

# REPORT FROM THE IMPAIRED DRIVING SAFETY COMMISSION

MARCH 2019



# INTRODUCTION

## IMPAIRED DRIVING SAFETY COMMISSION ACT:

Public Act 350 of 2016 (effective: 3-21-2017) created the Impaired Driving Safety Commission Act. The Commission was created within the Michigan State Police (MSP) pursuant to the Act and is required to research and recommend a scientifically supported threshold of  $\Delta^9$ -THC bodily content to provide evidence for per se impaired driving in the state of Michigan.

This report includes the results of the Commission's research, recommendations for the appropriate threshold of  $\Delta^9$ -THC bodily content to provide evidence for per se impaired driving, and recommendations for future legislative actions.

Appointed by Governor Rick Snyder, the Commission consisted of six members:

The Director of the Michigan State Police:

**Col. Kriste Kibbey Etue**

The MSP Director's designated representative:

**Lt. Col. Richard Arnold**

A qualified and registered patient under the Michigan Medical Marihuana Act:

**Ms. Margeaux Bruner**

A forensic toxicologist:

**Mr. Nicholas J. Fillingner**

A professor from a public research university in this state:

**Dr. Carol Ann Cook Flannagan**, whose expertise is in traffic safety

A professor from a public research university in this state:

**Dr. Norbert E. Kaminski**, professor of pharmacology and toxicology, whose expertise is in the area of cannabis pharmacology and toxicology

A physician licensed under the Public Health Code:

**Dr. William Ray Morrone**

(Legislature Service Bureau, 2017).

# STATUS OF MEDICAL AND RECREATIONAL MARIHUANA LAWS AND DRIVING PER SE LIMITS

## IN MICHIGAN:

Pursuant to MCL 257.625(1), Michigan law prohibits a driver from operating a motor vehicle while intoxicated. To be found guilty under this statute, prosecutors must show that the defendant was “under the influence” at the time he or she operated the motor vehicle. There are three ways a person can be “under the influence” per Michigan law. These three categories are alcoholic liquor, a controlled substance, or an intoxicating substance (or any combination of these three categories). Marihuana falls under MCL 257.625(1) because it is a controlled substance. In addition to the above, Michigan also has what is commonly referred to as the zero-tolerance drugged driving law. Pursuant to MCL 257.625(8), a driver shall not operate a motor vehicle if he or she has any amount of a Schedule 1 controlled substance in his or her body. Marihuana falls under this law because it is listed as a Schedule 1 controlled substance by both the Drug Enforcement Administration and the Michigan Public Health Code.

In 2008, Michigan voters passed the Michigan Medical Marihuana Act (MMMA). Under MCL 333.26427, the MMMA prohibits qualifying patients from operating, navigating, or being in actual physical control of any motor vehicle, aircraft, or motorboat while “under the influence” of marihuana. However, qualifying patients are protected when they engage in the medical use of marihuana, which includes “the acquisition, possession, cultivation, manufacture, use, internal possession, delivery, transfer, or transportation of marihuana or paraphernalia relating to the administration of marihuana to treat or alleviate a registered qualifying patient’s debilitating medical condition or symptoms associated with the debilitating medical condition.” MCL 333.26423(f).

In the 2013 Michigan Supreme Court case of *People v. Koon*, 494 Mich 1; 832 N.W.2d 724, the Court carved out an exception to Michigan’s zero-tolerance drugged driving law for qualifying patients. The Court held that it is not enough for a prosecutor to show that a patient has  $\Delta^9$ -THC in his or her system. In other words, the zero-tolerance drugged driving law does not apply to qualifying patients who comply with the MMMA. Rather, the standard for a patient is “under the influence,” as established under the MMMA, which generally means that the marihuana must have had a significant effect on a person’s mental or physical condition so that he or she was no longer able to operate a vehicle in a normal manner.

Another important Michigan Supreme Court decision deals with how the metabolite of marihuana is dealt with under the zero-tolerance drugged driving law. In 2010, the Court held in *People v. Feezel*, 486 Mich 184; 783 N.W.2d 67, that the presence of a marihuana metabolite, also known as 11-carboxy-THC, is not a Schedule 1 drug, and therefore a person cannot be prosecuted under MCL 257.625(8) if he or she has only the metabolite in his or her blood.

On November 6, 2018, Michigan voters chose to legalize recreational marihuana. The law went into effect on December 6, 2018, and is officially known as the Michigan Regulation and Taxation of Marihuana Act (MRTMA). Similar to the MMMA, the MRTMA also prohibits a person from operating, navigating, or being in physical control of any motor vehicle while “under the influence” of marihuana. While the Michigan Supreme Court’s opinion in *Koon* only provided an exception

# STATUS OF MEDICAL AND RECREATIONAL MARIHUANA LAWS AND DRIVING PER SE LIMITS

to the zero-tolerance drugged driving law for qualifying patients in compliance with the MMMA, due to the adoption of the same “under the influence” standard under the MRTMA, the exception to the zero-tolerance drugged driving law may now also apply to persons consuming marihuana under the MRTMA.

## IN THE UNITED STATES:

As of the date of this report, both recreational and medical marihuana have been legalized in 33 states and Washington DC (Procon.org, 2019). Currently six states have set impaired driving per se thresholds of  $\Delta^9$ -THC bodily content in blood (ng/ml) to provide evidence for per se impaired driving (Edmondson, L., 2016):

- Colorado: 5 ng/ml
- Montana: 5 ng/ml
- Nevada: 2 ng/ml
- Ohio: 2 ng/ml
- Pennsylvania: 1 ng/ml
- Washington: 5 ng/ml

Unlike the other states listed, Colorado’s limit of 5 ng/ml is a reasonable inference. A reasonable inference allows a jury to infer that a driver was impaired if his or her blood test result is 5 or more ng/ml  $\Delta^9$ -THC, but that inference can be rebutted by the defendant in legal proceedings with evidence to the contrary.

In Canada, the amount of  $\Delta^9$ -THC in one’s blood determines how the impaired driving offense is charged. An impaired driving charge for a person with  $\Delta^9$ -THC levels of 2-5 ng/ml blood carries a lesser penalty than a charge for  $\Delta^9$ -THC greater than 5 ng/ml blood. Canada also has a hybrid offense for impaired driving with  $\Delta^9$ -THC level of greater than 2.5 ng/ml blood combined with a Blood Alcohol Concentration (BAC) of 0.05 grams/100 ml.

The Commission reviewed and considered the legislation enacted in these jurisdictions as it went about its work.

