Drug-Impaired Driving
Research Needs

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The opinions, findings, and conclusions expressed in this report are those of the authors.

Introduction

The emergence of drug-impaired driving, notably marijuana-impaired driving, is a priority concern among road safety stakeholders. In particular, the availability and potency of marijuana has increased, and the legalization of different forms of marijuana has occurred in many jurisdictions around the world. Moreover, this drug type has warranted greater attention in light of evidence suggesting that marijuana is more commonly detected in fatally injured drivers than other types of illicit drugs.[1]

Of equal concern, in comparison to alcohol, much less is known about marijuana and driving in terms of the prevalence of the problem, the consequences on driving performance, and strategies to manage marijuana-impaired drivers. In sharp contrast, alcohol-impaired driving has been a topic of research for more than 60 years and the knowledge base and evidence are well-established. A clear understanding of the concentration–response relationship of alcohol has helped structure laws and enforcement efforts related to alcohol-impaired driving. Furthermore, roadside detection methods and measures of impairment are standardized for alcohol, and the knowledge base regarding alcohol countermeasures is also more advanced.

For these reasons, substantial investment in research about marijuana-impaired driving is essential to inform solutions. It is imperative that research is pursued across disciplines to increase the understanding of the problem and inform strategies to protect the public and reduce the incidence of fatalities and injuries as a result of marijuana-impaired driving. As a precursor to these research efforts, more robust and better data are paramount to create a strong foundation to increase knowledge and understanding of this issue. Practical strategies to fill these data gaps developed with the consideration of process variables and outcomes measures can help strengthen data collection efforts.

To this end, this report describes eight priority research topics that span several disciplines and identifies the top research needs in each area that are crucial to increase the understanding of this issue. These high-level research needs are based on key areas that emerged from the Alcohol, Other Drugs, and Transportation Committee midyear meeting in August 2017, and special session on marijuana and driving at the 97th Annual Meeting of the Transportation Research Board, organized by the Alcohol, Other Drugs and Transportation Committee, and hosted by TIRF. Agendas for these meetings are in the Appendix. The eight priority topics include

- Pharmacokinetics of Alcohol and Marijuana,
- Legislation and Enforcement,
- Prosecution and Courts,
- Toxicology,
- Supervision,
- Treatment,
- Public Policy, and
- Public Education and Awareness.

For each topic, current knowledge and important caveats are briefly summarized to provide context, and then key research questions are presented. The rationale for prioritizing each question is highlighted, and the topics and their associated research questions within each

section are discussed relative to the chronological flow of a drug-impaired driving case through the criminal justice system.

Of course, the research needs outlined in this report do not comprise an exhaustive list; instead this report highlights the most salient research questions that are viewed as priorities to be addressed by road safety stakeholders in the next decade.

NOTE

1. Traffic Injury Research Foundation, 2018.

Pharmacokinetics of Alcohol and Marijuana

CONTEXT OF THE ISSUE

Research demonstrates that the absorption, distribution, and elimination of marijuana from the body is substantially different than alcohol. Alcohol absorption, distribution, and elimination from the body follows a fairly constant pattern of water solubility with minor interpersonal differences. These processes are well-documented and are used to extrapolate the measured blood alcohol concentration (BAC) to a specific prior point in time. Conversely, due to high solubility of marijuana components in fat tissues, the absorption, distribution, and elimination of marijuana does not occur at a steady rate, with varying processes that depend on a variety of factors such as the route and frequency of intake; the dose of delta-9-tetrahydrocannabinol (THC)—the primary psychoactive substance in marijuana; titration of dose when smoked or vaporized; and user characteristics. Not only do these factors affect the amount of marijuana intake and metabolism, they also affect the degree of behavioral impairment. For example, if marijuana is ingested, the onset of the impairing effects of edible marijuana products occur more slowly and last longer.

Moreover, marijuana does not display a concentration–response relationship, as is the case with alcohol. The concentration–response relationship for alcohol is characterized by BACs that are strongly correlated with the degree of behavioral impairment. However, peak THC concentrations do not correlate well with the degree of behavioral impairment.[1] For example, peak THC concentrations occur during marijuana inhalation, prior to peak behavioral impairment, and behavioral impairment continues to be present at ensuing low THC concentrations from a single dose. The lack of a concentration–response relationship for marijuana has important implications for detection at the roadside and for this reason, reliance on THC concentrations in a driver's system or per se concentrations are not viable options to identify drug-impaired drivers. Although a specified per se limit would provide a clear cut-off, there is much debate concerning the validity of a per se limit for marijuana, as there remains to be strong scientific consensus regarding THC concentration in blood that constitutes driving impairment.[2]

At present, detection of drug impairment among drivers is largely reliant on behavioral indicators. However, a behavioral impairment test for marijuana must have high specificity so that it is possible to distinguish the effects of marijuana on behavior from the effects associated with other drugs. This means that a test of behavioral impairment at the roadside would be able to consistently identify a group of behavioral markers that are specific to marijuana impairment. Furthermore, it is important that behavioral impairment tests distinguish between generalized versus specific impairment criteria based on individual characteristics. General criteria based on a standard group of behavioral markers that indicate impairment can help detect potentially impaired drivers. However, criteria for specific impairment will help account for inter-individual variability to identify impairment that is typical of drivers with specific characteristics.

In light of this, although some research exists to help address these questions,[3] more research is needed to gain a deeper understanding of the markers of marijuana impairment that are associated with different forms of ingestion; measures of marijuana concentration that are indicative of driving impairment; and the effects marijuana has on crash risk. However, the identification of the most pressing research questions will ultimately be influenced by whether it

is more important to prioritize attempts to develop a per se level for marijuana versus a behavioral test for marijuana impairment, although evidence would suggest that the latter may be a more viable approach.

