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Working to Reform Marijuana Laws

**Cannabis and Driving:  
A Scientific and Rational Review  
(2011 Update)**

Paul Armentano  
Deputy Director  
NORML | NORML Foundation  
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Policy debates regarding marijuana law reform invariably raise the question: "How does society address concerns regarding cannabis consumption and driving?" The subject is worthy of serious discussion. NORML's Board of Directors addressed this issue by ratifying a "no driving" clause to the organization's "Principles of Responsible Cannabis Use"<sup>[1]</sup> stating, "Although cannabis is said by most experts to be safer with motorists than alcohol and many prescription drugs, responsible cannabis consumers never operate motor vehicles in an impaired condition."

Nevertheless, questions remain regarding the degree to which cannabis intoxication impairs actual driving performance. Unlike alcohol, which is known to increase drivers' risk-taking behavior and is a primary contributor in on-road accidents, marijuana's acute impact on psychomotor skills is subtle and its real-world impact in automobile crashes is inconclusive.

### Drugged Driving: True Threat Or False Panic?

Survey data indicates that approximately 112 million Americans (46 percent of the US population) have experimented with the use of illicit substances.<sup>[2]</sup> Of these, more than 20 million (8.3 percent of the population) self-identify as "current" or "monthly" users of illicit drugs,<sup>[3]</sup> and more than 10 million Americans say that they've operated a motor vehicle while under the influence of an illicit substance in the past year.<sup>[4]</sup> These totals, while far from negligible, suggest that the prevalence of illicit drug use among US drivers is far less than the prevalence of alcohol among this same population.<sup>[5]</sup>

To date, "[The] role of [illicit] drugs as a causal factor in traffic crashes involving drug-positive drivers is still not well understood."<sup>[6]</sup> While some studies have indicated that illicit drug use is associated with an increased risk of accident, a relationship has not yet been clearly established regarding the use of psychoactive substances and crash severity.<sup>[7]</sup> Some reviews of traffic fatality data indicate that, in general, drivers with the presence of illicit drugs in their system possess an enhanced fatality risk compared to sober drivers. However, this risk is far lower than the fatality risk associated with drivers who operate a vehicle with the presence of alcohol in their system above or near the legal limit for intoxication.<sup>[8]</sup> According to one review of the literature: "The risk of all drug-positive drivers compared to drug-free drivers is similar to drivers with a blood alcohol concentration of 0.05%. The risk is also similar to drivers above age 60 compared to younger drivers [around age 35]."<sup>[9]</sup>

Marijuana is the most common illicit substance consumed by persons who report driving after drug use.<sup>[10]</sup> Epidemiological research also indicates that cannabis is the most prevalent illicit drug detected in fatally injured drivers and motor vehicle crash victims.<sup>[11]</sup> Reasons for this fact are twofold. One, cannabis is by far the most widely used illicit drug among the US population, with nearly one out of two Americans admitting having tried it.<sup>[12]</sup> Two, marijuana is the most readily detectable illicit drug in toxicological tests. Marijuana's primary psychoactive compound, THC, may accumulate and be detected in blood for several hours in occasional users; in some chronic users, THC may be present in blood for a period of days after past use,<sup>[13-15]</sup> long after any performance impairing effects have worn off.<sup>[16]</sup> In addition, non-psychoactive byproducts of cannabis, known as

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metabolites, may be detected in the urine of regular users for days or weeks after past use.<sup>[17]</sup> (Other common illicit substances, such as cocaine or methamphetamine, do not possess such long half-lives.) Therefore, the substance's prevalence in toxicological evaluations of US drivers does not necessarily indicate that it is a frequent or significant causal factor in auto accidents. In fact, states that have experienced a significant increase in the total number of authorized medical cannabis users have in general experienced no proportional corresponding rise in traffic fatalities, and most have experienced a decline in overall fatal accidents.<sup>[18]</sup>