## COMMISSION MEETINGS:

The Commission met throughout 2018 and into March 2019, to fulfill its charge. Commissioners received presentations from subject matter experts in the following areas: Michigan criminal law; impaired driving prosecution, defense, investigation, and enforcement; substance abuse treatment; traffic safety research, analysis, and programming; pharmacology and toxicology; and forensic toxicology. Presentations and review of relevant research literature informed discussion resulting in completion of this report and the recommendations contained herein.

## PHARMACOKINETICS OF $\Delta^9$ -THC:

The plant, *cannabis sativa*, contains over 100 structurally-related compounds, termed cannabinoids. The primary cannabinoid responsible for the psychotropic effects (e.g., euphoria) produced by cannabis is  $\Delta^9$ -tetrahydrocannabinol ( $\Delta^9$ -THC). The chemical structure of  $\Delta^9$ -THC was first described in 1964 (Gaoni & Mechoulam, 1964).  $\Delta^9$ -THC produces its psychotropic effects, by binding to and activating a specific protein that is highly abundant in the brain, named cannabinoid receptor 1 (Matsuda, Lolait, Brownstein, Young & Bonner, 1990). The majority of cannabinoids present in cannabis do not possess psychotropic properties because they do not bind well to cannabinoid receptor 1 and therefore do not activate this receptor. An example of such a cannabinoid that is widely used for medicinal purposes (e.g., Epidiolex) and that possesses no psychotropic activity is cannabidiol, also known as CBD. Therefore, the psychotropic activity of cannabis or various preparations of  $\Delta^9$ -THC (e.g., oils and edibles) is achieved through delivery via the blood stream of  $\Delta^9$ -THC and its metabolite, 11-hydroxy-THC, to the brain.

The most common route of  $\Delta^9$ -THC administration is through inhalation, either by smoking cannabis or through the vaporization of various preparations containing  $\Delta^9$ -THC. A second common route of  $\Delta^9$ -THC administration is through oral consumption of products containing  $\Delta^9$ -THC or cannabis, termed “marihuana-infused products” or “edibles.”  $\Delta^9$ -THC can also be delivered via the oromucosal route (i.e., direct application to the mucus membrane in the mouth) through the use of cannabis tincture, which is most often an alcohol extract of cannabis. Cannabis tincture can also be used for topical application to the skin.

The pharmacokinetics and time to onset of psychotropic effects by  $\Delta^9$ -THC is highly dependent on the route of administration. This dependency is one of several particular challenges for measurement of  $\Delta^9$ -THC impairment in the context of driving, as will be described in later sections. Below, the basic pharmacokinetics—i.e., the processes of absorption, metabolism, distribution, and excretion—of  $\Delta^9$ -THC are described in the next paragraphs.

### Absorption

Inhalation of smoked cannabis or vaporization of  $\Delta^9$ -THC-containing products results in very rapid delivery of  $\Delta^9$ -THC to the bloodstream. After the first puff of a cannabis cigarette,  $\Delta^9$ -THC is detectable in plasma within seconds due to the lungs being highly vascularized and capable of rapid and efficient gas exchange. The peak plasma concentration of  $\Delta^9$ -THC is achieved within 3-10 minutes upon initiation of smoking cannabis (Grotenhermen, 2003). The amount of  $\Delta^9$ -THC delivered via the respiratory route is not only dependent on the amount of  $\Delta^9$ -THC inhaled but is also dependent on the duration of the puff, depth of inhalation and the duration of the breath hold. In general, the percentage of total  $\Delta^9$ -THC that is absorbed via the respiratory route is similar whether delivered via cannabis cigarette, pipe, or through vaporization.

Administration of  $\Delta^9$ -THC via the oromucosal route by application of tincture also results in rapid absorption of  $\Delta^9$ -THC. With  $\Delta^9$ -THC being dissolved in alcohol and applied to the inside of the mouth, delivery to the blood stream is expected to be rapid but neither as efficient nor as rapid as via inhalation.

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Oral administration of  $\Delta^9$ -THC by eating products that contain  $\Delta^9$ -THC results in slower and more variable absorption of  $\Delta^9$ -THC compared to inhalation. Peak plasma concentrations for oral administrations are typically attained approximately 120 minutes after consumption (Grotenhermen, 2003; Huestis, 2005).

Oral administration generally results in lower  $\Delta^9$ -THC blood concentrations than the same dosage of  $\Delta^9$ -THC delivered by inhalation.

## Distribution

Upon absorption,  $\Delta^9$ -THC rapidly distributes via the circulating blood to organs that are highly vascularized including the brain, kidney, liver, lungs, and heart. In addition, because cannabinoids, including  $\Delta^9$ -THC, are highly fat-soluble compounds they are readily stored in fat tissue and are then slowly released back into circulating blood over time. Due to this property, higher levels of cannabinoid accumulation in fat are observed in chronic cannabis users compared to occasional users.

## Metabolism and Excretion

The metabolism of  $\Delta^9$ -THC has been studied extensively. The primary site of  $\Delta^9$ -THC metabolism is the liver where  $\Delta^9$ -THC is converted to two major metabolites: 11-hydroxy-THC (11-OH-THC) and 11-carboxy-THC (11-COOH-THC) (Leighty, 1973). These metabolites undergo further processing, which make them more water soluble to facilitate excretion by urine and feces. 11-OH-THC possesses psychotropic properties that are the same as  $\Delta^9$ -THC.

Elimination of compounds is often measured in terms of half-life, the amount of time required to eliminate one half of the total amount of a given compound that has been absorbed. Elimination of  $\Delta^9$ -THC occurs in two distinct phases. There is an initial rapid elimination phase with a half-life of approximately 6 minutes followed by a long terminal elimination phase with a half-life of approximately 22 hours (Heuberger, Guan, Oyetayo, Klumpers, Morrison, Beaumer, van Gerven, Cohen & Freijer, 2015). This long terminal elimination phase is primarily due to rapid absorption of  $\Delta^9$ -THC in fat tissue followed by its slow release over time back into circulation (Lucas, Galettis, Song, Solowij, Reuter, Schneider, & Martin, 2018). In chronic users blood-plasma concentrations of  $\Delta^9$ -THC can remain above measurable levels (i.e., 1 ng/ml) for 48-72 hours after administration (Wall, Sadler, Brine, Taylor, & Perez-Reyes, 1983).

## Key Point

Due to the initial rapid elimination phase of  $\Delta^9$ -THC followed by the long terminal elimination phase, blood-plasma concentrations of  $\Delta^9$ -THC are indicative of *exposure*, but are not a reliable indicator of whether an individual is *impaired*.