There are two important caveats to studies designed to answer these questions. First, it is essential for research investigating drug-impaired driving to distinguish between persons exhibiting impaired driving due to marijuana versus drivers who are positive for marijuana but do not exhibit driving impairment. The former is defined as a driver whose driving ability is impaired by the cognitive or psychomotor effects of THC. The latter describes a driver with detectable THC in their system, but that does not necessarily demonstrate impairment at the time of driving. Second, studies examining the effects of marijuana on crash risk that use fatality data to examine the concentrations of THC in fatally injured drivers should acknowledge that the THC post-mortem distribution may not be reflective of THC concentrations at the time of crash.

Finally, in order to tackle these questions, consistent blood testing for drugs among drivers involved in all fatal and even serious injury crashes is essential. Improvements to data captured by the Fatality Analysis Reporting System (FARS) maintained by the National Highway Traffic Safety Administration (NHTSA) are underway, yet certain important limitations still exist and should be considered when interpreting data and study results. It should be noted that the testing rates of fatally injured drivers in FARS are inconsistent and often low in many states, and the types of drugs that are tested for are not consistent across states, nor are the laboratory concentration cut-offs for each drug.[4] However, some individual states have higher testing rates and more representative data, therefore studies using these data may be more informative. Ultimately, improvements to the data captured by the FARS database and national road safety data systems in other countries can make it possible to conduct international comparisons as well as facilitate research in respective countries. To this end, a list of essential data indicators, including outcome measures such as deaths, injuries, arrests, convictions, number of drug-impaired drivers, number of drug-positive drivers, number of drivers, total population, and process variables that may include possible predictors or covariates of certain outcome measures, could provide valuable guidance to increase uniformity in data collection across jurisdictions.

RESEARCH NEEDS

The research needs associated with the priority area of pharmacokinetics of alcohol and marijuana are listed in the following section according to chronological flow of a drug-impaired driving case. The most salient research questions are highlighted, but do not constitute an exhaustive list. Each research need is described in addition to the rationale for prioritizing each question.

1. **What are the impairment effects of acute marijuana use on driving?**
   The impairment effects of acute marijuana consumption vary with the dose, potency, route of ingestion, user characteristics, frequency of use, time after dosing, smoking typography, substance origin (marijuana or synthetic cannabinoids), and the combination with other drugs.
   – **Driving impairment and acute marijuana use.** Laboratory studies that examined the impairment effects of acute marijuana use on psychomotor and cognitive functions suggest that this drug can impair abilities such as motor control, executive

function, visual processing, short-term memory, and working memory in a dose-dependent fashion.[5] Other experimental studies suggest that marijuana can impair certain skills necessary for safe driving such as speed variability, lane positioning, and reaction time.[6] However, existing research is insufficient to suggest set markers of impairment and cannot currently support the development of a test that could be used by law enforcement at the roadside to detect impairment. Therefore, future studies that provide empirical evidence to support psychomotor, behavioral, or cognitive measures indicating the degree of driving impairment from acute marijuana use are essential to this issue. This research can provide an evidence-base for the development of suitable in-field tests for marijuana impairment and is a necessary step to develop a scientifically validated method to detect marijuana-impaired drivers. Moreover, there is a need to define chronic use that produces tolerance and to understand the evolution of tolerance among chronic users over time.

A greater understanding of the impairment effects of acute marijuana use in marijuana-naïve and chronic users, and consequently, the development of suitable in-field tests to measure the impairment effects of marijuana will provide law enforcement with the ability to assess drivers suspected of marijuana-impaired driving. Furthermore, research exploring the relationship between impairment tests and crash risk can subsequently be conducted to establish the test as a scientifically validated method to detect marijuana-impaired drivers on the road.

   – **Driving impairment and route of ingestion of marijuana.** Studies demonstrated that the route of marijuana ingestion (smoking, vaping, or edibles) affects the onset, intensity, and duration of the effects of the drug, and that the different routes of ingestion show little correlation. For example, peak THC blood concentrations occur during marijuana smoking, while peak psychoactive effects occur later and can last up to 4 h. However, edible marijuana products produce a delayed onset of psychoactive effects with THC blood concentrations reaching their peak at approximately 1 to 3 h after consumption. Furthermore, with each route of ingestion, there is inter-subject variability in terms of measurable THC concentrations and impairing effects, such that two individuals consuming the same marijuana product may demonstrate different concentrations of THC in their system and may not exhibit the same degree of impairment. A major factor is the titration of marijuana dose by the way in which the individual smokes the cigarette or blunt. Inter-subject variability is also related to user characteristics, such as tolerance level, where a chronic user experiences the effects of marijuana to a lesser degree than an occasional user when consuming the same marijuana product. However, the chronic frequent user will attempt to obtain higher blood concentrations from the marijuana based on how they smoke the drug to achieve similar pharmacodynamic effects. Intra-subject variability also exists, such that the same user can experience different THC concentrations and impairment effects after consuming the same marijuana product on two separate occasions.

Presently, the majority of studies focus on the impairment effects of smoked marijuana on driving, and only a small proportion of studies have examined the effects of other routes of ingestion. New marijuana products in a variety of formats and with higher THC concentrations are becoming available to users at an unprecedented pace, and the impairment effects of such marijuana products are largely unknown. There is some research to support how the route of ingestion affects impairment,[7] but more is needed to understand the inter and intra-subject variability of the impairment effects from different

routes of marijuana ingestion. These findings will have important implications for the development of an impairment test, as time course of THC blood concentrations and degree of impairment varies according to the route of ingestion. Furthermore, knowledge about the inter- and intra-subject variability in the impairment effects of different forms of marijuana will provide necessary information to develop an impairment standard. As a result of this variability, it is essential that the impairment standard acknowledge general versus specific criteria of impairment. Finally, this information is essential to develop messaging for marijuana-impaired driving public education campaigns and to educate the public about the effects of different forms of marijuana consumption, as well as how these forms can impair driving ability.

