC doses, different time lags between doses and testing or driving, differences in the tasks used to assess the effects, tolerance developed through frequent use, and the different dependent measurement employed and their relative sensitivity to small effects (Smiley, et al., 1986; Lenné, et al., 2010).

Despite the variability in results, this research has demonstrated the potential of marijuana to impair driving related skills. It does not show a relationship between THC levels and impairment. These

studies are conducted under carefully controlled conditions with precise measurements. Under these conditions even slight changes in performance are often statistically significant. Whether these often small changes in performance are practically significant (i.e., increase the risk of crash involvement) cannot be determined within this research framework.

An interesting finding from this research is that after smoking marijuana, subjects in most of the simulator and instrumented vehicle studies on marijuana and driving typically drive slower, follow other cars at greater distances, and take fewer risks than when sober (Stein, et al., 1983; Smiley, et al., 1981; Smiley, et al., 1986; Casswell, 1977; Robbe and O'Hanlon, 1993). These effects appear to suggest that the drivers are attempting to compensate for the subjective effects of using marijuana. In contrast, subjects dosed with alcohol typically drive faster, follow at closer distances, and take greater risks.

Given the large variety of driving related skills that are affected by THC, especially cognitive performance and judgment, the attempt by drivers who have ingested marijuana to compensate for the effects of marijuana is not likely to mitigate the detrimental effects on driving related skills.

Congress requested an assessment of methodologies and technologies for measuring driver impairment resulting from the use of marijuana, including the use of marijuana in combination with alcohol. The measurement of driver impairment is challenging since driver performance is a product of manual, cognitive, and perceptual skills, and the range of performance reflected in the normal driver population is large. Deficits in performance can arise from a variety of causes that include alcohol, marijuana and other drug use, distraction, drowsiness, emotional states (fear, excitement, anger), and other factors.

The DEC program includes a set of signs and symptoms (physiological, effects of the eyes, and behavior) that are indicative of marijuana use. They are used to determine if observed impairment is likely to be caused by marijuana. Almost all of these signs and symptoms are not based on driving impairment.

Current knowledge about the effects of marijuana on driving is insufficient to allow specification of a simple measure of driving impairment outside of controlled conditions. Other research methods can contribute to our understanding of the risk of driving after marijuana use and will be addressed later in this report.

The question of the combined use of alcohol and marijuana is definitely relevant to the issue of impaired driving. It is not uncommon to find people that have used both drugs. In a study of drug use by fatally injured drivers conducted in 1991, some 51.5 percent of the fatally injured drivers were found to be alcohol positive, while 6.7 percent were THC positive (Terhune, et. al. 1992). Of those who were THC positive over half were also positive for alcohol (the majority of which had high BAC levels).

In the 2013-2014 National Roadside Survey of Drug and Alcohol Use by Drivers, some 9.3 percent of all (daytime and nighttime) drug positive drivers also had a positive BrAC, while only 6.0 percent of drug negative drivers were positive for alcohol. Among daytime drivers, 2.5 percent of drug positive drivers were alcohol positive whereas 0.3 percent of drug negative drivers were alcohol positive.

Some studies have reported increased impairment on driving related skills when subjects are dosed on both alcohol and marijuana (Robbe and O'Hanlon, 1993; Smiley, et al., 1986). In other cases, no increased impairment is found. The relative amount of both drugs ingested may help explain this confusing result. In some cases, the effects of alcohol may be so dominant that the additions of low

doses of marijuana are not detectable. Further research may help clarify the effects of combined alcohol and marijuana use.

Thus, there are currently no evidence-based methods to detect marijuana-impaired driving. Marijuana has some regularly reported effects on driving related skills that might lend themselves to the development of marijuana-impaired driving detection techniques, similar to those that have been developed for alcohol-impaired driving (Harris, 1980 and Stuster, 1997). However, many of these effects can also be caused by alcohol, other drugs and driver conditions and activities like distraction, drowsiness, and illness. It is not possible to predict whether there might be a unique combination of cues that could be used by law enforcement to detect marijuana-impaired driving with a high degree of accuracy. Such a method would need to have an extremely low false positive rate (incorrectly identifying a driver as marijuana-impaired when they are not) to be useable by law enforcement.

Feasibility of Developing an Impairment Standard for Drivers under the Influence of Marijuana

Currently, there is no impairment standard for drivers under the influence of marijuana. Many of the reasons for this are discussed elsewhere in this report. They include the fact that there is no chemical test for marijuana impairment, like a BAC or BrAC test for alcohol that quantifies the amount of alcohol in their body, indicates the degree of impairment, and the risk of crash involvement that results from the use of alcohol. The psychoactive ingredient in marijuana, delta-9-tetrahydrocannabinal (THC), does not correlate well with impairment. While very high levels of THC do indicate recent consumption (by smoking marijuana) it is very unlikely a police officer would encounter a suspect and obtain a sample of blood or oral fluid within a short enough time for high THC levels to be detected. As was mentioned earlier, impairment is observed for two to three hours after smoking; whereas by an hour after smoking peak THC levels have declined 80% - 90%.

Without a chemical test, the alternative is to develop a psychomotor, behavioral or cognitive test that would indicate the degree of driving impairment and elevated risk of crash involvement due to marijuana use. As was described earlier in this report, marijuana has been show to impair critical driving related skills including psychomotor abilities like reaction time, tracking ability, and target detection, cognitive skills like judgment, anticipation, and divided attention, and executive functions like route planning and risk taking. However, available research does not support the development of such a psychomotor, behavioral or cognitive test that would be practical and feasible for law enforcement use at this time. It is certainly possible that when more research has been conducted on the impairing effects of marijuana use on driving, that can be shown to increase the risk of crash involvement, that it may be possible to develop such a test in the future.

NHTSA, and others, are currently conducting research toward that goal. We are funding a controlled dosing study of different ways to measure marijuana impairment in driving related skills in the hope that some of these measures will be amenable to use by law enforcement. The first step is to show that everyone dosed on marijuana shows an observable amount of impairment in a controlled laboratory setting. The next step would be to develop simplified versions of these measures that do not require sophisticated and expensive equipment that are suitable for field use by law enforcement. The last step would be to establish the relationship between the observed impairment on these tests and elevated risk of crash involvement. Success in the near term is not guaranteed, but possible.

Devices Capable of Measuring Marijuana Levels in Drivers

Conviction on a Driving Under the Influence of Drugs (DUID) charge, or evidence that marijuana played a role in a crash, typically requires evidence that the driver was impaired by marijuana at the time of arrest or the crash. While alcohol concentration (BAC or BrAC) is an accurate measurement of

alcohol impairment of driving, the presence of THC in the driver's body has not been shown to be a reliable measure of marijuana impairment of driving.

Traditionally, measurement of marijuana use by drivers has involved testing biological specimens for the presence of THC (typically blood samples, though urine and other substance have been used). As was stated previously, this testing can take days, weeks, or months before the results are available to law enforcement. The tests take a few hours or less to conduct, but large backlogs in many State laboratories conducting the testing can result in long delays before results are available. Such tests not only indicate whether THC was present in the sample tested, they also quantify the concentration or amount of THC detected. These toxicological tests confirm presence of THC but they do not indicate driver impairment or necessarily indicate recent marijuana use (when the THC levels are low).

Recent developments in testing technology have resulted in some companies offering oral fluid drug screening devices that could be used by law enforcement to provide a preliminary indication whether a laboratory test (e.g., GC/MS/MS) is likely to yield a positive result for THC. Examples of these types of oral fluid devices include the Alere DDS2©, which tests for five commonly abused drugs, and the Dräger DrugTest® 5000. See Table 1 for the drugs they are designed to detect and for the cutoff levels.

