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Driving While Stoned: Issues and Policy Options

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Abstract

THC is the most commonly detected intoxicant in US drivers, with approximately 13% of drivers testing positive for marijuana use, compared to the 8% that show a measurable amount of alcohol (NHTSA, 2015). Because cannabis use remains detectable for much longer than alcohol, and also for long after the driver is no longer impaired, the difference in rates does not show that stoned driving is more common than drunk driving. Nonetheless, cannabis intoxication while driving is on the rise and has been shown to impair reaction time and visual-spatial judgment.

Many states, including those where cannabis sales are now permitted by state law, have laws against cannabis-impaired driving based on the drunk-driving model, defining criminally intoxicated driving as driving with more than a threshold amount of intoxicant in one's bloodstream—a *per se* standard—as opposed to actual impairment. That approach neglects crucial differences between alcohol and cannabis in their detectability, their pharmacokinetics, and their impact on highway safety.

Cannabis intoxication is more difficult to reliably detect chemically than alcohol intoxication. A breath alcohol test is (1) cheap and reliable; (2) sufficiently simple and non-invasive to administer at the roadside; and (3) a good proxy for alcohol in the brain, which in turn is (4) a good proxy for subjective intoxication and for measurable driving impairment. In addition, (5) the dose-effect curve linking blood alcohol to fatality risk is well-established and steep.

None of those things is true for cannabis. A breath test remains to be developed. Oral-fluid testing can demonstrate recent use but not the level of impairment. A blood test requires a trained phlebotomist and therefore a trip to a medical facility, and blood THC levels drop very sharply over time-periods measured in minutes. Blood THC is not a good proxy either for recency of use or for impairment, and the dose-effect curve for fatality risk remains a matter of sharp controversy. The maximum risk for cannabis intoxication alone, unmixed with alcohol or other drugs, appears to be more comparable to risks such as talking on a hands-free cellphone (legal in all states) than to driving with a BAC above 0.08, let alone the rapidly-rising risks at higher BACs. Moreover, the lipid-solubility of THC means that a frequent cannabis user will always have measurable THC in his or her blood, even when that person has not used recently and is neither subjectively intoxicated nor objectively impaired. That suggests criminalizing only combination use, while treating driving under the influence of cannabis (however this is to be proven) as a traffic offense, like speeding.

The Dangers of Driving

Highway injuries contribute importantly to morbidity and mortality, and – after years of steady decline – are now on the rise again. In 2016, 37,000 were people killed in crashes on U.S. roads. That was the second consecutive year-on-year

increase, totaling some 14% over the two years. (NHTSA, 2017). The Centers for Disease Control and Prevention (CDC) cite motor vehicle crashes as the leading cause of death among 25-to-34-year-olds in the U.S. (CDC, 2017).

The high death and injury toll from motor vehicle accidents is due to the volume of driving rather than to its riskiness. Nearly 3 trillion vehicle passenger miles were logged in the U.S. in 2012 (National Highway Traffic Safety Administration [NHTSA], 2014) with rates of with 80 injuries and 1.1 deaths per 100 million vehicle passenger miles (NHTSA, 2014 and US Census Bureau, 2014). Thus, on average, a round trip to a destination five miles away creates a one-in-10-million fatality risk. It is the accumulation of such small risks across an enormous amount of traffic that leads to substantial injuries and deaths.

Not all trips carry the same risk. Drivers between 30 and 60 are safer (per mile) than younger or older drivers. Collision and fatality rates also rise dramatically when a driver is impaired by alcohol, other drugs, drowsiness, or distraction. Thus, policies that reduce the fraction of miles driven under the influence of intoxicants will reduce traffic fatalities.

The legalization of the commercial production and sale of cannabis will likely result in more miles driven under the influence of cannabis. Over the past quarter-century, changes in attitudes, policies, and cannabis markets have increased cannabis consumption dramatically: the number of daily and near-daily users increased by an estimated factor of eight between 1990 and 2014 (Hedden, 2015).[1] Estimated physical volume of cannabis consumption doubled between 2004 and 2014, and rising potency suggests that intoxication levels also rose (Hedden, 2015). Americans now spend an estimated 15 billion hours under the influence of cannabis per year, with no sign of consumption slowing soon (Wile, 2015.)

While drunk driving is almost universally disapproved of and regarded as dangerous, a plurality of cannabis users believe that driving under the influence of cannabis has no effect on, or even decreases, a driver's risk of crashing, and only 38% believe that driving under the influence of cannabis increases crash risk (Arnold and Tefft, 2016). This underestimation of the risks of intoxication coupled with current consumption trends means that even if cannabis intoxication only moderately increases per mile risk, the level of cannabis-impaired driving may be high enough to contribute significantly to highway injury and death. The use of cannabis in

[1] While rates cannabis use, and thus driving under the influence of cannabis, were likely substantially higher in the 1970's-1980's compared to the 1990's and perhaps even today, historical consumption data are difficult to gauge accurately due to a lack of consistent survey methodology.

combination with alcohol and other drugs may increase highway risk more than additively.