   – **Driving impairment and synthetic marijuana.** Synthetic marijuana is a chemically derived substance and a popular alternative to traditional marijuana from the hemp plant. It was created to mimic the effects of marijuana but goes undetected by standard drug tests because of its lack of binding to antibodies to THC. Existing evidence suggests that the effects of the synthetic form are similar to those observed with marijuana, but that synthetic marijuana can have a much stronger effect, and the effects can be dangerous and unpredictable. Although synthetic marijuana is not as frequently detected in drivers, the different chemical profile and varying degrees of strength of impairing effects renders synthetic marijuana an important topic of future research. Studies that aim to gauge the severity of impairment produced from this synthetic drug and the implications that the stronger impairment effects have on driving are essential to road safety initiatives.

   Additionally, studies addressing specific behavioral impairment effects of synthetic marijuana, if any, can help police officers more accurately identify the signs of impairment that are characteristic of drivers under the influence of synthetic marijuana. As synthetic marijuana would not be detected by an oral fluid device due to its chemical profile, these findings can enable officers to recognize the signs of impairment from synthetic marijuana in the absence of positive oral fluid results. Furthermore, knowledge about the impairment effects of synthetic marijuana is essential to road safety campaigns because synthetic marijuana is often marketed to the public as a "legal high" and a means of avoiding marijuana consumption laws. Campaigns that inform drivers about the impairing effects of synthetic marijuana and increase awareness that driving under the influence of this substance also constitutes a violation of laws is essential to road safety efforts.

   – **Driving impairment and polysubstance use.** The use of marijuana in combination with other drugs can produce impairment effects that are different than those observed from marijuana alone. Alcohol is the drug that is most commonly consumed with marijuana, and evidence suggests that alcohol has an additive and prolonged impairment effect when combined with marijuana.[8] Much less is known about the impairment effects of marijuana combined with drugs other than alcohol. Moreover, an epidemiological study shows a growing trend in using cocktails of various drugs, including prescription drugs and new psychoactive substances at low concentrations with unknown impairing effects.[9]

   Further research should aim to determine the combined impairment effects that are characteristic to polysubstance use, and specifically what markers of impairment are characteristic of driving under the influence of marijuana and alcohol combined. In preparation to address these questions, improvements in data collection, including blood

testing for all drugs among drivers involved in fatal and even serious injury crashes is important for researchers to tackle this issue. These data help illustrate important information about the crash risk associated with different combinations of substances and the degree to which they impair driving.

Understanding the impairment effects of marijuana in combination with other drugs is important to the detection of impairment at the roadside, as marijuana in combination with other drugs may present a different profile of impairment that may not be captured during a typical roadside screening. Furthermore, knowledge of the impairing effects of marijuana in combination with other drugs, and especially alcohol as it is the substance most often detected along with marijuana, is important to inform public education campaigns to raise awareness about the effects of combined drug use while driving and the additive nature of impairment effects.

2. What is the relationship between certain driving skills and crash risk?

Existing epidemiological studies examined the relationship between drivers that tested positive for marijuana and crash risk. Generally, these studies suggest that there is an approximate twofold increase in crash risk after consumption of marijuana. However, because the presence of marijuana does not necessarily imply impairment, future research should explore the relationship between certain skills necessary for safe driving and crash risk. Findings from this research can help develop measures of performance that capture impairment from marijuana use and can help determine the predictive value and scientific validity of impairment tests that are developed.

In addition, this research can provide road safety stakeholders with the knowledge to assess the risk of collision due to impaired performance in relation to certain driving skills. These results would be more robust than findings from research examining the relationship between marijuana use and crash risk generally, as this research suffers from many limitations. The relationship between specific driving skills and crash risk may offer a more representative assessment of the crash risk for individuals driving under the influence of marijuana.

3. What characteristics of crashes are most strongly associated with marijuana impairment?

Existing studies demonstrated that drivers who tested positive for marijuana were more likely to be at fault in crashes.[10] Although some studies have examined the association between measures of impairment from marijuana and crash characteristics such as severity of crash,[11] more research is needed. Future research should aim to identify crash characteristics associated with impairment from marijuana, using data from FARS. However, the use of fatal crash data will necessitate a deeper understanding of the post-mortem stability of THC and its metabolites in blood.[12] Other data systems, such as insurance data, may help augment the information that is available through the FARS database. It is important to note that the use of additional data sources would initially require assessment to determine their research value. Ultimately, to determine the crash characteristics most strongly associated with marijuana, more robust and better data are necessary, as more complete data collection efforts are essential to measure and study the drug-impaired driving problem.

Research to determine the crash characteristics most strongly associated with marijuana impairment would provide road safety stakeholders with a broader understanding of the issue. Results would also help support law enforcement by providing targeted information about crash

characteristics associated with marijuana impairment so that enforcement efforts can be tailored specifically to this problem.