### Cruising On Cannabis: Clarifying The Debate

While it is well established that alcohol consumption increases accident risk, evidence of marijuana's culpability in on-road driving accidents and injury is far less clear. Although acute cannabis intoxication following inhalation has been shown to mildly impair psychomotor skills, this impairment is seldom severe or long lasting.<sup>[19-20]</sup> (By contrast, virtually no published research exists assessing the oral ingestion of cannabis edibles on psychomotor performance). In closed course and driving simulator studies, marijuana's acute effects on psychomotor performance include minor impairments in tracking (eye movement control) and reaction time (break latency), as well as variation in lateral positioning (weaving), headway (drivers under the influence of cannabis tend to follow less closely to the vehicle in front of them), and speed (drivers tend to decrease speed following cannabis inhalation).<sup>[21]</sup> Notably, these impairments in performance are more likely to be manifested in driver simulator tests than in assessments of actual on-road behavior, where changes in performance are consistently nominal.<sup>[22]</sup> For example, A 2001 study evaluating the impact of marijuana intoxication on driving proficiency on city streets among sixteen subjects reported essentially no differences in subjects' driving performance after cannabis administration, concluding: "Performance as rated on the Driving Proficiency Scale did not differ between treatments. It was concluded that the effects of low doses of THC ... on higher-level driving skills as measured in the present study are minimal."<sup>[23]</sup> Similarly, a 1993 trial funded by the United States National Highway Traffic Association (NHTSA) evaluated subjects' driving performance after cannabis inhalation in high-density urban traffic. Investigators reported, "Marijuana ... did not significantly change mean driving performance."<sup>[24]</sup>

In general, cannabis-induced variations in driving behavior, when present, are less consistent or pronounced than the impairments exhibited by subjects under the influence of alcohol.<sup>[25]</sup> Unlike subjects impaired by alcohol, individuals under the influence of cannabis tend to be aware of their impairment and try to compensate for it accordingly, either by driving more cautiously<sup>[26]</sup> or by expressing an unwillingness to drive altogether.<sup>[27]</sup> Further, numerous studies report that experienced cannabis users develop tolerance to many of the changes in cognitive or psychomotor performance associated with acute cannabis intoxication.<sup>[28-30]</sup> Most recently, a 2010 double-blind, placebo-controlled study of 21 heavy cannabis users assessed the impact of alcohol or THC inhalation on measures of perceptual motor control (critical tracking task), dual task processing (divided-attention task), motor inhibition (stop-signal task), and cognition (Tower of London). Authors reported: "Alcohol significantly impaired critical tracking, divided attention, and stop-signal

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performance. THC generally did not affect task performance." They concluded, "[T]he present study generally confirms that heavy cannabis users develop tolerance to the impairing effects of THC on neurocognitive task performance."<sup>[31]</sup>

As a result, cannabis-induced variations in performance do not typically appear to play a significant role in on-road traffic accidents when the THC levels present in a driver's blood are low and/or cannabis is not consumed in combination with alcohol.<sup>[32-33]</sup> For example, a 1993 National Highway Traffic Safety Administration review of the role of drug use in fatal accidents reported, "[T]here is little if any evidence to indicate that drivers who have used marijuana alone are any more likely to cause serious accidents than drug free drivers."<sup>[34]</sup> A more recent assessment by Blows and colleagues noted that self-reported recent use of cannabis (within three hours of driving) was not significantly associated with car crash injury after investigators controlled for specific cofounders (e.g., seat-belt use, sleepiness, etc.)<sup>[35]</sup> A 2004 observational case control study published in the journal *Accident, Analysis and Prevention* reported that only drivers under the influence of alcohol or benzodiazepines experience an increased crash risk compared to drug-free controls. Investigators did observe increased risks -- though they were not statistically significant -- among drivers using amphetamines, cocaine and opiates, but found, "No increased risk for road trauma was found for drivers exposed to cannabis."<sup>[36]</sup>

A limited number of more recent studies and reviews have postulated a positive association between presumed recent, dose-dependent cannabis exposure and a gradually increased risk of vehicle accident.<sup>[37-39]</sup> However, this elevated risk was below the risk associated with drivers who had consumed even small quantities of alcohol.