Some states have now passed cannabis-specific intoxicated driving statutes that attempt to regulate cannabis in the same manner as alcohol, by creating a blood THC level that would define "stoned driving" as drunk driving is defined: by chemistry rather than by behavior. Driving under the influence of cannabis is already a criminal offense in all 50 states under catch-all impaired driving statutes (Armentano, 2013). Impaired driving statutes are not substance-specific and require evidence that a person both consumed a substance (licit or illicit) that could cause intoxication in his system and that substance caused physical or mental impairment that made the driver unable to drive safely; this is called the "actual impairment" standard (NOLO, 2014). The new laws, by setting a level of THC in blood (or saliva, or breath) that, combined with driving, is sufficient to prove the offense (the "*per se*" standard) eliminate the need for prosecutors to demonstrate behavioral impairment. That makes such cases much easier to prove, but at some risk of criminalizing behavior that is not in fact unduly risky. In the extreme, "zero tolerance" laws set the limit at zero and criminalize driving with any detectable amount of cannabis on board.

In addition, given the long and not-entirely-predictable periods during which THC remains in blood, *per se* laws based on blood levels make it difficult, or even impossible, for a driver who has used cannabis in the recent past to know whether driving would or would not constitute a crime. That risk is not present for alcohol. A can of beer, a glass of wine, a shot of spirits, and a mixed drink all contain about the same amount of alcohol (about three-quarters of a fluid ounce, a "standard drink"); the blood level of alcohol declines by approximately one drink per hour; and the number of drinks that will bring a user up to the .08% BAC legal limit is determined by body weight (roughly, four for an average-sized woman, five for an average-sized man). Therefore any drinker who can count, tell time, and subtract can determine with fair accuracy whether he or she would fail an alcohol breath test. Alternatively, a drinker can use an alcohol-breath testing device to take an actual measurement before getting behind the wheel. No such calculation will work for cannabis, and a cannabis blood test is not something a typical user can perform on himself or herself.

Eighteen states have cannabis-specific *per se* or zero-tolerance statutes. Six *per se* states (Colorado, Montana, Nevada, Ohio, Pennsylvania, and Washington) designate levels of THC and its metabolites (analogous to the 0.08% BAC standard) above which the driver is presumed to be impaired, while the other twelve states (Arizona, Delaware, Georgia, Illinois, Indiana, Iowa, Michigan, Mississippi, Rhode Island, Utah, South Dakota and Wisconsin) have zero-tolerance rules, creating criminal liability for the presence of any cannabinoid or metabolite in a driver's body

(NORML, 2016 and GHSA, 2016). Both Colorado and Washington (states in which recreational cannabis is legally available) adopted *per se* limits of five nanograms of THC (which in practice includes the two main THC metabolites, the active hydroxy-THC and the inactive and longer-lived carboxy-THC)[2] per milliliter of blood—though Colorado's "permissive inference" rule allows an affirmative defense that the driver's exceeding the five-nanogram threshold did not constitute impairment in fact (NORML, 2016).

This trend towards criminalizing driving under the influence of cannabis relies on two assumptions that are not fully supported by the available data: that driving under the influence of cannabis is dangerous enough to warrant criminal (as opposed to administrative) punishments and that *per se* standards are the best way to measure cannabis intoxication.

The Dangers of Impaired Driving

Measuring/Estimating Risk

The risks of unsafe driving behaviors and conditions can be measured both statistically, by studying actual accidents, and experimentally in the laboratory. Case-control studies compare the rate of detected cannabis use (however defined) in the drivers involved in accidents with the same rate in a control group of drivers on the same roads at the same times who did not crash, and then use the ratio of probabilities to establish relative risk: if, say, 3% of the controls test positive, but 6% of the crash-involved drivers, the relative risk is 2.

Researchers also use driving simulators to test drivers in virtual driving situations under conditions that would be dangerous if the subjects were actually driving on real roads, measuring both simulated "accidents" and also performance degradation on tasks such as maintaining distance. Closed-course tests (actual driving but on test tracks rather than the open road) have also been used to measure performance.

These methods can be used to measure how risk levels change as the level of intoxication increases: the results are shown in what are called "dose-effect curves," which plot measured risk or impairment (the effect) against the level of intoxication (the dose). Determining the dose-effect curve for cannabis poses a harder problem than for alcohol because the relationship between blood THC and impairment is

[2] For more information on the metabolism of cannabis and its byproducts, see Roth, 2015

more complex, because of the pharmacokinetics of cannabis (the long dwell-times in the body of both THC and some of its metabolic products), and because some blood tests fail to distinguish between the psychoactive THC molecule, and its active 11-hydroxy metabolite, on the one hand and the inactive carboxy form on the other.