The use of onsite oral fluid screening devices might encourage law enforcement to pursue a drug-impaired driving charge when they otherwise might not. However, the accuracy and reliability of these devices has not yet been clearly established. While some studies of these devices have been conducted, many were funded by the manufacturers (Logan, Mohr, Talpins, 2014; Moore, Kelley-Baker, Lacey, 2013; Logan, Mohr, 2015). At this time, there is insufficient evidence on this subject to draw a firm conclusion. NHTSA is currently conducting research that is designed to provide some preliminary information on the accuracy, reliability, sensitivity and specificity of five of these devices.

Table 1
Oral Fluid Drug Screening Devices
Drug Categories and Analytic Cut-Off Levels

Device	Drug Category	Cut-Off Level (ng/ml)	Device	Drug Category	Cut-Off Level (ng/ml)
Alere DDS2			**Dräger DrugTest® 5000**		
	Cannabis (THC)	25		Cannabis (THC)	5
	Amphetamine	50		Amphetamine	50
	Methamphetamine	50		Methamphetamine	35
				(MDMA)	75
	Benzodiazepine	20		Benzodiazepine	15
	Opiates	40		Opiates	20
	Cocaine	30		Cocaine	20
	Methadone	15		Methadone	20

Downloaded from the Alere website (http://www.alere.com/en/home/product-details/dds2-mobile-test-system.html) and from the Dräger website (http://www.draeger.com/sites/enus_us/Pages/Alcohol-and-Drug-Detection/Law-Enforcement.aspx) on March 16, 2016

While the presence of THC in a driver (blood, oral fluid, etc.) does not establish impairment, it also does not distinguish been active use of marijuana and environmental exposure or contamination. Some studies have shown that people exposed to second-hand marijuana smoke can test positive for THC (Cone, et al, 2015; Moore et al, 2006).

Methods to Differentiate the Cause of a Driving Impairment between Alcohol and Marijuana

There are no evidence-based methods to differentiate the cause of driving impairment between alcohol and marijuana. Given the increasing use of marijuana by drivers in the U.S., there are a number of efforts underway, including work by NHTSA, to develop ways of differentiating impairment by alcohol from marijuana. These efforts will take a number of years and a successful outcome cannot be guaranteed at this time.

Description and Assessment of Current State Laws Relating to Marijuana-Impaired Driving

All States have laws prohibiting driving while impaired (under the influence or intoxicated) by alcohol and other drugs (which includes marijuana). These laws have existed for many decades. Under such statutes a State must prove that the drug "caused" the impaired driving (i.e., a prosecutor must show a connection between drug ingestion and the incapacity or impairment of the driver).

In addition, some States have what is known as a *per se* law, that make it a criminal offense for a driver to have a drug or metabolite in his/her body while operating a motor vehicle. These "zero tolerance" laws specify that it is illegal to drive with any or more than a specific concentration of the drugs in blood or urine. They typically cover some or all Schedule I drugs as identified under the Controlled Substance Act of 1970[1]). In some cases they cover only specific drugs listed in the statute. They also exclude categories of drugs, for example, drugs used by a doctor's order (prescription). In some cases they explicitly exclude marijuana.

Fifteen States have drug per se (zero tolerance) statutes. In seven States (AZ, DE, GA, IN, MN, PA, and UT) it is illegal to have any amount of a drug or its metabolite in the body while operating a motor vehicle (note: the Minnesota law exempts marijuana). In five States (IL, IA, MI, RI, and WI) it is illegal to have any amount of a prohibited drug in the body while operating a motor vehicle. Three States (NV, OH, and VA) make it illegal to have specific amounts of specified prohibited substances in the body while operating a motor vehicle. Two States (NC and SD) make it illegal for a person under age 21 to drive with any amount of a prohibited drug or substance in their bodies. Five States (CA, CO, ID, KS, and WV) make it illegal for any drug addict or habitual user of drugs to drive a vehicle.

Only a few States (HI, NY, and CA) have DUID statutes separate from their alcohol driving under the influence (DUI) laws. In all other States, a driver violates a DUI statute if he/she drives under the influence of alcohol, drugs or a combination of alcohol and drugs. The violation is the same, as are the penalties. The one exception is the State of Washington in which there are different penalties for only drug use, as opposed to alcohol use or a combination of alcohol and drug use.

[1] The Controlled Substances Act, Title II of the Comprehensive Drug Abuse Prevention and Control Act of 1970, is the federal U.S. drug policy under which the manufacture, importation, possession, use and distribution of certain narcotics, stimulants, depressants, hallucinogens, anabolic steroids and other chemicals is regulated.

Twenty States (AL, AZ, AR, DE, GA, ID, IL, KS, KY, MT, NC, OK, PA, RI, SD, TN, TX, VT, WA, and WV) and Puerto Rico specifically disallow legal entitlement to use the drug as a defense to a DUID charge. Use of a drug pursuant to a valid prescription and/or according to directions is a defense to a DUID charge in several States.

All but five States (AL, AK, MA, NJ, and WV) extend their implied consent laws (i.e., to provide a specimen if requested by law enforcement) to DUID. However, both Alabama and Alaska make a provision for compulsory testing in cases involving serious injury or fatal crashes. Of the remaining 45 States (plus DC and PR) that extend their implied consent laws to drugged driving, nine (AR, IN, LA, MD, MN, NE, NM, OH, and RI) provide criminal penalties for a refusal to take a test under the implied consent law.

Twenty-eight States and the District of Columbia and Puerto Rico allow for a forced taking of a specimen over the objection of the driver, but this is generally in cases of a serious injury or fatal crash, and there is probable cause that the driver is under the influence of a drug. Based on the recent Supreme Court case in (Missouri v. McNeely is: 133 S.Ct. 1552 (2013)) it would appear that law enforcement is required to obtain a search warrant for blood tests except in special circumstances.

Under implied consent provisions, most State laws stipulate the type of specimen that police officers are authorized to collect. Thirty-four States permit blood and/or urine; eight States only allow for blood collection; six States permit saliva; and eight States (plus Puerto Rico) permit "other bodily substances."

With respect to sanctions, some States have relatively light sentences for first offenders, while others are more severe in their handling of first offenders. Some States have made a second or third offense a felony, whereas in other States felony status is not reached until the fourth or subsequent offense. Penalties, including fines and incarceration, differ from State to State. Many States utilize community service, house arrest, electronic monitoring, work release, restitution and assessment of cost and fees to supplement the court's ability to sanction offenders. Approximately 35 States provide for court-ordered substance abuse treatment and/or education for offenders. A growing number of States require participation in a program or treatment as a condition of probation or as a pre-requisite to reinstatement of driving privileges.

Clearly, there is great variability among the States in how they approach driving under the influence of drugs. The absence of a separate offense for driving under the influence of drugs makes it difficult to distinguish between DUID and DWI-alcohol arrest and disposition. A recent attempt to investigate the effectiveness of drug per se laws was unable to draw conclusions due to the paucity of objective data and the inability of State data systems to distinguish between DUID and DWI-alcohol arrests and convictions (Lacey, Brainard, and Snitow, 2010). In addition, in cases where a driver shows evidence of multiple impairments, the lack of difference in sanctions between drug- and alcohol-impaired driving provides little incentive for criminal justice officials to pursue a drugged-driving charge in addition to an alcohol offense.