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## BEHAVIORAL EFFECTS OF $\Delta^9$ -THC:

The behavioral effects of cannabis include euphoria and relaxation, altered time perception, hallucinations, lack of concentration, impaired learning and memory, and mood changes such as panic reactions and paranoia. The intensity varies with dose, administration route, expectation of effects and the user's environment and personality. This spectrum of behavioral effects prevents classification as a stimulant, sedative, tranquilizer, or hallucinogen. The physiological effects of cannabis include heart rate and diastolic blood pressure, conjunctival suffusion, dry mouth and throat, increased appetite, vasodilation, and decreased respiratory rate. Most behavioral and physiological effects of  $\Delta^9$ -THC return to baseline levels within 3-6 hours after exposure (Baselt, 2004; Huestis, 2007; Hartman & Huestis, 2013; Huestis, 2002).

Long-term cannabis use is associated with neuropsychological deficits such as memory impairment and changes in brain morphology (Lorenzetti, Lubman, Shittle, Solowij & Yücel, 2010). Chronic cannabis use may also lead to impairment in driving-related tasks, even after cessation. Chronic daily cannabis smokers abstaining from use performed poorly on critical tracking, which assesses human operator performance when a person perceives a discrepancy between a desired and actual state and aims to reduce the error by compensatory movement. While critical tracking did recover after 3 weeks of abstinence, it was still significantly worse compared to critical tracking in the control group. Similar results were observed in divided attention tasks, such as tracking performance and tracking control (Bosker, Karschner, Lee, Goodwin, Hirvonen, Innis, Theunissen, Kuypers, Huestis, & Ramaekers, 2010). In a somewhat related study, a cohort of heavy chronic cannabis smokers showed no significant differences in critical tracking or divided attention task performance up to six hours after smoking as compared to before smoking (Schwope, Bosker, Ramaekers, Gorelick, & Huestis, 2012).

## THC IMPAIRMENT AND RELATIONSHIP TO TRAFFIC SAFETY:

The relationship between ingesting cannabis and impairment in driving skills has been established in a number of studies, which are summarized in this section. These include laboratory studies of how  $\Delta^9$ -THC, the main active ingredient in cannabis, influences cognitive and motor skills, as well as analyses of crash data linking  $\Delta^9$ -THC detected in blood tests and crash risk and injury outcome.

In laboratory studies, including those using driving simulators and instrumented vehicles,  $\Delta^9$ -THC affects areas of the brain that control movement, balance, coordination, memory, and judgment (Lenné, Dietze, Triggs, Walmsley, Murphy, & Redman, 2010; Hartman, Huestis, 2013; Hartman, Brown, Milavetz, et al, 2015). Cannabis has been shown 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 (Ramaekers, Robbe, & O'Hanlon, 2000; Robbe & O'Hanlon, 1993; Liguori, Gatto & Robinson, 1998; Hartman & Huestis, 2013).

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Interestingly, in most of the simulator and vehicle studies, cannabis-impaired subjects typically drive slower, keep greater following distances, and take fewer risks than when sober (Compton, 2017). These effects appear to suggest that the drivers are attempting to compensate for the subjective effects of using cannabis. This is contrasted with alcohol-impaired subjects, who typically drive faster, follow more closely, and take more risks than when sober. That said, cannabis-impaired drivers attempting to compensate for the effects of cannabis are not likely to fully mitigate the effects of the drug on driving skills. Moreover, at least one study indicated that acute cannabis intoxication can result in *more* risk taking rather than risk compensation.

In spite of the relatively clear evidence of reduced driving-related skills in controlled studies (with known dosages), the relationship between cannabis ingestion and crash risk in the field is less well understood. The Governor's Highway Safety Association (GHSA) report on Drug-Impaired Driving (Hedlund, 2017) reviewed a number of studies, including several meta-analyses, that attempt to summarize the results of a larger number of individual studies.

One such review and meta-analysis by Elvik (2013) concluded that the best estimate of the crash risk increase due to cannabis is 26%, but that this is not statistically significant. Another meta-analysis by Schulze et al. (2012) concluded that ingesting cannabis increases crash risk by a factor of 1 to 3. Finally, another review by the National Academies of Sciences (2017) concluded that "there is substantial evidence of a statistical association between cannabis use and increased risk of motor vehicle crashes" and estimated the increased risk at 22% - 36%.

A carefully controlled epidemiological study by the National Highway Traffic Safety Administration (NHTSA) found the same 25% increase in risk when comparing crash-involved drivers to a control sample of non-crash-involved drivers who were selected from the same location as the crash, a week later (Compton, 2017; Lacey, Kelley-Baker, Berning, Romano, Ramirez, Yao & Compton, 2016). However, when the authors accounted for other risk factors such as age, gender, and the presence of alcohol, the effect disappeared. This suggests that the 25% risk increase might be at least partially due to other risk factors that co-occur with cannabis use. This includes drinking alcohol, which was often found with  $\Delta^9$ -THC in the blood. That said, this study focused on all crashes and most of the crashes were of low severity. In addition, because there is no clear relationship between blood levels of  $\Delta^9$ -THC and impairment, it is not known how impaired the  $\Delta^9$ -THC-positive drivers were in this study.

While there is some uncertainty as to the crash risk associated with cannabis impairment alone, the research is clear that the risk is lower than that of alcohol impairment (Compton & Berning, 2015). However, cannabis users are more likely to also drink alcohol before driving than non-users. Thus, polydrug use (use of 2 or more drugs, including alcohol) is quite prevalent among cannabis-impaired drivers. Since alcohol use while driving has been going down (Berning, Compton & Wochinger, 2015), the co-occurrence of alcohol and cannabis use can in itself be a risk that may increase with increasing cannabis use.



# SUPPORTING SCIENCE

From a public health perspective, it is important to know how much cannabis legalization affects crashes. A 2017 study of Colorado and Washington (Aydelotte, Brown, Luftman, Mardock, Teixeira, Coopwood, & Brown, 2017) looked at overall traffic fatality rates per travel mile in Colorado, Washington, and eight control states between 2009 and 2015. Compared to control states, the study found that there was a small but non-significant increase in fatalities per billion miles in those states compared to the controls. A 2018 study (Lee, Abdel-Aty, & Park, 2018) looked at the change in cannabis-related fatal crashes in states as a function of changes to laws in those states. Law categories included 1) prohibition, 2) decriminalization, 3) medical, and 4) full (recreational). At the time of the analysis, only 18 states fully prohibited cannabis. The study found that legalizing only medical cannabis had no statistically significant effect on fatal crashes involving cannabis. However, either decriminalizing or legalizing cannabis significantly increased cannabis-related fatal crashes by anywhere from 31-174%. It is likely that the difference in significance between these studies was due to the focus of the 2018 study on cannabis-positive fatalities as opposed to all fatalities. It is important to note that these studies do not determine whether or not the cannabis caused the fatalities, nor do they account for concurrent effects of alcohol.