The Risks of Driving Under the Influence of Alcohol, Cannabis, and their Combination

Driving while impaired by alcohol and other drugs is a major cause of vehicle collisions, injuries and deaths. In the U.S., approximately one-third of all fatal motor vehicle collisions include at least one alcohol-impaired driver (CDC, 2014). Since even sober driving carries some risk, intoxication cannot properly be blamed for all deaths where the driver was impaired. Clearly, though, fatalities are more common among chemically impaired drivers than among sober drivers; even when sampling on weekend nights, when impairment is at its peak, only roughly 8% of all drivers test positive for alcohol and even fewer (roughly 3%) test above the per se .08 BAC limit (Lacey et al, 2009).

ALCOHOL

Motorists driving under the influence of alcohol have a greater risk of being involved in a fatal motor crash than those who drive sober (Li et al, 2013). The average crash risk for a driver with any detectable level of alcohol in his or her system (BAC > 0.01%) is approximately 6.5 times as high as the risk for those who drive sober (Zador et al, 2000); that figure reflects the blended effects of lower risks at lower levels and higher risks at higher levels. Risk rises dramatically with the level of intoxication: drivers with a BAC of 0.09% (slightly above the legal limit) are 11 times as likely to be involved in a fatal crash as a sober driver would be; drivers with a BAC of 0.125% are 30 times as likely; and drivers with a BAC of 0.22% are 380 times as likely (Zador et al, 2000).

These relative risk figures are not multiples of the average fatality risk of 1.1 deaths per 100 million vehicle passenger miles, because that rate reflects drunk driving as well as sober driving. The baseline for a sober driver is roughly half that level. Therefore drivers just above the legal limit will generate about 3 deaths per 100 million vehicle passenger miles. So, even though impaired driving is always illegal and socially irresponsible, the vast majority of impaired drivers get to their destination safely. However, even at a modest risk per trip, the frequency of drunken driving (an estimated 112 million incidents per year, based on self-report and defined as driving "when you've had perhaps too much to drink") leads to thousands of fatalities (CDC, 2013, and Bergen et al, 2011).

The increase in driving risk from alcohol consumption is not distributed equally. Compared to sober drivers with the same demographic profile, alcohol leads

to greater risks for younger drivers and for men (Zador et al, 2000 and Voas et al, 2012). For example, a 16-year-old male with a BAC of 0.09% is 3 times as likely to be involved in a fatal crash as a 16-year-old female with the same BAC, and 5 times as likely to be involved in a fatal crash as the average driver with a 0.09% BAC (Zador et al, 2000). Despite the relevance of age and gender, BAC is still by far the dominant risk factor; an inebriated 16-year-old male is 52 times as likely to be involved in a fatal accident as a sober 16-year-old male. High BACs are particularly associated with fatal crashes; drivers with BAC above 0.08% are responsible for more than five-sixths of all deaths involving detectable amounts of alcohol (NHTSA, 2014).

CANNABIS

Research conclusions about the risk of driving under the influence of cannabis are still preliminary, with the answers to key questions, including the relative risk of driving under the influence of cannabis, still subject to fierce debate. Despite the uncertainty, three relevant facts are clear: driving under the influence of cannabis adds to crash risk, especially in combination with alcohol and other drugs; the risk of driving under the influence of cannabis alone, even at high levels, is much lower than the risk of driving under the influence of high levels of alcohol; and the pharmacokinetics of cannabis make it difficult to convincingly use chemistry to demonstrate impairment. .

Cannabis use acutely degrades driving ability, particularly on automated driving responses (Asbridge et al, 2012 and Grotenhermen et al, 2005). Cannabis use impairs both attention and psychomotor performance (Ramaekers et al., 2004). Additionally, consumption can cause drowsiness and lethargy, slow reaction times, and alter time perception, which can lead a driver to swerve or to follow other cars too closely (Ramaekers et al., 2004). Neither the quantity of cannabis (nor its primary active agent THC) consumed, or the blood level of THC, strongly predicts the degree of impairment. While higher THC concentrations generally have been found to correlate with higher impairment, the dose-effect relationship between cannabis consumption and crash risk has not yet been established (Sewell et al, 2009). This variation in cannabis impairment may be related to THC tolerance. A 2011 study on tolerance and cross-tolerance to neurocognitive effects of THC and alcohol in heavy cannabis users generally confirmed the conclusion of prior studies that heavy cannabis users develop tolerance to the impairing effects of THC (Ramaekers et al, 2011).[3]

[3] Higher tolerance by heavy users should not be interpreted as those users being minimally impaired when under peak influence of cannabis at their usual high doses. Higher THC concentrations are associated with higher levels of impairment overall, even

Despite these clear findings that cannabis negatively impacts many factors that are critical for safe driving, the epidemiological literature is mixed on the relative risk of cannabis-impaired driving compared to driving without cannabis, with two recent meta-analyses reaching different conclusions. Asbridge et al. (2012) found drivers who consumed cannabis less than 3 hours before driving were roughly twice as likely to be involved in a fatal motor vehicle crash per mile driven than non-cannabis-consuming drivers. Elvik (2013) found no significant increase in risk of fatal motor vehicle accidents from cannabis consumption; however, that same study did find a significant increase in risk of a crash causing property damage.