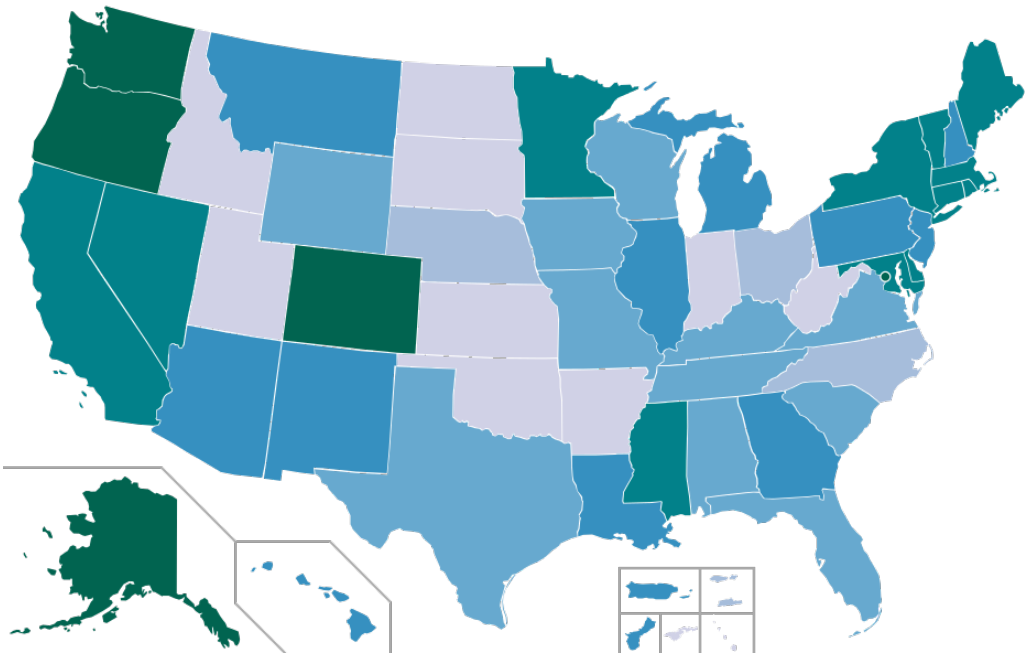
Other Relevant Marijuana Laws

Marijuana remains an illegal Schedule I drug from a federal perspective. However, due to the public's changing views of marijuana a majority of States have passed laws providing for some type of limited use of marijuana. These laws include outright legalization of personal recreational use, decriminalization

of personal use, State laws allowing therapeutic use ("medical marijuana"), and State laws allowing limited therapeutic marijuana use. The States that have passed these different laws are shown in Figure 5 below (note this information is accurate as of June 2016, many States have measures on their November ballots pertaining to marijuana use that will probably result in additional states legalizing recreational marijuana use and therapeutic use). Within these broad categories there are wide differences among individual statutes. Twenty-two States and two inhabited territories still conform to the federal position that marijuana possession and sales are illegal and prohibited entirely.

All of this State legislative activity may be sending a message to drivers that marijuana is not as dangerous as previously thought. However even if marijuana use is legal, that does not mean that driving impaired by marijuana is legal or safe. This is similar to the case for alcohol, which is a legal drug, but driving impaired by alcohol is illegal. This changing perception of the dangers of marijuana use is likely impacting personal choices regarding marijuana use. As more people choose to use marijuana it is likely more people will drive impaired by marijuana.

Figure 5
Marijuana Laws in the United States[1]



Jurisdiction with legalized cannabis.
Jurisdiction with both therapeutic use and decriminalization laws.[2]
Jurisdiction with legal psychoactive therapeutic cannabis use.
Jurisdiction with legal non-psychoactive therapeutic cannabis use.
Jurisdiction with decriminalized cannabis possession laws.
Jurisdiction with cannabis prohibition.

[1] Includes laws which have not yet gone into effect.
[2] Mississippi has only legal non-psychoactive therapeutic cannabis use.

Currently 25 States have passed therapeutic marijuana use laws (along with Washington, DC, Guam, and Puerto Rico). These States are shown in Table 2 below along with the year their therapeutic marijuana use laws were originally enacted (some have modified their therapeutic marijuana use laws one or more times since enactment). Some of the most recently passed measures have not gone into effect yet.

An additional ten States have a form of limited therapeutic marijuana use (with low THC and high CBD allowed). CBD is a cannabinoid that does not appear to be psychoactive and lacks most adverse side-effects but is believed to have potential for medical purposes.

Twenty-one States and the District of Columbia have decriminalized small amounts of marijuana. This generally means certain small personal-consumption amounts are a civil or local infraction, not a State crime (or are a misdemeanor with no possibility of jail time).

Decriminalization States are Alaska (which has subsequently legalized personal consumption and possession of small quantities), California, Colorado (also now has allowed legalization of personal consumption), Connecticut, Delaware (enacted in 2015), Illinois (enacted in 2016), Maine, Maryland,

Massachusetts, Minnesota, Mississippi, Missouri, Nebraska, Nevada, New York, North Carolina, Ohio, Oregon (also now with legalized personal consumption), Rhode Island, Vermont and Washington (now having legalized personal consumption), and the District of Columbia (also now with legal personal consumption). A number of cities and counties across the U.S. have also decriminalized personal use and possession of small quantities of marijuana.

Six of the States that have decriminalized possession or use of marijuana (Minnesota, Missouri, Nevada, North Carolina, Ohio and Oregon) have made it a low-level misdemeanor, with no possibility of jail for qualifying offenses. The other States that decriminalized marijuana use have specified small amounts of marijuana as a civil infraction. As noted above, four of the States that originally decriminalized personal use and possession of marijuana have subsequently legalized the personal recreational use of marijuana.

Table 2
States with Therapeutic Marijuana Use Laws and Date of Enactment

State	Date of Enactment	State	Date of Enactment
1. California	1996	2. Alaska	1998
3. Oregon	1998	4. Washington	1998
5. Colorado	2000	6. Hawaii	2000
7. Nevada	2000	8. Vermont	2004
9. New Mexico	2008	10. Michigan	2008
11. Rhode Island	2009	12. New Jersey	2009
13. Arizona	2010	14. Maine	2010
15. Delaware	2011	16. Montana	2011
17. Connecticut	2012	18. Maryland	2013
19. Massachusetts	2013	20. New Hampshire	2013
21. Illinois	2014	22. Minnesota	2014
23. New York	2014	24. Ohio	2016
25. Pennsylvania	2016		

Some States have passed more than one of these measures. The laws of the remaining twenty-two States and two inhabited territories follow the federal laws and prohibit marijuana possession and sales are illegal and prohibited entirely.

Table 3
States with Limited Therapeutic Marijuana Use Laws

State	Date Enacted	State	Date Enacted
Alabama	2014*	Iowa	2014
Kentucky	2014	Mississippi	2014
Missouri	2014	North Carolina	2014
South Carolina	2014	Tennessee	2014
Utah	2014	Wisconsin	2013

* Not yet effective

Table 4

States With Personalized Use Decriminalized

State	Date Enacted	State	Date Enacted
Alaska*	2014	California	1976
Colorado*	1975	Connecticut	2011
Delaware	2015	Illinois	2015
Maine	1976	Maryland	2014
Massachusetts	2008	Minnesota	1976
Mississippi	1977	Missouri	2014
Nebraska	1978	Nevada	2001
New York	1977	North Carolina	1977
South Carolina		Ohio	1975
Oregon*	1973	Rhode Island	2012
Vermont	2013	Washington*	2012
District of Columbia*	2014		

* Also has legalized personal possession and use of small amounts of marijuana

Table 5

States Legalizing Recreational Use[1]

State	Date of Enactment	Amount Allowed
Alaska	2015	1 oz.
Colorado	2014	1 oz.
Oregon	2015	8 oz.
Washington	2014	1 oz.
District of Columbia	2014	2 oz.