## PUBLIC ATTITUDES:

Finally, surveys of attitudes towards cannabis use and driving indicate that the public, especially regular cannabis users, is unaware of the risks associated with cannabis use and driving. The GHSA reported that:

In a survey, drivers believed that driving after drinking is a greater problem than driving after using cannabis (64% vs. 29%) and that driving after drinking is more common and increases crash risk more than driving after using cannabis (56% vs. 34% and 98% vs. 78%). Compared to drivers in other states, drivers in states with legal recreational cannabis more often said driving after using cannabis is a problem (43% vs. 28%) and were twice as likely to report using cannabis within the past year (16% vs. 8%) (Eichelberger, 2016).

In surveys and focus groups with regular marijuana users in Colorado and Washington, almost all believed that marijuana doesn't impair their driving, and some believed that marijuana improves their driving (CDOT, 2014; PIRE, 2014; Hartman & Huestis, 2013). Most regular marijuana users surveyed in Colorado and Washington drove "high" on a regular basis. They believed it is safer to drive after using marijuana than after drinking alcohol. They believed that they have developed a tolerance for marijuana effects and can compensate for any effects, for instance by driving more slowly or by allowing greater headways.

# SUPPORTING SCIENCE

## THC AND DRIVING IN MICHIGAN:

Table 1 shows the count of drug-involved crashes and drug-involved fatalities in Michigan using the most recent five years of data (University of Michigan, 2019). During the five-year period from 2013 to 2017, the number of drug-involved crashes and fatal crashes have increased steadily, with an overall increase of 44% for all crashes and 56% for fatalities over the five-year period. Note that specific drug test results were not available for drivers in more than 95% of these crashes. However, among those who were tested, cannabinoids were present in 70% of drivers.

*Table 1: Drug-Involved Crashes and Fatal Crashes in Michigan*

Year	All Drug-Involved Crashes	Fatal Drug-Involved Crashes
2013	2,002	142
2014	1,944	131
2015	2,227	159
2016	2,667	188
2017	2,880	221
<b>Total</b>	<b>11,720</b>	<b>641</b>

Positive tests for cannabinoids in crash-involved drivers have more than doubled over the five-year time frame. The total number of crash-involved drivers testing positive for cannabinoid drugs are shown in Table 2. It is likely that both the amount of drug testing and the number of  $\Delta^9$ -THC-positive drivers have increased during this time. With the small amount of testing and potential changes in testing, it is difficult to determine just how much the incidence of cannabis-impaired driving is changing in Michigan. However, it is very likely to be increasing (as the data suggest). Given the experience in other states, we expect that the number will continue to go up as Michigan implements its recreational marijuana policies (Aydelotte et al., 2017).

*Table 2: Count of Crash-Involved Drivers who Tested Positive for  $\Delta^9$ -THC or Other Cannabinoids*

Positive for cannabinoids	2013	2014	2015	2016	2017	Total
<b>Total</b>	79	92	102	165	174	612

Finally, of the 612 drivers who tested positive for cannabinoids, 540 of them also had alcohol tests with known results. Of these, 44% had been drinking before driving (i.e., had non-zero BAC) and 11% were over the 0.08 BAC limit. Since drug toxicology tests are often not done for crash-involved drivers with  $BAC \geq 0.1$ , it is likely that the actual proportion of over-BAC-limit cannabis-positive drivers is higher than 11%.

## STANDARDIZED FIELD SOBRIETY TESTS:

The Standardized Field Sobriety Tests (SFSTs) are a battery of tests performed during a traffic stop to determine if a driver is impaired. Although there are a number of different field sobriety tests, three have been scientifically validated by the NHTSA and are generally admissible in court (Burns, 2013):

1. Horizontal gaze nystagmus (HGN): The subject is instructed to follow the movement of a light (or finger or other object) with only the eyes and no head movement; impaired subjects cannot follow the movement smoothly and a distinct jerk will appear prior to 45°.
2. Walk-and-turn test (WAT): The subject must walk nine heel-to-toe steps on a line, turn, and return along the line with nine heel-to-toe steps.
3. One-leg stand (OLS): The subject must raise one leg and hold it ~6 inches up while counting slowly until told to stop (at 30 seconds).

The purpose of these tests is to determine the effect of the use of alcoholic liquor, a controlled substance, or other intoxicating substance (or a combination of these) on a person's capacity to think and act with ordinary care and therefore operate a motor vehicle safely. Therefore, the results of these standardized field sobriety tests, appropriately administered, are admissible in the trial of any civil or criminal action or proceeding arising out of an arrest for a cannabis driving offense.

The three validated tests were selected from a series of studies of many different candidate tests. The history of scientific research on these tests, the selection of the three above, and their subsequent validation in both laboratory and field tests is described by Marcelline Burns (2003). However, as Burns describes, the validation work on these tests was originally done on alcohol-impaired subjects and compared to corresponding blood or breath tests. In field studies, over 90% of officers' arrest decisions on the basis of SFSTs were supported by blood tests. In particular, the HGN test is the most scientifically reliable for detecting alcohol intoxication.

However, these tests were not originally validated on impairment by other substances, though they are used to detect any form of impairment. The use of SFSTs for detecting cannabis impairment has been studied more recently with mixed results.

The three validated SFSTs plus an additional sign associated with the HGN test—head movements or jerks (HMJ)—were investigated in a laboratory setting where cannabis intake was controlled (Papafotiou, Carter, & Stough, 2005). In that study, the SFSTs were found to be moderately associated with the level of blood  $\Delta^9$ -THC, with just under 50% of subjects in the high-THC condition identified as impaired at five minutes and 55 minutes after cannabis intake. When the HMJ test was added, the detection rate increased by 10%.

# SUPPORTING SCIENCE

Notably, studies suggest that HGN has a more limited association with cannabis impairment, which is different from its strong association with BAC. A 2016 study noted these results and looked at a wider variety of possible SFSTs to find those more closely associated with cannabis impairment. In field data, a number of SFSTs that were conducted by a Drug Recognition Expert (DRE) were compared to measured blood  $\Delta^9$ -THC levels in drivers. They found that the most diagnostic tests were the finger-to-nose (FTN) test and the Modified Romberg Balance (MRB) test with eyelid tremors (Hartman, Richman, Hayes, & Huestis, 2016).

## BLOOD LEVELS OF $\Delta^9$ -THC AND IMPAIRMENT:

The pharmacokinetics of cannabis section explains the pattern of blood levels of  $\Delta^9$ -THC as it is metabolized over time after cannabis ingestion. The key features of that process are 1) the initial rapid elimination phase, and 2) the long terminal elimination phase. The specific levels and time-course are different for different methods of ingestion.