4.   What component or element of marijuana is the best indicator of impairment?

To date, the majority of studies have focused on THC concentrations in the body and how they correlate with impairment since THC is the primary psychoactive cannabinoid in marijuana. Further research examining THC metabolites is warranted, as the active metabolite, 11–OH–THC has psychoactive properties, and the main secondary metabolite THC and THC–COOH may be indicative of mode of consumption and duration of use.[13] However, THC is one of more than 113 cannabinoids present in marijuana.[14] At present, scientific consensus regarding the relationship between THC concentrations in a driver's body and driving impairment from marijuana is lacking. To broaden the scope of understanding about how chemical compounds in marijuana may be related to impairment, future studies should examine other cannabinoids as predictors of impairment to determine if certain cannabinoids have a stronger relationship with impairment than THC. Prior to this research, it is a necessary that a validated test to detect marijuana impairment exists, ensuring comparability between the degree of impairment observed with each cannabinoid tested.

Additionally, the determination of a valid indicator of marijuana use is essential for the detection of marijuana at the roadside. Currently, an oral fluid device can detect THC concentrations in saliva above 5 ng/ml and the accuracy and reliability of the available oral fluid testing devices were preliminarily established. It is important for future studies to assess oral fluid devices further, in addition to other devices that may hold promise as a tool for officers to use at the roadside to detect recent marijuana use. The further examination of other chemical compounds detected in marijuana, such as cannabinol (CBN), tetrahydrocannabivarin (THCV), and cannabigerol (CBG), that appear in body fluids at low concentrations and dissipate rapidly,[15] will be important to help determine if these different markers of marijuana can enable officers to better detect impairment at the roadside.

Finally, studies identifying accurate toxicological indicators of impairment are paramount to support police investigations and legal proceedings in marijuana-impaired driving cases. Currently, toxicological tests can detect the presence of marijuana metabolites in blood, saliva, urine, hair, and nails, using a variety of analytical techniques. To complement this, research examining toxicological indicators of impairment would augment the existing potential of laboratory results and strengthen the available evidence in marijuana-impaired driving cases.

5.   What key domains should be the focus of research to develop a test for marijuana impairment?

Existing experimental studies suggest that marijuana impairs psychomotor and cognitive functions such as motor control, executive function, visual processing, short-term memory, and working memory. These findings provide a basis of empirical evidence, and it is essential that future studies use these experimental findings to determine the key domains that require investigation to develop a test to measure the degree of impairment from acute marijuana use.

Studies that address the key domains of marijuana impairment are a vital step towards the development of a scientifically validated test of marijuana impairment. The availability of a test for marijuana impairment can provide law enforcement with a valuable roadside screening tool, and once the validity and accuracy are established, it can provide officers with a means of identifying drivers suspected of marijuana-impaired driving. A test of marijuana impairment can

also augment the findings from chemical tests utilized at the roadside, as the presence of marijuana as indicated by a chemical test does not necessarily imply impairment.

NOTES

1. Huestis 2007; Compton 2017.
2. Grotenhermen et al. 2007; Newmeyer et al. 2017.
3. Hartman et al. 2016.
4. Berning et al. 2014.
5. Broyd et al. 2016; Ramaekers et al. 2004; Ramaekers et al. 2006.
6. Hartman et al. 2016.
7. Cone et al. 1988; Allen et al. 2007.
8. Lenné et al. 2010.
9. Willie et al. 2018; Richeval et al. 2018.
10. Drummer et al. 2004.
11. Romano et al. 2011; Li et al. 2017; Romano et al. 2017.
12. Holland et al. 2011.
13. Huestis and Smith 2018; Huestis et al. 1992; Fabritius et al. 2014; Karschner et al. 2016.
14. Aizpurua-Olaizola et al. 2016.
15. Huestis and Smith 2018; Newmeyer et al. 2016.

Legislation and Enforcement

CONTEXT OF THE ISSUE

Legislation to decriminalize[1] or legalize[2] marijuana is increasingly prevalent across jurisdictions. However, legislation and policy regarding these issues are advancing at a much faster pace than research studies needed to answer critical questions. At the same time, laws related to drug-impaired driving have not consistently received the same level of attention in all jurisdictions, although the enforcement of laws to prevent drug-impaired driving is an essential component of these policy decisions.

Historically, the ability to detect alcohol and demonstrate impairment even at low levels has precipitated the evidentiary requirement to link the presence of alcohol to behavioral evidence of impairment. As such, laws that necessitate the measurement of driver impairment have led to inherent complexities. In North America, laws to prevent driving under the influence of drugs are similarly designed to detect impairment among drivers. However, this impairment-based approach is reliant on the ability of police officers to prove driving impairment and link it to drug use which is much more challenging in the case of chronic drug users who may compensate for the impairing effects of their drug use and be better able to avoid detection.

In contrast, zero-tolerance laws for drugs and driving are used in some Western European nations, Australia, and New Zealand. In these countries, the operation of a motor vehicle with any detectable amount of drug is considered illegal, which poses fewer legal complexities and a lower evidentiary burden. A more detailed explanation of these approaches can be found in the Laws and Penalties section of the Drug-Impaired Driving Learning Centre (DIDLC) (www.druggeddriving.tirf.ca).

There are fundamental differences between the impairment-based approach, in which the objective is to detect drug-impaired drivers, compared to the zero-tolerance approach, which emphasizes the detection of drugs irrespective of actual impairment. Ultimately, the enforcement strategy that is adopted determines what comes next and the issues that flow from that must be managed. As evidenced by the different legislative approaches, there is no universal model for the enforcement of drug-impaired driving laws. However, part of the defining approach to drugs and driving is based on how jurisdictions have operationally defined enforcement surrounding alcohol and driving. Jurisdictions that adopt the same approach as alcohol-impaired driving and rely on linking quantifiable levels of alcohol to driving impairment should examine the lessons learned from the enforcement of impairment-based laws to avoid replicating unsuccessful policy decisions and inform strategies to reduce drug-impaired driving.