1 – For persons at least 21 years old

Description and Assessment of the Role of Marijuana as a Causal Factor in Traffic Crashes and the Extent of the Problem of Marijuana-Impaired Driving

The scope and magnitude of the marijuana-impaired driving problem in this country cannot be clearly specified at this time. However, there are a number of indicators that suggest that a problem exists. These include numerous cases of drivers involved in serious injury and fatal crashes who are held responsible, in part as a result of marijuana-impaired driving, along with a significant number of drivers arrested and convicted for marijuana-impaired driving. There is also clear evidence that an increasing number of people use marijuana, perhaps reflecting changing public attitudes toward marijuana use, possibly due, in part, to State medicinal marijuana laws, decriminalization of marijuana, and legalization of recreational use of marijuana (see the 2016 report from Monitoring the Future Annual Survey of Drug Use conducted by NIDA and the 2013-2014 National Roadside Survey). A series of nationally representative studies of driver use of alcohol and drugs conducted by the National Highway Traffic Safety Administration have found increased use of marijuana by drivers. These studies have provided the best empirical evidence regarding marijuana use by a wide swath of the American public (Lacey et al., 2009; Berning, Compton & Wochinger, 2015). Previous estimates of marijuana use have relied on self-report data, which likely included some underreporting. The NHTSA studies collected blood and oral fluid samples from paid volunteer drivers on the road and analyzed these samples for the presence of THC.

Prevalence of Marijuana Use by Drivers

Over the last five decades, NHTSA and/or the Insurance Institute for Highway Safety (IIHS) conducted five national surveys to estimate the prevalence of drinking and driving in the United States (Wolfe, 1974; Lund & Wolfe, 1991; Voas et al., 1998; Compton & Berning, 2009; Lacey et al., 2009). The first National Roadside Survey (NRS) was conducted in 1973, followed by national surveys of drivers in 1986, 1996, 2007, and 2013–2014. These surveys used a stratified random sample of weekend nighttime drivers in the contiguous 48 States and collected data directly from drivers on the road.

The 2007 NRS added procedures to the NRS for the first time to estimate the use by drivers of other potentially impairing drugs. Prior roadside surveys had only collected breath samples to determine breath alcohol concentration (BrAC). Due to developments in analytical toxicology, NHTSA determined it would be feasible in the 2007 and 2013–2014 surveys to determine driver use of a variety of potentially impairing drugs including illegal drugs as well as legal medications.

The National Roadside Surveys have shown a remarkable decreasing trend in alcohol use from the first survey in 1973 to the most recent one in 2013– 2014. Figure 6 shows the percentage of weekend nighttime drivers with BrACs across three categories: BrAC of .005 to .049 g/210L; BrACs of .050 to .079; and BrACs of .080 and higher. The surveys found a decline in each BrAC category. Further, there has been a large decrease in the percentage of drivers who were alcohol positive, from 35.9 percent in 1973 to 8.3 percent in 2013–2014. For BrACs of .08 and higher, there was a decrease from 7.5 percent in 1973 to 1.5 percent in 2013–2014, revealing an impressive 80 percent reduction in the percentage of alcohol-impaired drivers on the road on weekend nights (Berning, Compton, & Wochinger, 2015).

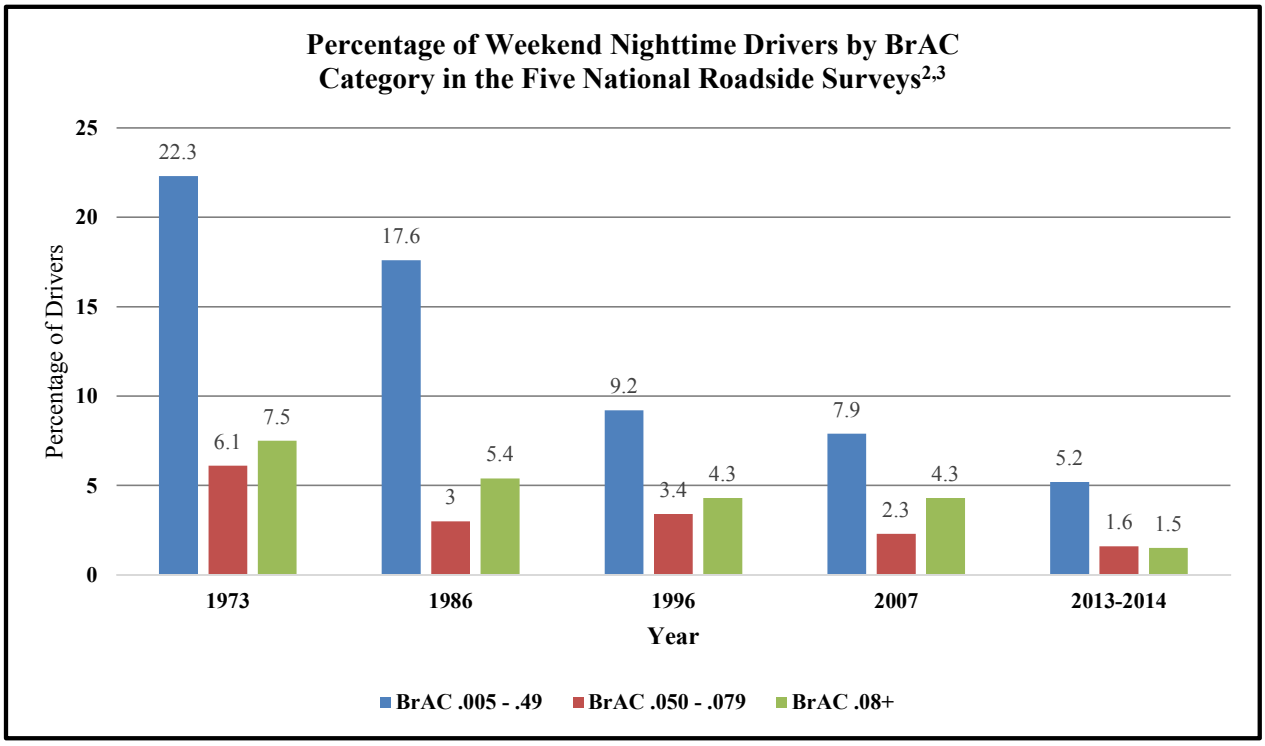
THC was by far the most prevalent drug detected in this representative sample of drivers. As shown in Table 6, 8.6 percent of the drivers tested positive for THC in 2007 and 12.6 percent tested positive for THC in 2013-2014. This represents a large 48 percent increase in the prevalence of drivers testing

positive for THC in just seven years. On the other hand, the percentage of drivers testing positive for alcohol declined from 12.4 percent in 2007 to 8.3 percent in 2013-2014, an approximately 33 percent decrease (Berning, Compton, & Wochinger, 2015).

This is the only reliable source of data on actual THC use by drivers (see Appendix 1 for a brief description of how this survey is conducted). NHTSA is not currently planning to update this information, as Congress has prohibited NHTSA from expending funds on this type of research (see the prohibition on using FY 2016 funds for this purpose per PL 114-113, Division L, Title 1, Section 142, dated 12-18-2015). Therefore, NHTSA, States, and law enforcement agencies will have to rely on increasingly outdated data to develop and evaluate measures to reduce drug-impaired driving. It is unlikely any other entity will have the capability and funding to undertake something of this complexity and magnitude.

In addition to these national roadside surveys, there have been two Statewide representative surveys of alcohol and drug use by drivers; one conducted in California in 2012 and the other designed to examine the effects of the legalization of recreational use of marijuana, specifically retail sales, in Washington in 2014 and 2015.

Figure 6



[2] .08 g/210 L = grams per 210 liters of breath. The illegal limit in all States is .08.
[3] From 1973 to 2004, the States had BrAC limits that ranged from .08 to .15.
After 2004, all States had BrAC limits of .08.