A potential explanation for this split is the difference in inclusion criteria. Asbridge et al (2012) excluded studies that tested for inactive metabolites whereas Elvik (2013) included studies that used inactive metabolites[4] as a proxy for cannabis consumption (e.g., Bates and Blakely, 1999). Such an inclusion would attenuate the connection between cannabis consumption and increased risk, as inactive cannabis metabolites persist long after intoxication has faded away. This reasoning is supported by the findings of Li et al. (2012), a meta-analysis which analyzed study results by sampling procedure. They found studies that used urine tests, which test for inactive metabolites[5], did not show a significant increase in fatal crash risk, while studies that used blood analysis and self-report, which respectively only test for active metabolites or consumption that would result in intoxicated driving, both found significant increases in fatal crash risk from cannabis consumption (Li et al., 2012). The very rapid decrease in THC levels after cannabis smoking--with a half-life measured in minutes rather than hours (Hartman et. al., 2016)—suggests that studies looking at all cannabis-impaired drivers may underestimate the risks of driving immediately after smoking (or, in the extreme, while smoking), while also suggesting detecting and proving that behavior would be extraordinarily difficult under routine law-enforcement conditions, due to the lack of a breath test and the impracticability of roadside blood draws.

Due to these conflicting results, research continues. The most recent case-control study to examine this issue was done by the National Highway Traffic Safety Administration (NHTSA), which examined blood samples, oral swabs, and self-report consumption data[6] for more than 3,000 crash-involved drivers and over 6,000 control drivers through a 20-month period (Compton & Berning, 2015). They found a slightly increased risk of fatal collisions (relative risk of 1.25 times baseline) from cannabis consumption, but that increase that disappeared once demographic

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though the relative and expected severity of impairment and level of crash risk at a given dose may vary based on the quantity of cannabis the user regularly consumes.

[4] For a summary of commonly tested metabolites, see Musshoff and Madea (2006).

[5] Specifically, 11-*nor*-9-carboxy-delta-9-tetrahydrocannabinol

[6] Testing only for active forms of THC.

variables (i.e., age and gender) were considered (Compton & Berning, 2015). Importantly, the NHTSA only tested for active molecules. Meta-analyses and individual studies that suggest risk generally report relative risks of 2 or less[7], approximating the RR of a blood-alcohol content of .04%, the legal limit for drivers of commercial vehicles, rather than RR of 11 to 52, depending on age and gender, associated with the BAC of .08-.10% that defines "drunken driving" for non-commercial drivers (Zador, 2000). A relative risk increase of 2 puts cannabis at the bottom of the list of drug categories; use of narcotics, stimulants, depressants, and polydrug use (two or more non-alcohol drugs) posed higher crash risk for drivers, ranging from 2.9 times from narcotics to 4.6 times from depressants (exclusive of alcohol) (Li et al, 2013; Compton & Berning, 2015). By contrast with alcohol, the increased risk of fatal crash involvement associated with drug use does not appear to vary materially by age group, sex, time of day, or geographic region (Li et al, 2013).

Thus, the fatal-collision risks associated with cannabis use alone do not seem to be comparable with those associated with commonly detected levels of alcohol use, or even with the established risk (RR of approximately 4) of "hands-free" cell phone use, which remains legal in every state.

COMBINED ALCOHOL AND CANNABIS USE

The simultaneous use of alcohol and cannabis is linked to higher levels of driver impairment than either alone (Ramaekers et al, 2000; Department for Transport, 2014). Drivers testing positive for both alcohol and other drugs were at more than twice the risk of being involved in a fatal crash as those impaired by alcohol alone (Li et al, 2013). Driving simulations show greater impairment from combined alcohol and cannabis use than that from either substance alone, even at low doses (Brady and Li, 2014). Experimental studies that evaluated the impact of cannabis and alcohol on driving skills determined that standard deviation of lateral position, time driven out of lane, reaction time, and standard deviation of headway were all more-than-additively impaired by the combination of the two drugs (Ramaekers et al, 2000). The substantial impairment and high vehicle crash risk from simultaneous alcohol and cannabis use suggests a synergistically deleterious effect on driving ability (Asbridge, 2014).[8]

Increasing driver awareness of these effects is important, especially for those who may erroneously conclude that they can avoid impairment by consuming each

[7] Some outlier studies have reported relative risk increases of up to 28.88 (see, for example Li et al., 2013; Grotenhermen et al, 2007; Asbridge, 2014; Koerth-Baker, 2014; for the extreme estimate, see Hels et al., 2011)

[8] But see, White (2017), a self-published manuscript claiming the population of combined cannabis-alcohol using drivers is heavily weighted toward drivers with high BACs and accounting for their higher BACs removes the observed synergistic effects.

substance at levels below legal limits. This need for increased education efforts is heightened by the results of several studies that identified heavy or increasing cannabis use in adults 21-and-over as having a spillover effect to increased binge drinking (Wen et al, 2014).