The incorporation of effective aspects of the legislation for alcohol-impaired driving should also be considered for policy decisions about drugs and driving. State or provincial–territorial legislation that prohibits open or accessible marijuana in a vehicle, similar to open-container laws for alcohol, may help mitigate drug-impaired driving in the same way that it has reduced opportunities for alcohol-impaired driving. Furthermore, the effectiveness of administrative penalties, which are more immediate sanctions that deter drivers from engaging in risky behavior is underscored and may have potential value to address drug-impaired driving. Research from Canadian jurisdictions have clearly established that immediate roadside and administrative penalties have been effective in reducing alcohol-impaired driving.[3]

In order to measure the effect of legislation to decriminalize or legalize marijuana on drug-impaired driving, baseline data of the magnitude of the problem prior to legislation are necessary. However, baseline data are not readily available, and as a result, the effects of legislation on drug-impaired driving are, to date, unknown. In principle, legislation to decriminalize or legalize marijuana is often intended to reduce the black market for this drug, however experiences from Washington state and Colorado have suggested that this is not the case. In addition, this legislation has often resulted in increased demand for Drug Recognition Expert (DRE) officers by police agencies to detect drug-impaired drivers. Of concern, there have been many challenges to date with the implementation of DRE programs and training of DRE officers. In fact, the DRE program is one of the most expensive and most challenging certifications for police officers to obtain, and there is limited guidance regarding how many trained DRE officers a jurisdiction may require. To this end, the use of an equivalent of the Police Allocation Model to estimate how many DREs are needed and optimal hours and location of deployment could provide important insight into the number of trained officers that jurisdictions may require. In addition, while many jurisdictions have an inadequate number of DRE officers, experiences from those that do underscore the importance of an organized call-out procedure to use them. Moreover, available DRE officers may also be underutilized as more patrol officers are trained in Advanced Roadside Impairment Detection Enforcement and feel more confident in arresting drug-impaired drivers without a DRE evaluation.

Despite certain challenges, successful DRE programs have traditionally included the following features:

- Scientific support from researchers and toxicologists;
- A strong sense of leadership from department chiefs and all frontline officers;
- Motivated and well-trained DRE officers able to consistently detect drug impairment, and clearly articulate reasons for stopping the vehicle, and provide effective court testimony; and
- Acceptance of DRE evidence by courts.

As the drug-impaired driving problem continues to evolve, DRE programs will face a critical test in the coming years. Therefore, it is essential that research is conducted to evaluate the effectiveness of DRE programs and to optimize their implementation. As such, clarity is needed to determine the main objectives of the DRE program, as well as a subsequent evaluation to determine if those objectives are being achieved.

Objectives of the DRE program may include:

- Removing impaired drivers from the road,
- Increased general and specific deterrence to reduce impaired driving,
- Supporting judicial outcomes that reduce recidivism, and
- Fewer people killed in drug-impaired driving crashes.

Consensus across police agencies regarding program objectives is crucial. Similarly, standard methods to collect data and undertake evaluations to determine whether objectives are indeed being achieved are equally important. This approach can facilitate comparisons across jurisdictions, and also contribute to the development of current national data regarding this problem. Moreover, uniformity can support the identification of best practices to optimize DRE programs.

To this end, technologies to help identify drug-impaired driving are under development and could be an essential tool for DREs. While the main focus has been on oral fluid testing technologies, other types of detection tools could also be valuable. For example, research suggests there is an association between regular marijuana use and retinal ganglion cell dysfunction.[4] As such, it is likely that other new technologies and data collection tools can help to inform research as well as real-world practices.

RESEARCH NEEDS

The research needs associated with the priority area of legislation and enforcement are listed in the following section according to chronological flow of a drug-impaired driving case. The most salient research questions are highlighted, but do not constitute an exhaustive list. Each research need is described in addition to the rationale for prioritizing each question.

1.   What is the effect of the decriminalization or legalization of recreational or medical marijuana on drug-impaired driving?
Some jurisdictions have decriminalized or legalized marijuana use, however the impact of this legislation on drug-impaired driving rates is largely unknown in many jurisdictions, mainly due to the absence of baseline data. As a result, it cannot be established whether any observed increases are a result of a higher prevalence of drug-impaired driving or simply a by-product of increased testing rates. Therefore, better data collection efforts and research are essential to fully comprehend the effects of this legislation. In particular, research is needed to conduct pre- and post-roadside surveys in states that legalize marijuana, as this can help illustrate the effects of this legislation on the prevalence drug-impaired driving.
Answers to this research question can help jurisdictions use collected data to track, monitor and evaluate the effects of marijuana decriminalization or legalization on road safety, and progress in reducing marijuana-impaired driving. Furthermore, the results of these studies can be instrumental to inform the development of best practices regarding the implementation of legislation.

2.   What are the costs and the benefits associated with legislation to decriminalize or legalize marijuana? Do the benefits outweigh the costs?
States that have decriminalized or legalized marijuana have experience to support studies investigating the costs and benefits associated with this legislation. For example, the legalization of marijuana in Washington state was intended to reduce the black market for this drug, but experiences suggest it has not. Furthermore, Washington observed an increase in the percentage of marijuana-positive drivers when comparing the prevalence from roadside surveys collected before and after the legalization of this drug. Therefore, research is needed to help inform jurisdictions that are considering new legislation for marijuana determine the costs and benefits associated with decriminalizing or legalizing marijuana and assess whether the benefits outweigh the costs. Important costs to be considered include the cost of increased enforcement and testing, the cost of crashes, the cost of addiction and the costs associated with increased hospitalizations.
Studies that address this question can help quantify the potential impact that decriminalizing or legalizing marijuana may have on their respective jurisdictions in terms of road safety. It can also help them to consider the impact of this legislation across sectors,

including law enforcement, transportation and health. A broader understanding of the implications can also help jurisdictions consider whether benefits of the legislation outweigh the costs, and how to anticipate potential costs and design a more effective implementation strategy for marijuana legislation.