Table 6
Weekend Nighttime Prevalence of Alcohol and THC
in 2007 Compared to 2013-2014

Substance	2007	2013 - 2014
Alcohol	12.4%	8.3%
THC	8.6%	12.6%

The California Statewide Roadside Survey was the first such survey conducted in one State. It examined the prevalence of alcohol, marijuana and other drug use by drivers (Lacey J, et al., 2012). The survey was modeled on data collection procedures used in the 2007 National Roadside Survey of Alcohol and Drug Use by Drivers, sponsored by NHTSA. The results showed that marijuana (THC) was the most frequently encountered drug with a prevalence rate of 7.4 percent of weekend nighttime drivers in California.

The study in Washington State was conducted jointly by the Washington Traffic Safety Commission and NHTSA. It followed the passage in 2012 of a citizen initiative to legalize personal recreational use of marijuana and was designed to assess whether the percentage of drivers who tested positive for THC increased after retail sales of marijuana became legal in July 2014.

Data was collected in three stages: 1) immediately before implementation of legal sales, 2) six months after implementation, and 3) one year after implementation. The results of the study showed an increase in THC positive drivers across the three waves: 14.6 percent, 19.4 percent, and 21.4 percent. These increases were not statistically significant. There was a statistically significant increase in daytime prevalence of THC-positive drivers between Wave 1 (7.8%) and Wave 3 (18.9%). While there was also an increase in drivers positive for THC at night across each successive wave (17.5%, 19.8%, and 22.2%), these were not statistically significant.

Estimating Crash Risk of Marijuana-Impaired Drivers

While the extent of use of alcohol by drivers and the risks posed by alcohol use have been well known for many decades, relatively little has been known about the use of other drugs by drivers and the associated risks. It is known that marijuana is the most frequently detected drug (other than alcohol) in crash-involved drivers as well as the general driving population (Terhune, 1982; Terhune et al., 1992; Lacey et al., 2009; Walsh et al., 2005; Berning, Compton & Wochinger, 2015), and drug-impaired driving is an issue of increasing public and governmental concern in the United States and in many other countries (Compton et al., 2009; Asbridge et al., 2012; ICADTS, 2007). While it is readily apparent that driving-related skills can be impaired by a wide variety of illegal substances and medications, the nature and scope of the drug-impaired driving problem has been difficult to define (Jones et al., 2003; DuPont et al., 2012; Houwing, 2013).

As previously discussed there is evidence that marijuana use impairs psychomotor skills, divided attention, lane tracking, and cognitive functions (Ramaekers, 2000; Robbe & O'Hanlon, 1993; Moskowitz, 1995; Hartman & Huestis, 2013). However, its role in contributing to the occurrence of

crashes remains less clear. Many studies, using a variety of methods, have attempted to estimate the risk of driving after use of marijuana (Li et al., 2012; Asbridge et al., 2012). The methods have included experimental studies, observational studies, and epidemiological studies. While useful in identifying how marijuana affects the performance of driving tasks, experimental and observational studies do not lend themselves to predicting real world crash risk.

Epidemiological Studies

Epidemiological studies differ in how they estimate risk. Culpability studies compare the rate at which crash involved, drug-positive drivers and drug-negative drivers are deemed to be at fault for their crashes. Case-control studies compare drug use by crash-involved drivers to drug use by non-crash involved drivers. In general, the case-control method is preferable since it can eliminate more sources of potential bias in estimating crash risk resulting from drug use (e.g., alcohol use is much higher at night and on weekends than during the day or on weekdays). The existing epidemiological research (both culpability and case-control studies) have produced contradictory estimates of risk for marijuana use. Some of these studies have suggested that marijuana use has minimal or no effect on the likelihood of crash involvement, while others have estimated a small increase in the risk of crash involvement.

Two recent population-based case control studies have estimated the crash risk of drug use by drivers by using NHTSA's Fatality Analysis Reporting System (FARS) 2007 data for the crash-involved driver population and the 2007 National Roadside Survey of Alcohol and Drug Use by Drivers for the control drivers (Li, Brady, & Chen, 2013; Romano, Torres-Saavedra, Voas, & Lacey, 2014). The Li study estimated the increased risk of crash involvement for drivers using marijuana at 1.83 times that of drug-free drivers, while the Romano study found no increased risk of crash involvement for those drivers testing positive for THC. However, current limitations in the FARS dataset do not allow calculation of unbiased, reliable and valid estimates of the risk of crash involvement that results from drug use (Berning & Smither, 2014).

Challenges in Estimating Crash Risk from Drug Use

Conducting case-control studies to estimate the risk of crash involvement from drug use presents many difficulties. The first challenge is obtaining reliable and accurate estimates of drug use. Many studies rely on self-reporting (which have obvious inherent problems) rather than actual measurement of THC in blood or oral fluid. Also, the extent of care regarding the matching of crash-involved and control drivers varies to a large extent among studies. The more carefully controlled studies, that actually measured marijuana (THC) use by drivers rather than relying on self-reporting, and that had a high degree of control of covariates that could bias the results, generally show low risk estimates or in a few cases no risk associated with marijuana use (Elvik, 2013).

Recent Meta-Analyses

A recent meta-analysis by Li (2012) used nine studies, five of which were based on self-report; of the remaining four studies, marijuana use was inferred from a urine test in three of the studies (which indicates the drivers were marijuana users but not necessarily had used marijuana prior to driving). The studies that used self-reporting produced increased crash risk estimates that ranged from 1.7 to 7.16 times as a result of marijuana use by drivers. The two studies that used urine to determine marijuana use resulted in risk estimates of 0.85 to 3.43 times, while the two studies using blood analysis had risk estimates of 2.10 and 2.11 times. The overall pooled risk estimate was 2.66 times.

Similarly, a meta-analysis by Asbridge (2012) also used nine studies, but six were culpability studies with only three using a case-control approach. One of the culpability studies used only FARS data (with associated limitations). Of the three using case-control methods, two used self-report by the control drivers and one used non-drug positive crash-involved drivers (meaning the controls were drug-free, crash-involved drivers). The risk estimates resulting from marijuana use ranged from 0.82 to 7.16 (two studies showing marijuana use reduced the risk of crash involvement while seven studies showed an increased risk). The pooled odds ratio for all nine studies was 1.92.

Recently, a large-scale population-based case control study (in which an attempt was made to have the crash and non-crash control drivers represent all crash-involved drivers and all non-crash involved drivers in the same jurisdiction) was conducted by the European Union to estimate the crash risk of drug use by drivers. A population-based study can benefit from a large sample of drivers covering a wide geographic area, which may improve the generalizability of findings. However, the scale of such studies typically limits the control of subject selection. In a population-based case control study, the case and control drivers are selected from different sources. For example, the crash-involved drivers might be injured drivers taken to a hospital after a crash, while the control drivers might be selected from general traffic. This method lacks the careful matching (day of week, time of day, location, direction of travel, etc.) used in smaller-scale studies, so it involves some compromise of control for the benefit of a much larger sample size.

DRUID Study

The recent population-based study known as Driving Under the Influence of Drugs, Alcohol and Medicines (DRUID), is the largest study of this type (Hels et al., 2010). This study, conducted in nine European Union (EU) countries: Belgium, Denmark, Finland, Italy, Lithuania, and the Netherlands used seriously injured crash-involved drivers while Norway, Portugal, and Sweden used fatally injured drivers. The crash-involved fatally injured driver sample came from a group of drivers for whom a drug test had been conducted, over a period of two to three years. Seriously injured drivers came from a sample of drivers taken to a hospital. Controls came from a roadside survey conducted in each of the respective countries, around the same general time period (e.g., over a year) in each country and represented a sample of drivers, in some cases, from the same general area from which the fatally and seriously injured drivers' crashes occurred. However, in only two of the countries did the controls come from the exact same area of the country as the crash-involved drivers. The specific locations of the crashes were not matched to the sites used to obtain the non-crash involved control drivers. Also, drug presence was determined from blood samples for all the crash-involved drivers, but eight of the countries used oral fluid to determine drug presence in the non-crash involved drivers (four countries also used blood for some control drivers).