Factors that Decrease the Risks of Stoned Driving

Intoxication patterns and the meta-cognitive awareness of cannabis users may reduce the impact of cannabis on driving safety. Laboratory studies of cannabis-impaired driving find perceptual and motor impairments of various kinds but not elevated risk of "crashes" in driving simulators (Sewell et al, 2009 and Smiley, 1998). Even at levels nearly twice the 5 ng/ml legal limit in some states, the measured performance degradation with respect to perceptual and motor tasks is approximately equivalent to that at the legal BAC threshold of 0.08 (Grotenhermen et al 2005). This discrepancy can be partially explained by the relatively minimal impact of cannabis on higher cognitive functions associated with driving, such as divided attention tasks. This means that complex tasks requiring conscious control, such as interpreting and anticipating traffic, are less affected by cannabis (Grotenhermen et al, 2005).

Further, drivers subjectively under the influence of cannabis are generally aware that they are impaired and adjust their driving accordingly by taking fewer risks and acting less aggressively--indeed, there is evidence they may *over*estimate their impairment, which is the opposite reaction of those under the influence of alcohol (Sexton et al, 2000; Sewell et al, 2009). This heightened awareness of impairment may account for the ability of cannabis-impaired drivers to correctly respond to a driving situation if given a warning; however, "where events are unexpected, such compensation is not always possible" (Grotenhermen et al, 2005).[9]

The relatively short duration of cannabis impairment might also mitigate its risk. The highest levels of impairment occur approximately 20 to 40 minutes after smoking, with no measured impairment after 2.5 hours for those who smoke 18mg THC or less (the dose most often used in experiments to duplicate a single joint)

[9] It might be the case that stoned drivers who are aware of being observed in experimental studies put special effort into driving as safely as possible and are able to drive more cautiously because of this focus, whereas stoned drivers on the road in normal driving situations have no such cue for heightened awareness and caution. However, the ability of test-observed stoned drivers to drive more safely may demonstrate that when attention is called to the need or desire to drive safely, especially because of their impairment, they not only comprehend the need and desire to do so, but, perhaps more significantly, also are still capable of doing so.

(Sewell et al, 2009). Even for higher doses, the effects of smoked cannabis tend to dissipate within 4 to 5 hours (Grotenhermen et al, 2005). The effects of oral cannabis are delayed compared to the effects of smoking, usually hitting their peak 2 to 3 hours after ingestion and lasting longer to an unpredictable extent depending in part on what else the cannabis consumer has in his or her stomach (Grotenhermen et al, 2005).

Cannabis use – even heavy, frequent use – has not been shown to impair driving ability after the period of acute impairment from cannabis consumption (Grotenhermen et al, 2005). A 2008 study of adolescent cannabis users found that after a month of abstinence the users showed subtle deficits in psychomotor speed, complex attention, planning and sequencing, and memory compared to non-cannabis using adolescents; however, no specific results relating to driving ability or impairment were found (Medinaet al, 2007). A study for the NHTSA on cannabis use and driving performance reported that performance impairments in a laboratory test showed the period of perceived "peak highs" correlated with impairment but that objective impairment generally dissipated more rapidly than the subjective feelings; this appears to be true even among consumers of higher-potency cannabis (Robbe and O'Hanlon, 1993; Ramaekers et al, 2006).

Factors that Increase the Risk of Stoned Driving

Trends in cannabis consumption and attitudes toward driving under the influence of cannabis suggest the risk of future increases in the frequency of stoned driving. Heavy use and potency of cannabis have consistently increased over the last few decades (University of Washington ADAI, 2013; SAMHSA, 2013; Kilmer et al, 2014), and it is estimated that current and continued changes in legalization of cannabis might increase time stoned by approximately 15 billion person-hours per year, with the bulk of that increase coming from frequent, heavy users (Kleiman, 2014). Heavy users [10] are predominantly young and male and account for approximately 23% of all users nationally (Light et al, 2014 and Kilmer et al, 2014). Heavy users consume larger doses per day than moderate or light users, meaning they are more likely to be intoxicated at a given moment and more likely to be more heavily intoxicated during a given period of intoxication (Kilmer et al, 2013 and Light et al, 2014). This is worrisome, as heavy users' consumption patterns indicate that they will be more likely to drive under the influence of cannabis and more likely to be heavily intoxicated while doing so.