3. What lessons have been learned from the enforcement of alcohol-impaired driving laws, and how can this knowledge be applied to drug-impaired driving enforcement?

Lessons learned from more than three decades of experience with per se limits for alcohol underscore some of the unintended negative effects of this approach. A per se limit for alcohol has suggested to drivers that it is "safe" to drive as long as they are under the threshold of the BAC limit, when in fact they may still be impaired. In other words, this approach has taught drivers that it is acceptable to drink as long as they are under the per se limit, instead of learning to separate drinking and driving because alcohol, even at low levels, is impairing. Setting a per se limit for marijuana that prohibits the operation of a motor vehicle at or above a specific level of THC present in a driver's system and is indicative of impairment is consistent with alcohol-impaired driving laws. A specified per se limit would provide a clear cut-off, however, there has been much debate concerning the validity of a per se limit for marijuana mainly due to a lack of scientific consensus regarding what level of THC in a volume of blood constitutes driving impairment.[5]

Research that highlights the lessons learned from the enforcement of alcohol-impaired driving laws will provide a clear path forward for jurisdictions that are considering the legalization of marijuana. Jurisdictions will be able to make informed decisions about the implementation of drug-impaired driving laws and ensure that unsuccessful enforcement strategies are not replicated.

4. Is there any relationship between THC oral fluid and blood concentration results that is reliable to provide conclusive evidence in court?

With alcohol-impaired drivers, breath testing has been the accepted standard for roadside testing because it is the least invasive and it is a reliable proxy for a BAC, which is the gold standard to confirm the amount of alcohol in the driver's system. This approach is based on a large body of evidence that reliably demonstrates that the measure of alcohol in blood is correlated with the measure of alcohol in a breath sample. Similarly, blood analysis to measure the concentration of THC in a driver's system offers one of the most reliable means of testing for recent drug use when drug-impaired driving is suspected. However, it is an invasive and inefficient method of sampling at the roadside. Conversely, the analysis of oral fluid samples presents a promising alternative since it is quick and non-invasive and can be undertaken at roadside to substantiate the DRE finding of impairment.

As such, research to better understand the relationship between the THC concentration in oral fluid and blood can increase efficiency at the roadside, while ensuring that testing is non-invasive. It would also enable courts to meet a high evidentiary standard of beyond a reasonable doubt. Therefore, future research is needed to explore the relationship between these two methods of sampling and gain a broader understanding of the complexities that exist. Ultimately, the ability to utilize oral fluid devices at the roadside with the knowledge of how the results can be extrapolated to blood THC levels can increase the ability of police to reliably remove marijuana-

impaired drivers from the road and better ensure that the results collected at the roadside are consistent with the toxicological findings, thus meeting the evidentiary needs in court.

5.   Are DRE programs an effective method to enforce drug-impaired driving laws, and how effective are these programs?

DRE programs exist across Canada, the United States, Europe, and Australia as well as among other jurisdictions. It is estimated that there are currently more than 8,600 trained DRE officers worldwide.[6] DRE programs serve as an important tool in the enforcement of drug-impaired driving laws. However, there have been several challenges associated with the implementation of DRE programs, including the high cost of the program, the level of training and demands of the certification process for DRE officers, and the need to better prepare officers for court testimony. In light of this, research is needed to evaluate the effectiveness of these programs, both individually and collectively, and to gauge deterrent effects associated with these programs.

In order to determine the effectiveness of DRE programs, clarity is needed regarding what objectives should be achieved as well as how they are being achieved. In addition, the types of data that must be collected in order to evaluate DRE programs must be established. Process indicators and outcome measures are essential to assess the effectiveness of DRE programs. Potential indicators may include: number of DRE evaluations, number of arrests, number of charges, number of court cases, number of convictions, rate of recidivism, and number of fatal crashes.

Additionally, uniform definitions of variables, standard methods to collect data and consensus about program objectives and methods to conduct evaluations are equally important. This approach can facilitate comparisons across jurisdictions and also contribute to the development of current national data about these programs.

An important caveat related to comparisons of the effectiveness of individual DRE programs is the ability of jurisdictions to conduct random drug tests. Jurisdictions where random testing is permitted should be distinguished from those where random testing is not permitted as this will have important implications for the number of drivers tested and level of deterrence achieved.

6.   How effective is DRE compared to other enforcement strategies for impaired driving, and how can these alternative approaches be incorporated into legislation and enforcement practices related to drug-impaired driving?

Research to address the overall effectiveness of DRE programs in comparison to other methods of enforcement, such as regular patrol, checkpoints with public campaigns, saturation patrols, and oral fluid devices is critical to determine the effectiveness of DRE programs versus other enforcement strategies. Findings from this research can help justify investment in DRE programs based on demonstrated reductions in drug-impaired driving. To address this research need, evaluation studies of the effectiveness of individual DRE programs can provide data to determine how DRE programs generally compare to other types of enforcement strategies.

The effectiveness of DRE programs in comparison to other enforcement strategies can provide an overarching assessment of the effectiveness of DRE programs that can be used to justify its widespread implementation and inform strategies to prevent drug-impaired driving. Moreover, the effectiveness of alternative approaches to enforce drug-impaired driving laws should be established. Understanding the added value of regular patrol, checkpoints with public campaigns, saturation patrols, or oral fluid devices can provide direction to optimize enforcement strategies. As such, research is needed to determine which approaches are most effective to

incorporate into the accepted enforcement practices. In addition, best practices should be established to guide the implementation of approaches that prove to be most effective. Specifically, research to determine how the use of oral fluid devices can complement current enforcement practices can help jurisdictions that are considering mandating the use of this device at the roadside.