Odds ratios were used to estimate the risk of crash involvement after marijuana use in the fatally and seriously injured drivers. The results for the seriously injured drivers showed considerable national variability, ranging from 0.29 times (reduced crash involvement) to 25.38 times (increased crash involvement). The combined risk was 1.39 times that of drug-free drivers, but this was not statistically significant. For fatally injured drivers the estimated risk ranged from 3.91 to 28.88, while the combined risk was 1.33 times (also not statistically significant).

In a pooled analysis of the DRUID data, the highest risk of crash involvement was for drivers with high alcohol concentrations (above .12 BAC)—they had a crash risk 20–200 times that of sober drivers. Drivers with BACs between .08 and .12 were estimated to be 5–30 times more likely to crash than sober

drivers. Drivers positive for THC were estimated to be at elevated risk (1–3 times that of drivers not positive for THC), similar to drivers with BAC levels between .01 to < 0.05. The DRUID report noted that some of the risk estimates were based on few positive cases and/or controls which resulted in wide confidence intervals.

In order to further understand the risk of drug use by drivers, NHTSA, with funding support from the National Institute on Alcohol Abuse and Alcoholism (NIAAA), contracted with the Pacific Institute for Research and Evaluation (PIRE) to conduct the largest and most comprehensive study to address alcohol and drug crash risk in the United States through a case-control study, that employed a rigorous design involving a precise matching of cases and controls.

This case control study collected information from crash-involved and non-crash involved drivers for 20 months (2010 – 2012) in Virginia Beach, Virginia.

NHTSA's "Crash Risk" Study

This case control crash risk study is the first large-scale study in the United States to include drugs other than alcohol. It was designed to estimate the risk associated with alcohol- and drug-positive driving. Virginia Beach, Virginia, was selected for this study because of the outstanding cooperation of the Virginia Beach Police Department and other local agencies with our stringent research protocol. Another reason for selection was that Virginia Beach is large enough to provide a sufficient number of crashes for meaningful analysis. Data was collected from more than 3,000 crash-involved drivers and 6,000 control drivers (not involved in crashes). Breath alcohol measurements were obtained from a total of 10,221 drivers, oral fluid samples from 9,285 drivers, and blood samples from 1,764 drivers.

Research teams responded to crashes 24 hours a day, 7 days a week over a 20-month period. In order to maximize comparability, efforts were made to match control drivers to each crash-involved driver. One week after a driver involved in a crash provided data for the study, control drivers were selected at the same location, day of week, time of day, and direction of travel as the original crash. This allowed a comparison to be made between use of alcohol and other drugs by drivers involved in a crash with drivers not in a crash, resulting in an estimation of the relative risk of crash involvement associated with alcohol or drug use. In this study, the term marijuana is used to refer to drivers who tested positive for delta-9-tetrahydrocannabinal (THC). Drivers who tested positive for inactive cannabinoids were not considered positive for marijuana.

The drug most frequently detected in the oral fluid and blood of drivers was THC, detected in 7.6 percent (n = 234) of the crash-involved drivers and 6.1 percent (n = 379) of the control drivers. To estimate the risk of crashing associated with drug use, logistic regression was used to obtain odds ratios (that are close to relative risk estimates). Odds ratios estimate the probability of an event (i.e., crash) over the probability that such an event does not occur. If a variable (i.e., drug use) is not associated with a crash, the odds ratio of crash involvement associated with that variable will be 1.00. Odds ratios above 1.00 indicate a positive relationship, with stronger relationships reflected by higher odds ratios.

The unadjusted odds ratio for THC was 1.25, representing a significantly elevated risk of crashing by about 1.25 times or 25 percent. These unadjusted odds ratios must be interpreted with caution as they do not account for other factors that may contribute to increased crash risk. Other factors, such as demographic variables, have been shown to have a significant effect on crash risk. For example, male drivers have a higher crash rate than female drivers. Likewise, young drivers have a higher crash rate

than older drivers. To the extent that these demographic variables are correlated with specific types of drug use, they may account for some of the increased crash risk associated with drug use.

When the odds ratios were adjusted for demographic variable of age, gender, and race/ethnicity the significant increased risk of crash involvement associated with THC disappeared. The adjusted odds ratio for THC positive drivers was 1.05 (95% Confidence Limit of 0.86 – 1.27). This adjusted odds ratio was not statistically significant.

A final adjustment was made for the presence of alcohol. When both demographic variables and the presence of alcohol were taken into account, the odds ratio for THC declined further to 1.00 (95% Confidence Limit of 0.83 – 1.22). This means there was no increased risk of crash involvement found over alcohol or drug free drivers.

As was described above, there was no difference in crash risk for marijuana-positive drivers who were also positive for alcohol than for marijuana-positive drivers with no alcohol, beyond the risk attributable to alcohol. Further analyses examined the potential interaction between drug use and breath alcohol concentration. No statistically significant interaction effect on crash risk was found between for THC positive drivers and BrAC level.

More information on the methodology of this study is available in a Research Note (Compton and Berning, 2015 which can be downloaded at: http://www.nhtsa.gov/staticfiles/nti/pdf/812117-Drug_and_Alcohol_Crash_Risk.pdf

Recommendations

Increase the Use of Effective and Efficient Methods for Training Law Enforcement Personnel, Including Drug Recognition Experts, to Detect or Measure the Level of Impairment of a Motor Vehicle Operator who is Under the Influence of Marijuana by the Use of Technology or Otherwise.

Currently, training for law enforcement officers to detect and recognize marijuana impairment in drivers is available in three increasingly detailed levels. Officers at the highest level of training are capable of making determinations about which drug category (or categories) may be contributing to a driver's inability to operate a vehicle. Depending on the individual State and local requirements, not all officers may receive training in DUID prior to completing their basic training requirements or afterwards.

To improve consistency in training, NHTSA developed an 8-hour course, Drugs That Impair Driving, which can be used in conjunction with the Standardized Field Sobriety Test (SFST) training. NHTSA considers SFST training the foundation for all impaired driving detection training. The Drugs That Impair Driving course was developed to provide a general description of drugs, signs that may indicate drug use and medicinal conditions that show signs similar to drug use. The course was also developed to acquaint officers with the most common types of drugs that impair driving.

A second level course, the 16-hour Advanced Roadside Impaired Driving Enforcement Program (ARIDE), is designed to give officers the ability to apply information they have learned about DUID to make effective arrests based on probable cause that provides the necessary evidence for prosecution. In order to accomplish this goal, the program seeks to increase the officer's overall knowledge of the general manifestations of alcohol and drug impairment and to increase their ability to recognize these

indicators in the drivers they encounter during their enforcement duties. If these drivers are suspected to be impaired, then officers will be better informed in the arrest decision.

In order to expand the number of law enforcement officers who might take this training, NHTSA, along with the IACP, offers an online version of this training program that is available to law enforcement agencies.

The highest level of training comes in the form of the Drug Evaluation and Classification (DEC) program (NHTSA, 2007). In the early 1980s NHTSA started to take the DEC program, based on the Los Angeles Police Department's Drug Recognition Expert (DRE) program, nationwide. The DEC program trains officers to identify the signs and symptoms of drug use that could be used to determine whether a suspected impaired driver was impaired by drugs and to rule out other possible causes such as neurological deficits, diseases, and illness. The procedure was designed to aid the officer in determining what specific type of drug was the likely cause of the observed impairment. The program was intended to help develop evidence of impairment and guide the analyses of biological specimens when looking for the presence of drugs other than alcohol in impaired drivers. The DEC training requires 9 days in the classroom and additional days of field certification testing. The program is designed to provide a limited number of DREs in a jurisdiction. It is not designed for the routine patrol officer.