A 2007 case-control study published in the *Canadian Journal of Public Health* reviewed 10-years of US auto-fatality data. Investigators found that US drivers with blood alcohol levels of 0.05% -- a level well below the legal limit for intoxication -- were three times as likely to have engaged in unsafe driving activities prior to a fatal crash as compared to individuals who tested positive for marijuana.<sup>[40]</sup> A 2005 review of auto accident fatality data from France reported similar results, finding that drivers who tested positive for any amount of alcohol had a four times greater risk of having a fatal accident than did drivers who tested positive for marijuana in their blood.<sup>[41]</sup> In the latter study, even drivers with low levels of alcohol present in their blood (below 0.05%) experienced a greater elevated risk as compared to drivers who tested positive for higher concentrations of cannabis (above 5ng/ml). Both studies noted that overall few traffic accidents appeared to be attributed to driver's operating a vehicle while impaired by cannabis.

Following the publication of these papers, various investigators have attempted to associate specific THC blood levels to driver impairment.<sup>[42-43]</sup> However, there are many reasons why such an association should be interpreted with extreme caution. First, peak THC blood levels following inhalation do not consistently correspond with levels of peak impairment.<sup>[44]</sup> (In fact, subjects who inhale THC typically ascertain their highest THC blood levels within minutes, well before the drug's

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impairing effects have reached their peak.) As a result, it is virtually impossible to make inferences regarding a subject's impairment based upon the presence of THC alone in a single sample.<sup>[45-46]</sup>

Second, cannabis' effect on psychomotor performance varies widely among individual subjects, particularly among those who are cannabis experienced versus those who are naive. As a result of these extreme variations, even experts who are on record in support of estimated blood/THC impairment standards acknowledge that such thresholds "are not necessarily applicable to each and every driver an individual."<sup>[47]</sup>

Third, recent studies of chronic cannabis consumers indicate that residual levels of THC may be present in blood without associated impairment of performance for several days after past use.<sup>[48-49]</sup> This accumulation of THC in chronic consumers "leads to cannabinoid concentrations in sober phases that resemble concentrations found in occasional users after acute cannabis use,"<sup>[50]</sup> thus making the universal application of a specific blood/THC impairment standard inappropriate.

Finally, at this time there is no practical method for law enforcement officers at the scene to collect blood samples from suspected DUI cannabis drivers in a timely manner. This delay in collection (which may typically be as long as several hours), combined with the THC's complex and inconsistent pharmacokinetics, make it impossible to infer whether, or to what extent, a subject was previously impaired based solely on a positive blood test result.<sup>[51]</sup>

For these reasons, NORML does not endorse the imposition of per se laws for drivers who test positive for THC in the blood without additional demonstrable evidence of psychomotor impairment. In particular, NORML opposes the imposition of so-called 'zero tolerance' per se standards, which legally define a motorist impaired if he or she tests positive for the presence of any amount of THC or THC metabolite in their blood or urine.<sup>[52]</sup>

### Defining A Rational 'Drugged Driving' Policy

The above review illustrates the need for further education and understanding regarding the effects of cannabis upon driving behavior. While its adverse impact on psychomotor skills is less severe than the effects of alcohol, driving under the acute influence of cannabis still may pose an elevated risk of accident in certain situations, especially among inexperienced cannabis consumers. However, because marijuana's psychomotor impairment is subtle and short-lived, consumers can greatly reduce this risk by refraining from driving for a period of several hours immediately following their cannabis use.

By contrast, motorists should never be encouraged to operate a vehicle while smoking cannabis. Drivers should also be advised that engaging in the simultaneous use of both cannabis and alcohol can in some instances significantly increase their risk of accident compared to the consumption of either substance alone.<sup>[53]</sup> Past use of cannabis, as defined by the detection solely of inactive cannabis metabolites in the urine of drivers, is not associated with an increased accident risk.<sup>[54]</sup>

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Educational or public service campaigns targeting drugged driving behavior should particularly be aimed toward the younger driving population age 18 to 25 -- as this group is most likely use cannabis<sup>[55]</sup> and report having operated a motor vehicle shortly after consuming pot.<sup>[56]</sup> In addition, this population may have less driving experience, may be more prone to engage in risk-taking behavior, and may be more naïve to pot's psychoactivity as compared to older, more experienced populations who are more likely to be tolerant to the drug's performance-impairing effects. This younger population also reports a greater likelihood for having driven after using cannabis in combinations with other illicit drugs or alcohol.<sup>[57]</sup> Such an educational campaign<sup>[58]</sup> was implemented nationwide in Canada by the Canadian Public Health Association and could readily be replicated in the United States. Arguably, such a campaign would enjoy enhanced credibility if coordinated by a private public health association or traffic safety organization, such as the American Public Health Association or the AAA Automobile Club, as opposed to the federal Office of National Drug Control Policy -- whose previous public service campaigns have demonstrated limited influence among younger audiences.<sup>[59]</sup> Most recently, the Colorado Department of Transportation launched its own 'drugged driving awareness' campaign at the statewide level.<sup>[60]</sup>