7. What are the key issues to improve DRE testimony in court?

DRE officers must deliver court testimony as a competent expert in the science of DRE. Such testimony requires substantial knowledge of the underlying scientific principles that support DRE evidence to withstand evidentiary challenges that are increasingly put forward by defense counsel. Often, DREs may be challenged with regard to the symptoms displayed by individual subjects and how this may vary in comparison to the set standard for classifying a symptom as normal versus impaired. DREs are also often challenged regarding the possibility that the observed symptoms may be due to other medical or environmental reasons.

Therefore, research to address these common issues raised in court is essential to strengthen DRE testimony to withstand evidentiary challenges. This research is paramount since anecdotal evidence indicates that the success or failure of DREs in court plays a critical role in determining whether officers continue their commitment to the program or let their certification lapse. Furthermore, research about these evidentiary challenges is important to increase the credibility of the program and promote widespread acceptance of DRE testimony by courts.

8. What strategies are available to help researchers and police officers keep pace with the rapidly changing use of drugs and drug types in the field?

New trends in drug use or drug type are evolving at an unprecedented pace. Researchers and police officers alike must undertake concerted efforts to keep pace with this continually evolving issue. Substance combinations, new substances, and regional differences in drug use represent some of the complexities faced. A wide variation in combined substances can produce alternative impairment effects that may not be readily understood or recognized. New substances also present an issue, as they are developed at a rapid pace with the intention to act as an alternative that mimics the effects of the illegal substance of origin. Therefore, it is essential that research identify strategies to help road safety stakeholders keep pace with the rapid development of new drugs and the changing use of drugs and drug types in the field.

Ultimately, strategies to enhance current understanding of these issues can help broaden the existing knowledge base and stimulate further research questions as a result of greater recognition and awareness of this issue. More efficient strategies to help road safety stakeholders stay abreast of the rapidly changing knowledge landscape can also help officers anticipate emerging trends in drugged driving and tailor enforcement efforts accordingly.

NOTES

1. Decriminalization of marijuana is defined as the removal of the criminal prosecution for personal marijuana use, however civil penalties still exist. The substance is considered illegal and thus the manufacturing and sale of marijuana remains illegal and the possession of large quantities can lead to criminal penalties.
2. Legalization of marijuana is defined as the removal of laws banning the possession and personal use of marijuana. The production and sale of the substance is regulated by the state.

3. Byrne et al., 2017.
4. Lyons and Robson, 2017.
5. Lyons and Robson, 2017.
6. International Association of Chiefs of Police, 2018.

Prosecution and Courts

CONTEXT OF THE ISSUE

In the United States, all states require drivers charged with a drug-impaired driving offense to appear in criminal court. However only a small proportion of drug-impaired driving cases are processed in criminal court simply because some drugs, particularly marijuana, are more commonly detected in combination with alcohol. As such, cases are more likely to proceed on the alcohol charge and, while drugs may be suspected, further testing is not necessary to sustain the charge if sufficient alcohol is present. For this reason, drug-impaired driving cases represent a small proportion of the impaired driving cases that go to court.

On average, drug-impaired driving cases are more complex to prosecute and require more time and resources due to limitations associated with scientific evidence and also testing protocols. In Canada, these cases take twice as long to resolve as an alcohol-impaired driving case, and the former is less likely to result in a guilty verdict.[1] There are many deficiencies associated with drug-impaired driving cases, and some of the most prominent issues include:

- Poor documentation of impairment evidence,
- Limited or inadequate resources for testing,
- Charges laid for alcohol-impaired driving despite the presence of polysubstance use if the amount of alcohol is sufficient to sustain a charge,
- Insufficient number of DREs in rural areas, and
- Inadequate testimony from toxicologists.

Knowledge of drug-impaired driving generally, and the DRE program specifically, is limited among prosecutors and judges. Impaired driving cases are typically handled by prosecutors who have limited experience, and the complexity of evidence related to drug-impaired driving cases is daunting, even for experienced prosecutors. Most prosecutors learn on the job and require intensive training and continuing education for impaired driving cases. This may be offered through state associations and designated Traffic Safety Resource Prosecutors. Some states such as California have adopted the use of vertical prosecution in which the same prosecutor will review, file, and prosecute all drug-impaired driving cases, and this has enabled a select few, experienced prosecutors who are well versed in drug-impaired driving evidence to specialize in these cases and improve court outcomes, although this is not an option in many jurisdictions.

Similarly, knowledge of drug-impaired driving is also limited among judges who manage diverse criminal caseloads and must learn many areas of the law. More concerted and consistent educational opportunities must be provided to the judiciary to increase knowledge of drug-impaired driving, the DRE program, and the science that supports it.

Finally, although administrative license revocation is widely utilized as an immediate penalty for persons arrested or convicted of alcohol-impaired driving, this penalty is not yet applied to drug-impaired driving in most jurisdictions, however a few provinces in Canada have recently implemented this tool, including Ontario and British Columbia.

Priority questions associated with this topic include the identification of the most compelling evidence in court, and which evidentiary gaps can be most easily remedied. The

effectiveness of prosecution and the key areas of training to prepare new prosecutors are also underscored.

RESEARCH NEEDS

The priority research needs related to prosecution and the courts are described below according to the chronological flow of a drug-impaired driving case through the criminal justice system. The most salient research questions are highlighted, but do not constitute an exhaustive list. Each research need is described in addition to the rationale for prioritizing each question.