Numerous studies of the relationship between blood levels of  $\Delta^9$ -THC and performance measures are reviewed in detail in Huestis (2002). Another review focused specifically on driving-related skills can be found in Hartman & Huestis (2013). A critical observation in these studies is that there is a delay in the observed effects of impairment relative to when blood levels of  $\Delta^9$ -THC peak. That is, the effect of  $\Delta^9$ -THC on the central nervous system occur after the initial rapid elimination phase, decoupling the measured blood levels of  $\Delta^9$ -THC from the impairment that it produces.

For example, Papafotiou et al. (2005) conducted a laboratory study in which subjects smoked controlled doses of cannabis, after which they drove on a test track and were given SFSTs at regular intervals. Blood was also extracted at regular intervals and tested for  $\Delta^9$ -THC. Immediately after completion of the smoking procedure (which took some period of time), blood  $\Delta^9$ -THC levels were at their highest measured level of 70.59 ng/ml for the high dose (2.93%  $\Delta^9$ -THC cigarette) and 55.46 ng/ml for the low dose (1.74%  $\Delta^9$ -THC cigarette). Twenty minutes later, the blood  $\Delta^9$ -THC levels were 13.85 and 12.84 ng/ml, respectively. After 75 minutes, both groups were near or below 5 ng/ml (the legal limit in several states). In contrast, driving performance did not show any significant impairment at 30 minutes after completion of smoking, but it was significantly worse at 80 minutes, as measured by lateral control (“straddling the line” while driving).

Two key points must be made about the relationship between measured blood  $\Delta^9$ -THC levels and impairment. First, behavioral measures of impairment are often negatively related to blood- $\Delta^9$ -THC levels, particularly for smoked cannabis. Peak blood levels occur very quickly after smoking and are often associated with no behavioral decrement. The effect of  $\Delta^9$ -THC on the central nervous system (resulting in impairment) occurs more slowly while the initial rapid elimination phase occurs and blood- $\Delta^9$ -THC levels drop.

## SUPPORTING SCIENCE

Second, regular users of cannabis respond differently to the same dose of  $\Delta^9$ -THC than occasional or infrequent users of cannabis due to a phenomenon termed “tolerance.” Through frequent use, drug tolerance ensues such that higher doses of a drug are required to produce the same effects as achieved initially. Indeed, there is strong scientific evidence that tolerance does occur with regular and frequent use of cannabis (Colizzi, & Bhattacharyya, 2018). The implications of tolerance to cannabis are that lower blood  $\Delta^9$ -THC levels in infrequent users may result in impairment that would only be experienced at higher  $\Delta^9$ -THC levels by regular cannabis users.

The consequence of these results for setting per se limits is that blood  $\Delta^9$ -THC can fail to detect impaired drivers (when blood levels are low and impairment is high). It can also inappropriately flag unimpaired drivers or chronic users whose blood levels are higher in general (see section on behavioral effects of  $\Delta^9$ -THC) even when not impaired.

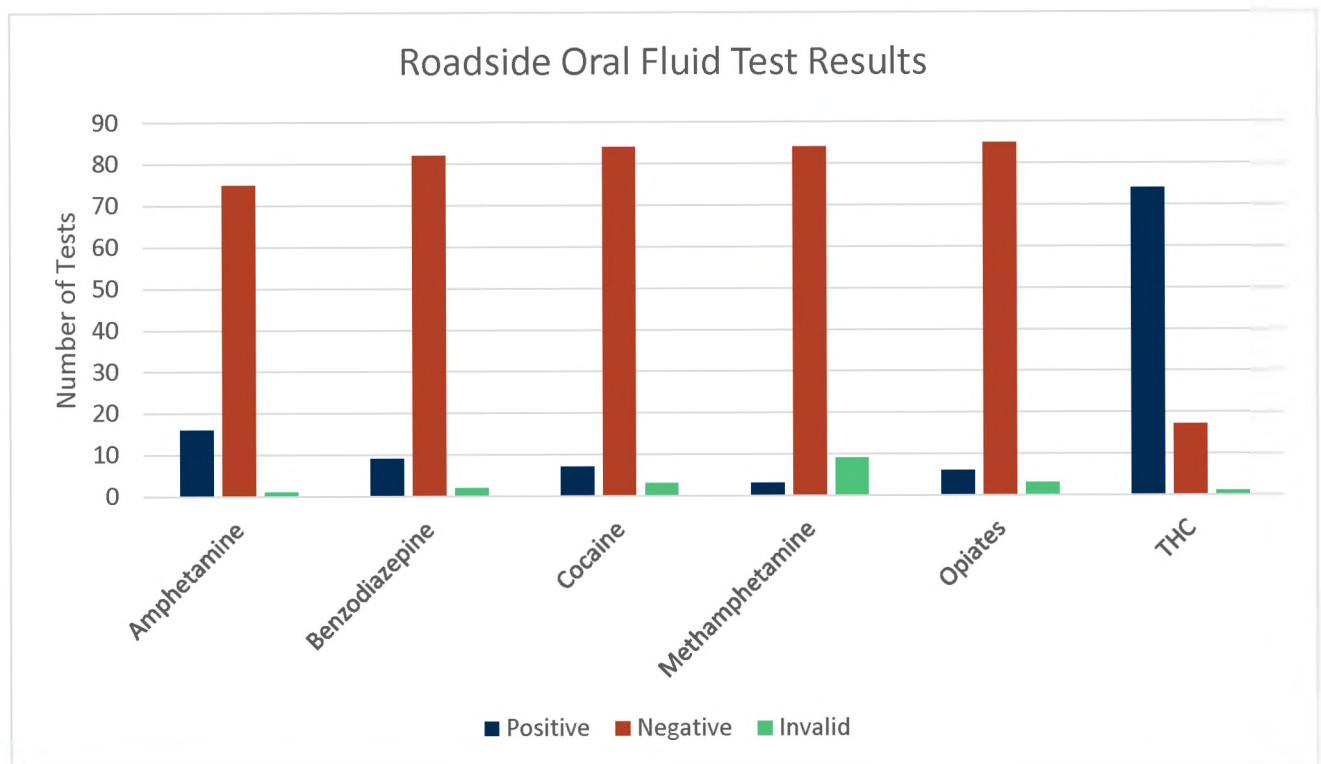
# ORAL FLUID

## STATUS IN MICHIGAN:

Public Act 243 of 2016 authorized the MSP to establish a pilot program in five counties in Michigan for roadside oral fluid testing to determine whether an individual is operating a vehicle while under the influence of a controlled substance. The legislation stipulated that the preliminary oral fluid test be performed by a certified DRE. A certified DRE means a law enforcement officer trained to recognize impairment in a driver under the influence of a controlled substance rather than, or in addition to, alcohol (Legislature Service Bureau, 2015).