Finally, increased efforts should be made within the law enforcement community to train officers and DREs (drug recognition experts) to better identify drivers who may be operating a vehicle while impaired by marijuana. Changes may also be adopted to roadside Standardized Field Sobriety Test making these evaluations more sensitive to drivers who may be under the influence of cannabis. Preliminary scientific evaluations of these tests in controlled conditions have shown that subjects' performance during modified SFSTs may be positively associated with dose-related levels of marijuana impairment.<sup>[61]</sup>

Though the development of roadside cannabis-specific detection testing (similar to an alcohol breathalyzer test) is still in its infancy, an argument may be made for the provisional use of such tests by specially trained members of law enforcement. In addition, the development of point-of-collection cannabis-sensitive technology to rapidly identify the presence of THC in drivers, such as a roadside saliva test, would provide utility to law enforcement in their efforts to better identify suspected intoxicated drivers. The development of such technology would also increase public support for the taxation and regulation of cannabis by helping to assuage concerns that liberalizing marijuana policies could potentially lead to an increase in incidences of drugged driving.<sup>[62]</sup> Such concerns are a significant impediment to the enactment of marijuana law reform, and arguably must be sufficiently addressed before a majority of the public will embrace any public policy that proposes regulating adult cannabis use like alcohol.

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*Paul Armentano is the Deputy Director of NORML and the NORML Foundation. Mr. Armentano is a nationally recognized expert in the field of marijuana policy, health, pharmacology, and pharmacokinetics. He has attended various international conferences on the subject of cannabis and toxicology, including those sponsored by the Society of Forensic*

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Toxicologists (SOFT), the American Academy of Forensic Sciences (AAFS), and The International Council on Alcohol, Drugs & Traffic Safety (ICADTS). He has coordinated campaign and lobbying efforts in numerous states pertaining to drugged driving and he was an independent consultant on the Canadian Public Health Association's "Pot and Driving" campaign, a project to increase awareness among young Canadians age 14 to 18 about the risks of cannabis-impaired driving. Mr. Armentano has authored peer-reviewed papers on the subject of marijuana, driving, and public policy, including most recently 'Driving Under the Influence,' which appears in *The Pot Book: A Complete Guide to Cannabis -- It's Role in Medicine, Politics, Science, and Culture* (editor: Julie Holland, M.D., Park Street Press, 2010). He may be contacted via e-mail at: paul@norml.org.

### Footnotes

[1] Adopted by NORML's Board of Directors, February 3, 1996. Read all of NORML's "Principles of Responsible Use"

[2] US Department of Justice, Bureau of Justice Statistics. *Drug and Crime Facts: Drug Use Among the General Population*. Online document accessed November 24, 2007.

[3] US Department of Health and Human Services, Substance and Mental Health Services Association, Office of Applied Studies. *2006 National Survey on Drug Use and Health: National Results*. Online document accessed November 24, 2007.

[4] Ibid.

[5] US Department of Transportation, National Highway Traffic Safety Administration. *State of Knowledge of Drugged Driving: FINAL REPORT*. September 2003.

[6] Ibid.

[7] Smink et al. 2005. Drug use and the severity of traffic accident. *Accident, Analysis and Prevention* 37: 427-433.

[8] Franjo Grotenhermen. *Drugs and Driving: Review for the National Treatment Agency, UK*. Nova-Institut (Germany). November 2007.

[9] Ibid.

[10] US Department of Health and Human Services, Substance and Mental Health Services Association, Office of Applied Studies. *Driving After Drug or Alcohol Use, 1998*. Online document accessed November 24, 2007.

[11] US Department of Transportation. 2003. op. cit.