As was mentioned previously, the DEC program has expanded to all fifty States and the District of Columbia. There are currently over 8,000 certified DREs in the program. The ARIDE training is not designed to provide the same level of expertise as that demonstrated by DREs. An ARIDE trained officer who encounters a suspected marijuana-impaired driver, would likely summon a DRE to conduct the DEC program evaluation, if one is available.

In summary, training is currently available to law enforcement personnel in a tiered approach, ranging from basic information about the different types of drugs that can impair driving, signs and symptoms that may indicate drug use (including impaired driving cues), to a more detailed training program that equips officers to better recognize when a driver is likely to be impaired by alcohol, marijuana and other drugs and collect the necessary information to support an arrest and prosecution. Finally, there is the DEC program that provides officers with much more detailed information about different classes of drugs that can impair driving, trains them to use standardized examination and test procedures to build a convincing case of drug-impaired driving.

Impaired driving training is resource-intensive in terms of cost and time away from normal duties. Law enforcement agencies typically operate with limited funding and staff and face competing demands. Most patrol officers will not often encounter a marijuana-impaired driver, so the current tiered approach is a reasonable way of efficiently dealing with drug-impaired driving.

Continue Research to Enable Development of an Impairment Standard for Driving Under the Influence of Marijuana, and in the Meantime, Maintain Training and Other Support to Enable Law Enforcement Officers and Prosecutors to Pursue Cases Using Available Evidence.

As the previous sections of this report have indicated, the poor correlation of THC level in the blood or oral fluid with impairment precludes using THC blood or oral fluid levels as an indicator of driver impairment. The use of BAC or BrAC as an indicator of driving impairment has assisted law enforcement and prosecutors in being able to show that an alcohol-impaired driver has a BAC that has been demonstrated to increase crash risk. The use of THC level cannot serve this same role for marijuana-impaired driving (Dupont, Voas, Walsh, Shea, Talpins, & Neil, 2012).

Toxicologists are not able to provide expert testimony that a specific amount of THC present in a suspect's blood (or other specimen) is definitively associated with being impaired by marijuana and render the driver unable to drive safely.

It should be noted that the DEA has recently provided revised guidance in August of 2016, to researchers, that should make it easier to obtain and conduct studies using marijuana (21 CFR Part 1301 Docket Number DEA 447 Dated July 15,2016). This should spur more research that may help to address some of the issues that are currently unresolved about marijuana and driving.

Expert witness testimony by toxicologists that a BAC or BrAC level found in a suspect's blood or breath that was over the legal limit, indicates the suspect was too impaired to drive safely is fairly routine testimony in alcohol-impaired driving trials. However, the absence of BAC or BrAC evidence in an alcohol-impaired driving case is not a bar to successful prosecution. Drivers frequently refuse to take a BAC or BrAC test.

A 2012 NHTSA study of BAC test refusals estimated that approximately 21 percent of all suspected alcohol-impaired drivers requested to take a BAC or BrAC test refuse. That study did not find a consistent difference in conviction rates between drivers who took a BAC test and drivers who refused the test. Interestingly, those drivers who refused to take the requested BAC test received substantially higher penalties upon conviction (Jones & Nichols, 2012).

A properly trained officer who follows good investigatory techniques and carefully documents their observations can make a convincing case that a driver was too impaired by alcohol to drive safely. The same is true for suspected marijuana-impaired drivers. The lack of an "impairment standard" equivalent to BAC level does not prevent the successful prosecution of a marijuana-impaired driver. The lack of toxicological evidence simply means that the officer has to offer other evidence that the driver was under the influence of marijuana and too impaired to drive safely.

Whether there is some other more formal and standardized way to determine that a marijuana-impaired driver is too impaired to drive safely (a test that correlates with increased crash risk) remains to be determined. NHTSA has research underway that attempts to develop a relatively simple field test for law enforcement use that would indicate that a suspect is impaired by marijuana. This type of test would not indicate driving impairment (law enforcement observations would be required for that evidence), but would be a useful tool for law enforcement, nonetheless.

A number of States have set a THC limit in their laws indicating that if a suspect's THC concentration is above that level (typically 5 ng/ml of blood), then the suspect is to be considered impaired. This per se limit appears to have been based on something other than scientific evidence. Some recent studies demonstrate that such per se limits are not evidence-based.

A recent study looked at the THC levels in DUID cases in Washington State between August 2009 and June 2013 where blood samples were sent to the State toxicology laboratory for testing. All of these cases involved suspects believed to be impaired by marijuana by the arresting officer or DRE. All of the samples were screened positive by a cannabinoid ELISA immunoassay test. The blood was then analyzed for THC (cut off 1 ng/ml) using three dimensional gas chromatography mass spectrometry. A total of 3,814 cases tested positive for THC above 1 ng/ml.

These cases were then evaluated as to whether the THC concentrations exceeded certain thresholds, specifically, the 2 ng/ml per se threshold applied in Ohio and Nevada and the 5 ng/ml threshold applied in Colorado and Washington State. The results showed that a sizeable proportion (24.2%) of all drivers (who were suspected of marijuana-impaired driving), had blood THC concentrations below the per se

threshold in Ohio and Nevada, while an even larger proportion (62.8%) had concentrations below the per se threshold in Washington and Colorado.

The adoption of a 5 ng/ml per se law for THC would appear to result in the exclusion of a large number of drivers who law enforcement officers believe to be impaired by marijuana but whose blood THC concentrations will fall below this artificial per se threshold during the minimum 1 - 2 or more hours it will take to collect a blood sample following a stop, investigation and arrest. This will place a large burden of the officer to make the case through objective evidence of impairment along with signs and symptoms associated with marijuana use. The blood THC concentrations will often impede, rather than assist, in making the case to a judge or jury who has to determine whether a suspect is impaired (under the influence) as a result of their marijuana use (Logan, 2015).

Another recent study conducted using Washington State data was designed to examine whether the concentration of THC in a drivers blood was a reliable indicator of impairment. This study used 602 drivers arrested for impaired driving in which only THC was detected, with a sample of 349 drug-free control drivers, for which the subject's performance in the DRE exam were available. Results showed significant differences in the THC positive and negative drivers in terms of poorer performance on the psychophysical tests (walk-and-turn test, one-leg-stand test, and finger-to-nose test) along with indicators like red bloodshot and watery eyes, eyelid tremor, lack of convergence and rebound dilation. Having found differences between THC positive and THC negative drivers, the relationship between blood THC concentration and performance on tests for impairment was examined. Poor correlation between THC concentration and performance was found, which again indicates that blood THC level is not a reliable indicator of impairment.

Finally, an assessment of whether the combination of the physiological, cognitive and psychomotor indicators could reliably predict whether the driver's THC concentration was above or below 5 ng/ml threshold was conducted. No differences were found except for the finger-to-nose test. Some individual signs, symptoms, and tests had weak correlations with the THC concentration being above or below the threshold, but none of them met basic sensitivity levels for correctly predicting impairment status. The conclusion of the study was that "there is no evidence from the data collected, particularly from the subjects assessed through the DRE exam, that any objective threshold exists that establish impairment base on THC concentrations in suspects placed under arrest for impaired driving" (Logan, Kacninko, & Beirness, 2016).