## RESULTS FROM THE ORAL FLUID ROADSIDE ANALYSIS PILOT PROGRAM (MSP, 2019):

As a result of DRE-observed driver behavior and SFSTs, 89 drivers were arrested during the initial phase of the pilot program. Of those arrested, positive oral fluid roadside test results were reported for 83 drivers.



Results of the oral fluid roadside tests are detailed in the above chart (MSP, 2019). Of the 92 oral fluid roadside tests conducted, 21 returned positive results for the presence of two or more drugs. Eight tests provided negative results for all six drug categories. Six negative test results were further validated by either independent lab results, MSP forensic lab results, or both, showing negative results as well. The entirety of the Oral Fluid Roadside Analysis Pilot Program report can be viewed at: [https://www.michigan.gov/documents/msp/Oral\\_Fluid\\_Report\\_646833\\_7.pdf](https://www.michigan.gov/documents/msp/Oral_Fluid_Report_646833_7.pdf).

# FINAL RECOMMENDATIONS

## PER SE LIMIT RECOMMENDATION:

The Michigan Impaired Driving Safety Commission was created within the Michigan State Police pursuant to the Impaired Driving Safety Commission Act, 2016 PA 350 (MCL 28.791 to MCL 28.796). The Commission was charged with conducting research and to recommend a scientifically supported threshold of  $\Delta^9$ -tetrahydrocannabinol ( $\Delta^9$ -THC) bodily content to provide evidence for per se impaired driving in the state of Michigan.

The Commission carefully reviewed the most current as well as past scientific peer-reviewed literature. Likewise, the Commission invited experts in the areas of specific relevance to the Commission's charge to make presentations to the Commission and answer questions. Based on the total body of knowledge presently available, the Commission finds there is no scientifically supported threshold of  $\Delta^9$ -THC bodily content that would be indicative of impaired driving due to the fact that there is a poor correlation between driving impairment and the blood (plasma) levels of  $\Delta^9$ -THC at the time of blood collection. This poor correlation between driving impairment and the blood (plasma) concentrations of  $\Delta^9$ -THC at the time of blood collection is based on several factors that include:

1. Elimination of  $\Delta^9$ -THC undergoes very rapid elimination over several hours with a half-life (the amount of time required to eliminate one half of the total amount of  $\Delta^9$ -THC) of approximately 6 minutes followed by a long terminal elimination phase possessing a half-life of approximately 22 hours, or more (Heuberg et al., 2015). Due to the rapid initial elimination phase,  $\Delta^9$ -THC levels may be very low by the time blood is drawn for a blood test, which could underestimate the  $\Delta^9$ -THC levels at the time an individual was driving. By contrast,  $\Delta^9$ -THC has a long terminal elimination phase due to its absorption into fat tissue followed by its slow release over time back into the blood (Lucas et al., 2018). In long-term cannabis users, blood concentrations of  $\Delta^9$ -THC can remain above 1 ng/ml for 48-72 hours after administration (Wall et al., 1983). Therefore, current "no tolerance" policy in the state of Michigan, which assumes impairment at the level of detection,  $\geq 1$  ng/ml, might falsely conclude that an individual is impaired.
2. Regular users of cannabis respond differently to the same dose of  $\Delta^9$ -THC than occasional or infrequent users of cannabis due to a phenomenon termed "tolerance." Through frequent use, drug tolerance ensues such that higher doses of a drug are required to produce the same effects as achieved initially. Indeed, there is strong scientific evidence that tolerance does occur with regular and frequent use of cannabis (Colizzi, & Bhattacharyya, 2018). The implications of tolerance to cannabis are that lower blood  $\Delta^9$ -THC levels in infrequent users may result in impairment that would only be experienced at higher  $\Delta^9$ -THC levels by regular cannabis users.

*Therefore, because there is a poor correlation between  $\Delta^9$ -THC bodily content and driving impairment, the Commission recommends against the establishment of a threshold of  $\Delta^9$ -THC bodily content for determining driving impairment and instead recommends the use of a roadside sobriety test(s) to determine whether a driver is impaired.*

# FINAL RECOMMENDATIONS

## LAW ENFORCEMENT AND PROSECUTION EDUCATION:

In line with the recommendation to use a roadside sobriety test(s) to determine whether a driver is impaired, the Commission recommends additional training in impaired driving detection and investigation for law enforcement officers and prosecutors throughout the state.

Since 2010, the Michigan Commission on Law Enforcement Standards (MCOLES) has required completion of the NHTSA *DWI Detection and SFST* program for all basic law enforcement academy students. In addition, the Michigan Office of Highway Safety Planning (OHSP) requires that all officers assigned to grant funded impaired driving enforcement initiatives have completed the same program.

The Commission recommends that in addition to these existing requirements, MCOLES considers mandating all licensed officers complete the 16-hour Advanced Roadside Impaired Driving Enforcement (ARIDE) training program. The ARIDE program is designed to increase officers' ability to observe and identify the signs of driver impairment related to drugs, alcohol, or a combination of both. The program includes refresher training for administering SFSTs and is designed as an intermediate course between the SFST and DRE training programs. Currently, approximately 20% of licensed officers in Michigan have been trained in ARIDE.

The Commission also recommends expansion of the DRE training program. There are only approximately 160 active DREs in Michigan at present; there are counties that do not have a DRE within their jurisdiction. Though not feasible to require all officers be trained to the DRE level, expansion of the program to enable callout response for enforcement situations in which this level of expertise may be of assistance (injury and fatal traffic crashes, for instance) is advised.

The Commission recommends expansion of the Prosecuting Attorneys Association of Michigan (PAAM) Traffic Safety Training Program (TSTP). This program prepares prosecutors for the complexities of impaired driving case law and court practices; it is an essential component of the state's efforts to deter impaired driving.



# FINAL RECOMMENDATIONS

## PUBLIC EDUCATION:

The Commission recommends the development of public education efforts designed to inform the public about the effects of cannabis consumption and potential dangers of driving under the influence of cannabis. In addition, the Commission recommends that these efforts be developed in collaboration with cannabis stakeholder groups.

As reported in the 2018 GHSA Report, “Marijuana messaging must address two points: 1) That marijuana can impair driving, and 2) That driving while impaired by marijuana is illegal.”

## FUTURE RESEARCH:

The Commission recommends additional research be conducted to develop and validate methodologies to aid in assessing impairment of skills required for the operation of a motor vehicle due to the influence of cannabis. This may include SFSTs and oral fluid testing in assessing whether an individual is operating a vehicle while under the influence of a controlled substance.