[12] October 23-24, 2002 CNN/Time poll conducted by Harris Interactive.

[13] Skopp et al. 2003. Serum cannabinoid levels 24 to 48 hours after cannabis smoking. *Archives of Criminology* (Germany) 212: 83-95.

[14] Toennes et al. 2008. Comparison of cannabinoid pharmacokinetic properties in occasional and heavy users smoking a marijuana or placebo joint. *Journal of Analytical Toxicology* 32: 470-477. "Heavy users might exhibit measurable

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cannabinoid concentrations in blood, even if the last cannabis use was more than 24 hours ago. This is due to redistribution from deep compartments and to the prolonged elimination of THC."

[15] Karschner et al. 2009. Do Delta- 9-tetrahydrocannabinol concentrations indicate recent use in chronic cannabis users? *Addiction* 104: 2041-2048. "Substantial whole blood THC concentrations persist multiple days after drug discontinuation in heavy chronic cannabis users."

[16] Ronen et al. 2007. Effects of THC on driving performance, physiological state and subjective feelings relative to alcohol. *Accident, Analysis and Prevention* 40: 926-934. "No THC effects were observed after 24 h on any of the measures."

[17] Musshoff and Madea. 2006. Review of biological matrices (urine, blood, and hair) as indicators of recent or ongoing cannabis use. *Therapeutic Drug Monitor* 28: 155-163.

[18] National Highway Traffic Safety Administration, *Fatalities and Fatality Rates By State, 1994-2009*. Online document access September 6, 2011.

[19] According to the US Department of Transportation, National Highway Traffic Safety Administration. *State of Knowledge of Drugged Driving: FINAL REPORT*. op. cit., "Experimental research on the effects of cannabis ... indicat[e] that any effects ... dissipate quickly after one hour."

[20] According to the 2004 National Highway Traffic Safety Administration factsheet, *Drugs and Human Performance*, peak acute effects are typically reached within 10 to 30 minutes after inhalation.

[21] US Department of Transportation. National Highway Traffic Safety Administration. *State of Knowledge of Drugged Driving: FINAL REPORT*. op. cit. Other summaries include: Ramaekers et al. 2006. Cognition and motor control as a function of Delta-9-THC concentration in serum and oral fluid: Limits of impairment. *Drug and Alcohol Dependence* 85: 114-122; David Hadorn. "A Review of Cannabis and Driving Skills," In: *The Medicinal Uses of Cannabis and Cannabinoids*. (eds: Guy et al). Pharmaceutical Press, 2004; Canadian Senate Special Committee on Illegal Drugs, *Cannabis: Summary Report: Our Position for a Canadian Public Policy*. 2002. (See specifically: Chapter 8: "Driving Under the Influence of Cannabis"); Alison Smiley. "Marijuana: On-Road and Driving-Simulator Studies," In: *The Health Effects of Cannabis*. (eds. Kalant et al) Canadian Centre for Addiction and Mental Health, 1999.

[22] US Department of Transportation, National Highway Traffic Safety Administration. *Marijuana and Actual Driving Performance: Final Report*. November 1993. "It appears performance is more affected by THC in laboratory (settings) than (in) actual driving tests."

[23] Lamers and Ramaekers. 2001. Visual search and urban driving under the influence of marijuana and alcohol. *Human Psychopharmacology* 16: 393-401.

[24] US Department of Transportation, National Highway Traffic Safety Administration. *Marijuana and Actual Driving Performance: Final Report*. op. cit.

[25] David Hadorn. 2004. op. cit. and US Department of Transportation. 2003. op. cit.

[26] According to the US Department of Transportation National Highway Traffic Safety Administration. *State of Knowledge of Drugged Driving: FINAL REPORT*. op. cit., "The extensive studies by Robbe and O'Hanlon (1993), revealed

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that under the influence of marijuana, drivers are aware of their impairment, and when the experimental task allows it, they tend to actually decrease speed, avoid passing other cars, and reduce other risk-taking behaviors."

[27] Menetrey et al. 2005. Assessment of driving capability through the use of clinical and psychomotor tests in relation to blood cannabinoid levels following oral administration of 20mg dronabinol or of a cannabis decoction made with 20 and 60mg delta-9-THC. *Journal of Analytical Toxicology* 29: 327-338.