A third study that also made use of Washington State data involved drivers in crashes and/or arrested for suspected driving under the influence, who were investigated by the Washington State Patrol in which blood samples were tested for the presence of alcohol and other drugs (including marijuana) during the time period 2005 – 2014. An interesting facet of this study was an estimate of time between the crash or arrest and when the blood draw occurred. Time to the blood draw was not always possible to calculate due to inadequacies in the records. The median time to draw blood was 165 minutes (almost three hours). The median estimated time to draw blood for THC-positive drivers was 139 minutes. Drivers negative for THC (but positive for a THC metabolite carboxy-THC) was 175 minutes. This study found a clear relationship between the time that is required to do a blood draw and THC concentration, where the longer time to the blood draw the lower the THC concentration (Banta-Green, Rowhani-Rahbar, Ebel, Andris, and Qiu, 2016).

Methods for Increasing Data Collection Regarding the Prevalence and Effects of Marijuana-Impaired Driving

Encourage States to Collect Data Regarding the Prevalence of Marijuana Use by Drivers and Among Those Arrested for Impaired Driving

There is a need to improve data collection regarding the prevalence and effects of marijuana-impaired driving. NHTSA has collected some data on the prevalence of marijuana use by drivers on a national basis, though NHTSA has been prohibited from continuing to collect this information.[1] In contrast, there is little State level data about the prevalence of use of marijuana by drivers being collected. As States continue to change their laws regarding marijuana use in general and as it relates to driving, this lack of State level data prevents evaluation of the effect of policy changes on driver behavior, including willingness to drive while under the influence of marijuana, as well as the effect of marijuana on crashes, deaths and injuries.

While assessing the number of people driving impaired by marijuana is not currently feasible, a first step is to measure the number of drivers positive for THC on our nation's roads or on a State's roads. As the number of THC positive driver's increases, it is likely that the number of marijuana-impaired drivers will also increase. Measuring the prevalence of THC positive drivers is currently feasible as shown by NHTSA's two most recent national roadside surveys of alcohol and drug prevalence conducted in 2007 and 2013-2014, and the two State surveys of the prevalence of alcohol and drug positive drivers.

Reliable trend data on the prevalence of marijuana positive drivers at the State level would allow for the evaluation of effects of marijuana laws such as:

- Therapeutic marijuana use laws
- *Per Se* limits for marijuana (THC)
- Decriminalization of personal use of marijuana
- Legalization of personal recreational use of marijuana

For example, State surveys could assess the effect of legalized recreational marijuana use on the number or percentage of people driving after using marijuana. However, such studies require both pre- and post-legalization data. Similarly, without consistent THC testing of impaired driving arrestees over time, reports that compare THC positive rates before and after a policy has gone into effect are very difficult to interpret, as they may simply reflect increased testing rates.

We recommend that States be encouraged to conduct prevalence studies of the number and proportion of drivers testing positive for THC. Due to the current Congressional prohibition[1] on NHTSA conducting national studies of alcohol and drug use by drivers, national data will not be available.

States that do not distinguish between drug-impaired and alcohol-impaired driving in arrest or disposition data significantly limit their ability to assess the extent of drug-impaired driving and evaluate the impact of countermeasures. Similarly, the lack of standardized and complete State record systems limits NHTSA's ability to make clear inferences about the scope of the national drug-impaired-driving problem.

[1] – PL 114-113, Division L, Title I, Sec. 142 (12/18/2015) prohibits NHTSA from using FY 2016 funds to conduct national roadside studies of alcohol and drug use by drivers.

Establishing and maintaining Statewide arrest data would allow States and others to evaluate the effectiveness of law enforcement programs on impaired driving, such as the impact of the DEC program on DUID arrest rates and convictions. Similarly, accurate and complete data about arrests and convictions for drug-impaired driving would allow documentation of the effects of drug per se statutes on arrest and convictions.

NHTSA recommends the following data and record system improvements:

- States should develop record systems that distinguish among alcohol, drugs, or both for impaired driving cases. These records should be integrated into computerized data systems of statewide arrest records, the court record systems, and motor vehicle records. One way to accomplish this would be to have separate offenses for driving impaired by alcohol and driving impaired by drugs.

- State records systems should document which drugs are used by drug-impaired drivers. This information would be helpful for law enforcement, toxicologists, and prosecutors.

- Standard toxicological screening and confirmation procedures should be developed for drug testing laboratories to use in identifying and confirming the presence of drugs that impair driving. These methods should include standard analytic procedures and minimum detection thresholds. There also should be training requirements for the personnel operating these tests.

In addition to these data and record system needs, NHTSA recommends the following change in State statutes:

- State statutes should be amended to provide separate and distinct offenses and sanctions for alcohol- and drug-impaired driving that could be applied individually or in combination to a single case. This would provide an incentive for law enforcement officers to pursue a possible drug-impaired driving charge even when a BAC equal to or above the limit of .08 g/dL has already been established.

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Appendix 1

Brief Description of the National Roadsides Survey Procedure

The National Roadside Survey is a nationally representative survey of driver alcohol and drug use. It uses a multi-stage sampling procedure to select survey locations in 60 Primary Sampling Units (PSU) across the continental U.S. At each PSU, five actual survey locations were selected at random based on roadway type and safety considerations.

The survey is conducted off of the roadway in an adjacent parking area.

As a driver approaches a survey site they will pass several large orange construction style signs that say "*Paid Volunteer Survey"* and one illuminated variable message board sign also saying they are approaching a paid volunteer survey site. As the drivers reached the survey site, there was another large orange sign saying "*Paid Volunteer Survey"* at the entrance to the survey site. In the survey site facing approaching traffic is a large banner that says *"National Roadside Survey"* (approximately three feet by five feet). Typically there are flares placed in the roadway as the motorist approached the survey site. For safety purposes, where there were multiple lanes of traffic approaching the survey site, traffic may have been diverted to a single curbside lane through use of large orange traffic cones.

The typical survey site accommodated approximately eight cars at a time. When the survey parking places were occupied, no additional vehicles were allowed into the survey site (approaching vehicles were waved on to continue down the street). When a survey team member was available, the next eligible car was allowed into the survey site (waved in at the curb cut entrance to the parking area). This was done so that someone was immediately available to speak to the driver of a car that pulled into the survey site. Drivers of trucks or commercial vehicles were not eligible to participate.

As soon as a driver pulled into the survey site a survey team member approached their vehicle, greeted them and briefly explained what the survey was all about. They were asked if they wished to participate, if they agreed they were directed into one of the parking places. If they were not interested in participating they were thanked for stopping by and directed out of the survey site back onto the street.

At each survey site there were two law enforcement officers, in uniform, with marked police vehicles. The officers and vehicles were not allowed in the survey site but were located adjacent to the survey site where they were clearly visible. Depending on the local law enforcement agency practices and procedures, the police vehicle might have had their emergency lights flashing. Some law enforcement agencies insisted that their officers (rather than a survey team member) direct traffic at the entrance to the survey site (either waving an eligible vehicle into the site or waving approaching vehicles to not stop or attempt to enter the survey site when all of the survey team members were busy). The officers were present for the safety of the survey team and participants.

After hearing a description of the study purpose and procedure, the driver had to provide verbal consent in order to participate. During the survey the drivers were asked a number of questions, to provide a breath sample, oral fluid sample and blood sample. At each stage they had to verbally acknowledge they understood what had been told to them and consented to continue. The driver was free to decline any part of the survey while completing the rest of the survey.

During the 2013-2014 National Roadside Survey a small number of drivers generated some sensational and inaccurate publicity about the survey. Unfortunately, these individuals garnered fairly extensive publicity. No attempt to discern the accuracy of these reports were made before they were recirculated through social media and as "news reports." In a subsequent study using essentially the same procedures, extensive publicity was generated in advance of the study in order to prevent misinformation being spread. State and local press were invited to attend a "mock" survey site and go through the study protocol themselves. During and after this subsequent roadside survey there were no complaints or inaccurate stories spread by the media.

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