## DRUGGED-DRIVING COMMISSION:

The Commission conducted an extensive review of the existing state of scientific knowledge to develop its recommendations. However, as research continues, future results may change our understanding of this issue. Therefore, the Commission recommends the establishment of a permanent Drugged-Driving Commission to review new research and the experience of other states to keep the Legislature apprised of emerging relevant information.

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# GLOSSARY OF TERMS

**$\Delta^9$ -tetrahydrocannabinol ( $\Delta^9$ -THC):** The primary psychotropic compound in marijuana.  $\Delta^9$ -THC belongs to a broader family of compounds that possess a similar chemical structure termed, cannabinoids.

**11-carboxy-THC:** A major metabolite of  $\Delta^9$ -tetrahydrocannabinol and possesses minimal psychotropic properties.

**11-hydroxy-THC:** A major metabolite of  $\Delta^9$ -tetrahydrocannabinol and possesses psychotropic properties.

**Absorption:** The movement of drugs and chemicals across biological membranes to enter the body.

**Binding Affinity:** The strength in which a drug binds with specificity to a protein, typically a receptor or enzyme. Typically, the higher the affinity of specific binding between a drug and receptor the greater the biological activity that is initiated.

**Bioavailability:** the percentage of the total amount of a drug or chemical that is absorbed after administration and that is available to exert its biological activity.

**Biphasic:** a process possessing two distinct phases or stages.

**Cannabidiol (CBD):** A chemical naturally produced by the cannabis sativa belonging to the family of compound termed cannabinoids. CBD has minimal psychotropic activity.

**Cannabinoid Receptor 1:** A protein on the surface of cells to which cannabinoids bind to initiate their biological activity. Cannabinoid receptor 1 is highly abundant on neural cells within the brain and is responsible for the euphoric effects associate with marijuana.

**Cannabis Sativa:** plant also termed marijuana, which is the source of plant-derived cannabinoid compounds, including  $\Delta^9$ -tetrahydrocannabinol (THC).

**Distribution:** once absorbed, the movement of drugs and chemical throughout the body that occurs primarily via circulation in the blood stream.

**Drug Half-Life:** the period of time required to metabolize and/or eliminate one half of the total amount of a drug that has been absorbed.

**Excretion:** elimination of compounds from the body in urine and feces.

**First Pass Metabolism:** the process by which when drugs and chemicals are absorbed for the gastrointestinal tract and enter the blood stream they are first transported to the liver to undergo metabolism.

**Metabolism:** the conversion of compounds by drug metabolizing enzymes primarily present in the liver to more water-soluble chemicals to enhance their utilization by the body and their excretion in urine and feces.

# GLOSSARY OF TERMS

**Oromucosal Route:** exposure that occurs through the application of chemicals to the mucosal membrane of the oral cavity.

**Peak Plasma Concentration:** the highest concentration of a drug or chemical present within plasma after initial exposure or administration.

**Plasma Concentrations:** the amount of a drug or chemical present in the liquid (i.e., non-cellular) portion of blood.

**Psychotropic Effects:** Changes in brain function and resulting in alterations in perception, mood, consciousness, cognition, and/or behavior that are typically caused by exposure to a chemical.

**Respiratory Route:** Exposure to an agent by inhalation via the lungs.

**Structurally-Related Compounds:** Chemicals possessing a similar basic chemical structure and belonging to a “family” of compounds with similar chemical and/or biological properties.

**Tincture:** a concentrated liquid herbal extract.

**Vascular:** related to blood vessels.

# REFERENCES

- Aydelotte, J. D., Brown, L. H., Luftman, K. M., Mardock, A. L., Teixeira, P. G., Coopwood, B., & Brown, C. V. (2017). Crash fatality rates after recreational marijuana legalization in Washington and Colorado. *American Journal of Public Health, 107*(8), 1329-1331.
- Baselt, R.C. (2004). *Disposition of Toxic Drugs and Chemicals in Man* (7th ed.). Foster City, CA: Biomedical Publications.
- Berning, A., Compton, R., & Wochinger, K. (2015, February). Results of the 2013-2014 national roadside survey of alcohol and drug use by drivers. *Journal of Drug Addiction, Education, and Eradication, 11*(1), 47.
- Bosker, W.M., Karschner, E.L., Lee, D., Goodwin, R.S., Hirvonen, J., Innis, R.B., Theunissen, E.L., Kuypers, K.P.C., Huestis, M.A., Ramaekers, J.G. (2013, January 2). Psychomotor Function in Chronic Daily Cannabis Smokers during Sustained Abstinence *PLoS One; 8*(1). Retrieved from <https://doi.org/10.1371/journal.pone.0053127>
- Burns, M. (2003, December 1). An overview of field sobriety test research. *Perceptual and motor skills, 97*(3\_suppl), 1187-1199.
- CDOT (2014). *Drive High, Get a DUI: CDOT Marijuana Impaired Driving Campaign*. PowerPoint presentation, Denver, CO: Colorado Department of Transportation.
- Compton, R. P. (2017, July). *Marijuana-impaired driving-a report to Congress*. Washington DC: National Highway Traffic Safety Administration.
- Compton, R. P. & Berning, A. (2015, February). *Drug and alcohol crash risk*. Washington, DC: National Highway Traffic Safety Administration.
- Colizzi, M., & Bhattacharyya, S. (2018, October). Cannabis use and the development of tolerance: a systematic review of human evidence. *Neurosci Biobehav 93*, 1-25.
- Edmondson, L (2016, July). Driving under the influence of cannabis. *Capitol Research*. Retrieved from <http://knowledgecenter.csg.org/kc/content/driving-under-influence-cannabis>
- Elvik, R. (2013, November). Risk of Road Accident Associated with the Use of Drugs: A Systematic Review and Meta- analysis of Evidence from Epidemiological Studies. *Accident Analysis & Prevention, 60*, 254-267.
- Gaoni, Y., & Mechoulam, R. (1964, April). Isolation, Structure, and Partial Synthesis of an Active Constituent of Hashish. *Journal of the American Chemical Society, 82*(8), 1646-1647.
- Grotenhermen, F. (2003). Pharmacokinetics and pharmacodynamics of cannabinoids. *Clinical Pharmacokinetics, 42*, 327-360.
- Hartman, R. L., & Huestis, M. A. (2013). Cannabis effects on driving skills. *Clinical chemistry, 59*(3), 478-492.