[28] D'Souza et al. 2008. Blunted psychotomimetic and amnestic effects of delta-9-tetrahydrocannabinol in frequent users of cannabis. *Neuropsychopharmacology* 33: 2505-2016. "These data suggest that frequent users of cannabis are either inherently blunted in their response to, and/or develop tolerance to the psychotomimetic, perceptual altering, amnestic, endocrine, and other effects of cannabinoids."

[29] Ramaekers et al. 2009. Neurocognitive performance during acute THC intoxication in heavy and occasional cannabis users. *Journal of Psychopharmacology* 23: 266-277. "THC did not affect the performance of heavy cannabis users except in the stop signal task, i.e. stop reaction time increased, particularly at high THC concentrations. Group comparisons of overall performance in occasional and heavy users did not reveal any persistent performance differences due to residual THC in heavy users. These data indicate that cannabis use history strongly determines the behavioural response to single doses of THC."

[30] Hart et al. 2010. Neurophysiological and cognitive effects of marijuana in frequent users. 2010. *Pharmacology, Biochemistry and Behavior* 96: 333-341. "In summary, the current data suggest that frequent marijuana users may show fewer behavioral signs of disruption during intoxication than infrequent users, even when difficult memory tasks are used to assess cognitive performance. ... These data emphasize the importance of taking into account the drug-use histories of research participants and examining multiple measures when investigating marijuana-related effects on cognitive functioning."

[31] Ramaekers et al. 2010. Tolerance and cross-tolerance to neurocognitive effects of THC and alcohol in heavy cannabis users. *Psychopharmacology* 214: 391-401.

[32] United Kingdom Department of Environment, Transport and the Regions, Road Safety Division *Cannabis and Driving: A Review of the Literature and Commentary*. Online document accessed November 24, 2007. "Overall, we conclude that the weight of the evidence indicates that ... there is no evidence that consumption of cannabis alone increases the risk of culpability for traffic crash fatalities or injuries for which hospitalization occurs, and may reduce those risks."

[33] Gregory Cheshier and Marie Longo. "Cannabis and Alcohol in Motor Vehicle Accidents," In: *Cannabis and Cannabinoids: Pharmacology, Toxicology, and Therapeutic Potential*. (eds. Grotenhermen et al.) Haworth Press, 2002.

[34] US Department of Transportation, National Highway Traffic Safety Administration. Marijuana and Actual Driving Performance: Final Report. op. cit.

[35] Blows et al. 2004. Marijuana use and car crash injury. *Addiction* 100: 605-611.

[36] Movig et al. 2004. Psychoactive substance use and the risk of motor vehicle accidents. *Accident Analysis and Prevention* 36: 631-636.