Cannabis users generally underestimate the dangers of driving under the influence of cannabis and express a willingness to drive under its influence. (This

[10] Heavy users are those who use on 21 days or more each month; this includes medical users (Kilmer et al, 2014)

seems to contradict the finding that cannabis-impaired drivers are more self-aware about their impaired state than alcohol-impaired drivers, but it may reflect their understanding of that self-awareness and a belief that their attempts to compensate by driving more carefully and more slowly are more fully successful than is in fact the case.) Almost half of marijuana users (46%) believe that driving within an hour of cannabis use has no effect on, or decreases, a driver's risk of crashing, and only 38% believe ingesting marijuana increases crash risk (Arnold and Tefft, 2016). By contrast, only 11% of alcohol users believe that driving within an hour of alcohol consumption has no effect or decreases a driver's risk of crashing, and more than 55% believe that it increases crash risk (Arnold and Tefft, 2016). Studies indicate that driving after using cannabis is viewed by cannabis users as being safer than driving after alcohol consumption (Whitehill et al, 2014). Many younger drivers who drive under the influence of cannabis take the position that driving high is not a safety risk, with some even believing that cannabis improves driving performance by heightening awareness and concentration (Arterberry et al, 2013). Given these attitudes, it is unsurprising that cannabis is the most commonly detected psychoactive drug in drivers (Asbridge, 2014; Whitehill et al, 2014; Compton & Berning, 2015). As with consumption, these trends are concentrated in demographic groups that are predisposed to risky driving, creating the potential for a synergy of risk factors (Asbridge, 2014 and Whitehill et al, 2014).

Discouraging Impaired Driving

Regulating impaired driving requires a set of rules about what constitutes impairment, a means to reliably and accurately detect impairment, and a set of sanctions for detected impairment. Defining impairment and creating reliable procedures to detect it requires answering difficult technical and legal questions, and defining appropriate sanctions requires balancing individual rights and interests against social impact. For alcohol, reaching politically acceptable answers to these questions took decades of debate, activism, and research, leading to the current *per se* system, which defines "impairment" in purely terms of blood alcohol content.[11] The current ubiquity of that system, which makes it seem normal and natural, is a recent phenomenon.

Even though alcohol impairment can be inferred from cheap, simple, non-invasive breath testing, developing the technical knowledge and tools to reliably detect alcohol intoxication took decades of false starts, with attempts to ascertain intoxication from saliva, urine, and even cerebrospinal fluids all showing promise before failing (Roth 2015). When drunk-driving laws were first passed and for many years thereafter, the primary evidence in drunk-driving cases was provided by the

[11] For a more thorough discussion of the history of and debate surrounding the adoption of per se limits for alcohol, see Roth, 2015.

testimony of the arresting officer as to the pattern of driving that led to the initial stop and the results of behavior-based "field sobriety tests" such as standing on one foot, counting backwards, and walking a straight line. Such testimony often failed to convince juries: opinion, even trained opinion, is less convincing than the (apparently) objective numerical results of a chemical test, and is potentially subject to the officer's conscious or unconscious biases and to false positives when some condition other than intoxication – such as physical disability or drowsiness – is responsible for the driver's inability to properly perform the directed task. Blood testing to support a *per se* standard proved impracticable because a blood draw is sufficiently invasive to require a warrant[12] and requires training and professional credentials which law enforcement officers rarely have.

Once a reliable breath-based test was developed in the 1930's, it took another three decades of research to establish the dose-effect curve linking alcohol level to driving performance. Strong pressure from anti-drunk-driving activists and vigorous promotion by the federal government were required to secure the adoption of *per se* drunk driving laws; prior to this, juries routinely refused to convict drivers with BACs over the legal limit due to doubts about the driver's actual impairment. [13] Breathalyzer-based per se BAC statutes were strongly promoted by the federal government because of their significant advantages to law enforcement However, breathalyzers were initially resisted; only exhaustive scientific research proving their reliability, added to growing awareness of the death toll from drunken driving, led to their eventual acceptance (Roth 2015).[14]

There is some tendency to take the solution found for alcohol and apply it directly to the very different problems created by cannabis. That is unlikely to result in either an efficient solution, or a just one.

Defining, measuring and regulating alcohol impairment

Alcohol impairment closely tracks the level of alcohol in the brain; blood alcohol closely tracks brain alcohol; breath alcohol closely tracks blood alcohol. Thus a breath test – which a police officer can administer at the roadside – is a sufficient

[12] While this issue has not been settled for cannabis, the Supreme Court recently ruled in *Birchfield v. North Dakota*, 579 U.S. ___ (2016) that warrantless blood draws to determine a driver's alcohol intoxication was unconstitutional. However, this decision was explicitly colored by the availability of a less intrusive means of assessing alcohol intoxication (i.e., a breathalyzer), which does not yet exist for cannabis.

[13] For a full history of how breathalyzers and BAC came to dominate drunk driving laws, see Roth, 2015.