# REFERENCES

- Hartman R.L., Brown T.L., Milavetz G., et al. (2015). Cannabis effects on driving lateral control with and without alcohol. *Drug Alcohol Dependence*. 154, 25-37. Retrieved from <https://doi.org/10.1016/j.drugalcdep.2015.06.015>
- Hartman, R. L., Richman, J. E., Hayes, C. E., & Huestis, M. A. (2016). Drug recognition expert (DRE) examination characteristics of cannabis impairment. *Accident Analysis & Prevention*, 92, 219-229.
- Hedlund J. (2017). *Drug-Impaired Driving: A Guide for States*. Retrieved from [https://www.ghsa.org/sites/default/files/2017-07/GHSA\\_DruggedDriving2017\\_FINAL\\_revised.pdf](https://www.ghsa.org/sites/default/files/2017-07/GHSA_DruggedDriving2017_FINAL_revised.pdf)
- Heuberger, J. A., Guan, Z., Oyetayo, O. O., Klumpers, L., Morrison, P. D., Beumer, T. L., van Gerven, J. M., Cohen, A. F., & Freijer, J. (2015). Population pharmacokinetic model of THC integrates oral, intravenous, and pulmonary dosing and characterizes short- and long-term pharmacokinetics. *Clinical Pharmacokinetics*, 54, 209-219.
- Huestis, M. A. (2002). Cannabis (Marijuana)- effects on human behavior and performance. *Forensic Science Review*, 14(1), 15-60.
- Huestis, M. A. (2005). Pharmacokinetics and metabolism of the plant cannabinoids, delta9-tetrahydrocannabinol, cannabidiol and cannabinol. *Handbook of Experimental pharmacology*, 168, 657-690.
- Huestis, M.A. (2007, August). Human Cannabinoid Pharmacokinetics. *Chemistry & Biodiversity*, 4(8), 1770-1804.
- Lacey, J. H., Kelley-Baker, T., Berning, A., Romano, E., Ramirez, A., Yao, J., . & Compton, R. (2016). Drug and alcohol crash risk: a case-control study (No. DOT HS 812 355). United States: National Highway Traffic Safety Administration.
- Lee, J., Abdel-Aty, A., & Park, J. (2018, September). Investigation of associations between marijuana law changes and marijuana-involved fatal traffic crashes: A state-level analysis. *Journal of Transport & Health*, 10, 194-202.
- Legislature Service Bureau. (2017). Act 350 of 2016. Retrieved from <http://legislature.mi.gov/doc.aspx?mcl-Act-350-of-2016>
- Legislature Service Bureau. (2019). Senate Bill 0207 (2015). Retrieved from <http://legislature.mi.gov/doc.aspx?2015-SB-0207>
- Leighty, E. G. (1973, July1). Metabolism and distribution of cannabinoids in rats after different methods of administration. *Biochemical Pharmacology* 22, 1613-1621.
- Lenné M.G., Dietze P.M., Triggs T.J., Walmsley S., Murphy B., Redman J.R. (2010). The effects of cannabis and alcohol on simulated arterial driving: Influences of driving experience and task demand. *Accident Analysis Prevention*, 42(3):859-866. Retrieved from <https://doi:10.1016/j.aap.2009.04.021>

# REFERENCES

- Liguori, A., Gatto, C. P., & Robinson, J. H. (1998). Effects on marijuana on equilibrium, psychomotor performance, and simulated driving. *Behavioural pharmacology*, 9, 599-610.
- Lorenzetti, V., Lubman, D.I., Whittle, S., Solowij, N. & Yücel, M. (2010). Structural MRI findings in long-term cannabis users: what do we know?, *Substance Use & Misuse*, 45(11), 1787-1808.
- Lucas, C. J., Galettis, P., Song, S., Solowij, N., Reuter, S. E., Schneider, J., and Martin, J. H. (2018). Cannabinoid disposition after human intraperitoneal use: an insight into intraperitoneal pharmacokinetic properties in metastatic cancer. *Clinical Therapeutics* 40, 1442-1447.
- Matsuda, L. A., Lolait, S. J., Brownstein, M. J., Young, A. C., and Bonner, T. I. (1990, September). Structure of a cannabinoid receptor and functional expression of the cloned cDNA. *Nature*, 346(6284), 561-564
- Michigan State Police. (February 2019). Oral Fluid Roadside Analysis Pilot Program. Retrieved from [https://www.michigan.gov/documents/msp/Oral\\_Fluid\\_Report\\_646833\\_7.pdf](https://www.michigan.gov/documents/msp/Oral_Fluid_Report_646833_7.pdf)
- National Academies of Sciences, Engineering, and Medicine. (2017). *The health effects of cannabis and cannabinoids: Current state of evidence and recommendations for research*. Washington, DC: The National Academies Press.
- Papafotiou, K., Carter, J. D., & Stough, C. (2005). An evaluation of the sensitivity of the Standardized Field Sobriety Tests (SFSTs) to detect impairment due to marijuana intoxication. *Psychopharmacology*, 180(1), 107-114.
- Papafotiou, K., Carter, J. D., & Stough, C. (2005). The relationship between performance on the standardised field sobriety tests, driving performance and the level of  $\Delta^9$ -tetrahydrocannabinol (THC) in blood. *Forensic Science International*, 155(2-3), 172-178.
- PIRE (2014). *Washington State Roadside Survey*. Calverton, MD: Pacific Institute for Research & Evaluation.
- Procon.org. (2019). Retrieved from <https://medicalmarijuana.procon.org/view.resource.php?resourceID=000881>
- Ramaekers, J. G., Robbe, H. W. J., & O'Hanlon, J. F. (2000). Marijuana, alcohol and actual driving performance. *Human Psychopharmacology: Clinical and Experimental*, 15(7), 551-558.
- Robbe, H. W. J., & O'Hanlon, J. (1993). Marijuana's effect on actual driving: summary of a 1-year experimental program. In *Proceedings International Council on Alcohol, Drugs and Traffic Safety Conference, 1993*, 603-611.
- Schwoppe, D. M., Bosker, W. M., Ramaekers, J. G., Gorelick, D. A., & Huestis, M. A. (2012). Psychomotor performance, subjective and physiological effects and whole blood Delta(9)-tetrahydrocannabinol concentrations in heavy, chronic cannabis smokers following acute smoked cannabis. *Journal of Analytical Toxicology*, 36, 405-412.

# REFERENCES

Schulze, H., Schumacher, M., Urmeew, R., Auerbach, K., Alvarez, J., Bernhoft, I. M., de Gier, H., ... & Zlender, B. (2012). Driving under the influence of drugs, alcohol and medicines in europe—findings from the DRUID project. Lisbon: European Monitoring Centre for Drugs and Drug Addiction.

University of Michigan. 2019. Michigan Traffic Crash Facts. Retrieved from <https://www.michigantrafficcrashfacts.org>

Wall, M. E., Sadler, B. M., Brine, D., Taylor, H., and Perez-Reyes, M. (1983). Metabolism, disposition, and kinetics of delta-9-tetrahydrocannabinol in men and women. *Clinical Pharmacology & Therapeutics*, 34, 352-363.