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- [37] Drummer et al. 2004. The involvement of drugs in drivers killed in Australian road traffic crashes. *Accident, Analysis and Prevention* 36: 239-248. "Drivers with THC in their blood had a significantly higher likelihood of being culpable than drug-free drivers. For drivers with blood THC concentrations of 5 ng/ml or higher the odds ratio was greater and more statistically significant."
- [38] Laumon et al. 2005. Cannabis intoxication and fatal road crashes in France: a population base case-control study. *British Medical Journal* 331: 1371-1377.
- [39] Sewell et al. 2009. The effect of cannabis compared with alcohol on driving. *The American Journal on Addictions* 18: 185-193. "Case-control studies are inconsistent, but suggest that while low concentrations of THC do not increase the rate of accidents, and may even decrease them serum concentrations of THC higher than 5 ng/mL are associated with an increased risk of accidents."
- [40] Bedard et al. 2007. The impact of cannabis on driving. *Canadian Journal of Public Health* 98: 6-11.
- [41] Laumon et al. 2005. Cannabis intoxication and fatal road crashes in France: a population base case-control study. op. cit.
- [42] Ramaekers. Commentary on Cannabis and Crash Risk: Concentration Effect Relation. In: *Transportation Research Circular E-C096: Drugs and Traffic*. 2006.
- [43] Grotenhermen et al. 2007. Developing per se limits for driving under cannabis. *Addiction* 102: 1910-1917.
- [44] Ramaekers et al. Dose related risk of motor vehicle crashes after cannabis use: an update. In: *Drugs, Driving, and Traffic Safety* (eds. Vester et al.) World Health Organization, 2009. "Individual drivers can vary widely in their sensitivity for THC induced impairment as evinced by the weak correlations between THC in serum and magnitude of performance impairment."
- [45] US Department of Transportation, National Highway Traffic Safety Administration. *Marijuana and Actual Driving Performance: Final Report*. op. cit. "One of the program's objectives was to determine whether it is possible to predict driving impairment by plasma concentrations of THC and/or its metabolite, THC-COOH, in single samples. The answer is very clear: it is not. Plasma of drivers showing substantial impairment in these studies contained both high and low THC concentrations; and drivers with high plasma concentrations showed substantial, but also no impairment, and even some improvement."
- [46] Elliot et al. Marijuana DUI Workgroup: Recommendation to the Drug Policy Task Force and Colorado Commission on Criminal and Juvenile Justice. 2011. "Whereas BAC (Blood Alcohol Content) can be accurately measured and correlated with behavioral impairment, this may not be the case with cannabis ... Alcohol is water soluble; cannabis is stored in the fat and is metabolized differently, making a direct correlation with behavior difficult to measure."
- [47] Ramaekers et al. 2006. Cognition and motor control as a function of Delta-9-THC concentration in serum and oral fluid: Limits of impairment. op. cit.
- [48] Toennes et al. 2008. Comparison of cannabinoid pharmacokinetic properties in occasional and heavy users smoking a marijuana or placebo joint. op. cit.

[49] Karschner et al. 2009. Do Delta-9-tetrahydrocannabinol concentrations indicate recent use in chronic cannabis users? op. cit.

[50] Toennes et al. 2008. Comparison of cannabinoid pharmacokinetic properties in occasional and heavy users smoking a marijuana or placebo joint. op. cit.

[51] Wille et al. 2010. Conventional and alternative matrices for driving under the influence of cannabis. *Bioanalysis* 2: 791-806. "[I]n DUID cases, the delay between the accident and the final blood draw can be long and back-extrapolation is not an option due to the complex pharmacokinetic profile of THC."

[52] According to the 2011 White House Drug Control Strategy, Action Items: 1.5.A: Encourage States to Adopt Per Se Drug Impairment Laws: "Fifteen states have passed laws clarifying that the presence of any illegal drug in a driver's body is per se evidence of impaired driving. ONDCP will work to expand the use of this standard to other states and explore other ways to increase the enforcement of existing DUID laws." A state-by-state summary of DUI laws is available from NORML.

[53] Ramaekers et al. 2004. Dose related risk of motor vehicle crashes after cannabis use. *Drug and Alcohol Dependence* 73: 109-119. "Experimental studies have shown alcohol and THC combined can produce severe performance impairment even when given at low doses. The combined effect of alcohol and cannabis on performance and crash risk appeared additive in nature, i.e. the effects of alcohol and cannabis combined were always comparable to the sum of the effects of alcohol and THC when given alone."

[54] Ibid.

[55] US Department of Justice, Bureau of Justice Statistics. op. cit.

[56] US Department of Health and Human Services, Substance and Mental Health Services Association, Office of Applied Studies. 1998. op. cit.

[57] Ibid.

[58] Canadian Public Health Association. "The Pot and Driving Campaign."

[59] US Government Accountability Office. ONDCP Media Campaign: Contractor's National Evaluation Did Not Find that the Youth Anti-Drug Media Campaign Was Effective in Reducing Youth Drug Use: Report to the Subcommittee on Transportation, Treasury, the Judiciary, Housing and Urban Development, and Related Agencies, Committee on Appropriations, U.S. Senate. August 25, 2006.

[60] <http://www.coloradodot.info/programs/alcohol-and-impaired-driving>

[61] Papafotiou et al. 2005. An evaluation of the sensitivity of the Standardised Field Sobriety Tests (SFSTs) to detect impairment due to marijuana intoxication. *Psychopharmacology* 180: 107-114.

[62] Looby et al. 2007. Roadside sobriety tests and attitudes toward a regulated cannabis market. *Harm Reduction Journal*. Online document accessed November 24, 2007.