[14] Roth (2015) correctly notes that politics (specifically, efforts to decrease juries' de facto nullification of previous drunk driving laws) also played a large role in driving the ubiquity of and perhaps excessive reliance on breathalyzers.

proxy for impairment. Consequently, driving with a blood-alcohol concentration (BAC) above 0.08 percent (0.08 g of alcohol/100 ml of blood) as measured by a breathalyzer is illegal in all 50 states and the District of Columbia (GHSA, 2016). For drivers under 21 years of age (the legal drinking age in the U.S.) and commercial vehicle drivers, the standards are even more restrictive. Many states have a zero-tolerance standard for BAC for drivers under 21 (GHSA, 2016). The National Highway Systems Designation Act of 1995 required all states to set 0.02 BAC or lower as the driving under the influence (DUI) measure for drivers under 21 years old or face reductions in their federal highway funds (US GAO, 1999 and Thompson Reuters, 2014). All states ultimately adopted such a standard, so the BAC limit for DUI for all US drivers under 21 is between 0.00 and 0.02 (IIHS, 2014 and Thompson Reuters, 2014). For bus drivers, truck drivers and other professionals with a commercial driver's license, the BAC in most states is 0.04, in accordance with the Federal Motor Carrier Safety Administration (FMCSA) standard.

Convicted drunk drivers face a variety of penalties: suspension or even revocation of the driver's license, fines, community service requirements, and mandated alcohol treatment. The mandatory installation of an ignition interlock – which in effect requires the driver to take a breath test before starting the vehicle – is increasingly common. (GHSA, 2016).

A second or subsequent DUI conviction, or a conviction where the BAC level exceeds not only .08% but some higher level as well, or where the driver's behavior is especially reckless – can lead to jail time; some states make such sentences mandatory, and some make a third DUI is a felony. (NOLO, 2014 and Mothers Against Drunk Driving, 2012). At any one time about 50,000 people are serving jail or prison sentences for DUI. [15] If drunken driving results in death, the driver can be charged with manslaughter.

[15] This DUI incarceration estimate was developed using information from FBI Uniform Crime Reports – 2011 (FBI,2014) and a Bureau of Justice Statistics Special Report on DWI Offenders Under Correctional Supervision (Maruschak, 1999)

Defining, Measuring, and Regulating Cannabis Impairment

Drunk driving regulations, limits, and tests have been accepted as providing a blueprint for creating stoned-driving laws; the familiarity of that set of rules in the context of alcohol makes them seem natural. However, cannabis differs significantly from alcohol: detection is far more difficult, risk (except in the presence of other drugs, including alcohol) is far lower, and the dose-effect curve is less well established.

DETECTION

Cannabis is a complex substance, especially when compared to alcohol. Cannabis smoke is known to contain more than 400 possibly psychoactive compounds, with, among them, more than 2,000 known metabolites, some of which are themselves psychoactive while others, despite close chemical similarity, are not (Roth 2015). Some of these metabolites are detectable before impairment begins and persist long after impairment has subsided (Roth 2015). Alcohol, by contrast, contains a single psychoactive substance (ethyl alcohol), which creates no long-lasting metabolites and is quickly excreted from the body (Roth 2015).

THC, the most psychoactive chemical in cannabis, "appears in plasma immediately after the first puff [...] with concentrations peaking approximately 13 min. after smoking" (Desrosiers et al, 2014) and falling off rapidly. Cannabis impairment peaks approximately 20-40 minutes after smoking (Sewell et al, 2009). Alcohol impairment, by contrast, closely tracks blood alcohol concentration (Schwope et al 2012 and Tupler et al, 1995).[16] Cannabinoids and their metabolites are lipid-soluble and are re-released into the bloodstream for days after cannabis use. One study of heavy cannabis users reported 24% of subjects tested positive for active levels of THC after seven days of abstinence (Karschner et al 2009). Thus a *per se* rule, even if carefully drafted and based on technology capable of distinguishing between active and inert metabolites, carries a substantial risk of criminally punishing someone for impaired driving who was not, in fact, impaired.

There is no breath test for cannabis, although research is underway. Blood tests cannot be conducted by law enforcement officers roadside, and the very rapid

[16] The time differences between peak detectable cannabinoid concentrations and peak cannabis impairment are an example of "counter-clockwise hysteresis" or "the retardation or lagging of an effect behind the cause of the effect" (Schwope et al., 2012, and Pleuvry, 2005).

but not perfectly predictable decrease in THC concentration means that a blood test conducted one or two hours after the initial stop is likely to be inconclusive. The long half-lives of cannabinoid metabolites mean that positive urinalysis results demonstrate some use of cannabis in the several days (or, for frequent heavy users, weeks) before the test, but not that the person tested had used recently enough to be still impaired[17]. A breath test or a cheek swab might be designed to give a positive result for about as long as actual impairment lasts, but there are to date no such tests whose results have been accepted as valid in court (Grotenhermen et al., 2005; Cone and Huestis, 2007; Himes et al, 2013).

There are at least two promising alternatives to either chemical testing or expert-based behavioral testing: gaze testing and computerized analysis of driving patterns. Various drugs, including cannabinoids, have been shown to produce characteristic eccentricities in the tiny movements of the eyeball while the subject attempts to look straight ahead. It is possible that a field test nearly as simple and reliable as the alcohol breath test might be developed on that principle, with the result generated by a testing device rather than an expert observer. Similarly, there is evidence that drugs produce characteristic variations in subtle aspects of driving performance, such as the frequency and pattern of small changes in direction to stay in lane and small changes in speed to maintain following distance. Those, too, might turn out to be detectable by a computerized pattern-recognition process.[18]

Unless and until such tests are developed and accepted, enforcement will have to depend either on field sobriety tests (always partly subjective, and vulnerable to false-positive results from physical or behavioral deficits not caused by intoxication) or on chemical tests likely to produce high rates of both false-positive and false-negative results with respect to actual driving impairment.

RISK

As noted above, even if cannabis impairment is present, it creates (unless combined with alcohol or other drugs) only a fraction of the risks associated with driving at the legal 0.08 BAC threshold, let alone the much higher risks associated with higher levels of alcohol. Even if the testing situation were better-resolved than it currently is, criminally penalizing driving under the influence of cannabis (alone) criminally with arrest and possibly incarceration is disproportionate to how we treat

[18] See, e.g., Joh (2016) for the problems inherent in any system of automated enforcement with surveillance

driving under comparably severe impairments (e.g., driving while using a cellphone, or while drowsy).[19] Those risky behaviors a typically punished – if at all – as traffic infractions, like speeding or running a stop sign, not as criminal offenses.

Per se rules based on metabolites are also hard to square with the principle that someone subject to a criminal law should be able to reliably determine whether some contemplated course of conduct is in violation of a given law. While a drinking driver can easily use readily-available charts (based on body weight, number of drinks consumed, and time since the last drink) to determine whether he or she is above the legal limit a cannabis-using driver facing a *per se* rule does not have that capability. For a drinking driver, 0.08% BAC equates with three or four drinks (depending on body weight) and the liver will remove from the bloodstream the equivalent of about one drink per hour. If a person had X drinks starting Y hours ago, then a typical-sized man will be below the limit as long as X minus Y is less than 4, while a typical-sized woman will be below the limit as long as X minus Y is less than 3. A cautious drinker might want to wait an extra hour, or even give himself or herself a breath test with commercially available devices (now including cell-phone accessories). By contrast, the time-course of blood cannabinoid levels is not nearly so predictable, so someone who has recently used cannabis has no better than a guess about whether driving would mean breaking a stoned-driving law defined by a chemical test.

Conclusion: What is to be Done?

A cheek swab or breath test that could detect with reasonable accuracy cannabis use within the past two or three hours might provide the basis for a *per se* stoned-driving rule with acceptable false-positive and false-negative rates. So might a gaze test or computer-based pattern recognition that could detect the unique deficiencies in driving performance or cognitive abilities caused by cannabis use. Until then enforcement must rely on field sobriety testing, with all its drawbacks.

Even assuming that an acceptable test can be developed, the argument above suggests that stoned driving alone (not involving alcohol or other drugs) should be treated as a traffic infraction rather than as a crime, unless aggravated by recklessness, aggressiveness, or high speed.

[19] Driving while using a handheld cellphone to make a call increases damage/injury causing crash risk roughly two-fold (Dingus 2016). While most states allow driving while using of "hands-free" cellphones, there is evidence that cellphone risk comes more from the distraction of carrying on a conversation than from the mechanical challenge of driving with only one hand on the wheel (Ship, 2010).

However, the synergistic dangers of cannabis plus alcohol plus driving are large enough to justify criminalization. One approach – assuming, again, the development of an acceptable technology of cannabis-impairment testing – would be to redefine drunk driving to include driving with any measurable blood alcohol concentration while also impaired by cannabis, or perhaps simply within three hours of using cannabis. In addition to reflecting the greatly enhanced risks of poly-drug-impaired driving, such a law would be easy to obey. The duration of measurable impairment after cannabis use may be somewhat unpredictable, but the time-course of blood alcohol content is much less so: X hours (or, to be on the safe side, X+1 hours) after consuming X drinks, BAC will be near zero. So anyone who has used cannabis within the past few hours would simply need to wait that long after drinking before driving to avoid a criminal charge.

In parallel, stoned driving could be discouraged by making it a traffic offense – again, assuming a test of adequate accuracy – and by aggressive promotion of anti-stoned-driving messages to cannabis users, many of whom do not currently believe that stoned driving is dangerous. States that allow the sale of cannabis – either under medical recommendation alone or for general adult use – might reasonably require licensed cannabis producers and retailers to communicate such messages prominently in their advertising, on their websites, and at the point of sale, and to do so more vigorously and effectively than the producers and retailers of alcoholic beverages currently communicate messages about not drinking and driving.

Compared to criminalizing stoned driving, the policy proposed above would doubtless lead to somewhat more impaired driving and therefore somewhat more collisions, injuries, and even deaths (Larkin 2015). But the same might be said of not criminalizing driving while drowsy, or while using a cell phone, or speeding. The interests of safety do not deserve lexicographic preference over the principles of justice, and criminalizing an only modestly risky behavior by creating a law that makes people guess about whether their behavior is legal or not violates those principles.

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