1.   What data points or pieces of evidence are most compelling in court?
There is a substantial evidentiary burden associated with drug-impaired driving cases. As a result, the evidence presented in court proceedings is often complex, and generally requires an intimate and precise understanding of the scientific research regarding the effects of drugs on driving, and the analysis of toxicological samples. In light of the technical nature and sheer volume of evidence, it is essential to investigate which types of evidence are most compelling in court, and which types are most likely to support a conviction. Greater knowledge regarding the types of evidence or research that are most compelling can help improve the presentation of drug-impaired driving cases and increase the deterrent effect of laws generally. In addition, this knowledge can enable law enforcement officers and prosecutors to focus evidence collection and case preparation strategies to more efficiently use limited resources and manage court time required in these cases.

2.   What are the most significant deficiencies in evidence that contribute to "not guilty" decisions by judges or juries in drug-impaired driving cases? What is the biggest evidentiary gap that is fixable?
Research is needed to identify the most important deficiencies in evidence presented in drug-impaired driving cases to date. An analysis of rulings in drug-impaired driving cases would provide important insights regarding the evidence relied upon to support a guilty verdict. Similarly, it would help to identify evidence that was considered insufficient and contributed to a not guilty verdict. It would also provide direction to prioritize evidentiary gaps that most often contribute to not guilty verdicts.
A better understanding of these deficiencies is much needed to ensure that adequate and complete evidence is presented in drug-impaired driving cases, and to strengthen DRE training strategies and educational opportunities for prosecutors. The inability to address gaps associated with evidence in drug-impaired driving cases will ultimately decrease the number of drug-impaired driving cases that are presented in court, undermine the confidence of DREs and prosecutors in handling these cases, decrease the likelihood that drug-impaired drivers are convicted, and thereby erode the deterrent effect of drug-impaired driving laws and enforcement strategies.

3.   How effective is the prosecution of drug-impaired driving cases? For example, does the prosecution of drug-impaired driving cases more often result in dismissals, negotiated plea agreements, or trials which may result in a not guilty or guilty decision?

In light of the quantity of training and volume of resources that are invested to enforce drug-impaired driving laws, it is crucial to determine the effectiveness of prosecution in drug-impaired driving cases. An analysis of case dispositions to gauge rates of dismissals, pleas and guilty verdicts at trial would provide much-needed insight regarding the effectiveness of prosecution and assess whether the level of resources devoted to prosecuting these cases is appropriate. It may also help to identify opportunities to improve the prosecution of these cases and most efficiently utilize resources.

This knowledge is essential to assess the current effectiveness of prosecutorial practices and determine what improvements can be made to employ the most efficient strategies that produce the best outcomes in drug-impaired driving cases. This research can also serve to improve the current outcomes of these cases. At present, the most common outcomes are that drug-impaired driving charges are not pursued in lieu of alcohol charges, or that cases result in plea agreements.

4.   What types of education about drug-impaired driving cases can enable prosecutors to successfully prosecute drug-impaired driving cases, including those defended by knowledgeable defense experts?

Many prosecutors that handle impaired driving cases are unfamiliar with the science and evidence associated with these cases; they may also possess limited trial experience. Impaired driving cases are most often assigned to new or junior prosecutors, and once they gain experience, they focus their attention on other types of criminal cases. As such, prosecutors often report being under-prepared for impaired-driving cases. Although Traffic Safety Resource Prosecutors have been created in many jurisdictions and are available to support prosecutors and deliver education to them, research is needed to determine the most effective training to prepare them specifically for drug-impaired driving cases so that they can face challenges from seasoned defense attorneys and obtain better outcomes in court.

In order to ensure that drug-impaired driving laws have a deterrent effect and drug-impaired drivers are removed from the road, research is needed to identify the most effective ways to prepare prosecutors to handle these cases and obtain appropriate outcomes.

NOTE

1.   Statistics Canada, 2016.

Toxicology

CONTEXT OF THE ISSUE

There is considerable variability in the analytical capability of testing laboratories because of differences in drug test profiles and analytical procedures. The gold standard for drug-impaired driving testing involves the use of blood confirmatory toxicology tests, however, it is important that blood specimens are collected in a timely manner following a traffic stop since drug metabolism in the body during the time delay will limit the evidentiary value of the analysis.

Oral fluid (saliva) testing is based on the free circulation of drugs in the body, and is currently used in many countries around the world to test drivers for drug consumption. The advantages of oral fluid collection for this application have been widely published. The main reason for its implementation is the speed of sample collection compared to blood, which generally requires a warrant to be sought, and always requires medically trained personnel to be present.

In 2007, the National Safety Council published standardized testing protocols for laboratories.[1] Updated standardized test protocols were also published in 2013 and 2017,[2] however, these recommendations have not been widely adopted. Laboratories report moving towards adoption of standard cut-offs for blood and urine, with oral fluid planned in some cases for future inclusion.

The increasing interest in the use of oral fluid as a biological test matrix for drug-impaired driving has prompted calls for more research. The wide availability of novel psychiatric substances has forced forensic laboratories to extend testing panels; and recently the National Transportation Safety Board called for research involving the study of synthetic drugs, and the retrospective testing of urine samples in drivers of heavy trucks.

RESEARCH NEEDS

The research needs associated with the priority area of toxicology are listed in the following section according to chronological flow of a drug-impaired driving case. The most salient research questions are highlighted, but do not constitute an exhaustive list. Each research need is described in addition to the rationale for prioritizing each question.

1. What drugs should be included in the standard test conducted on samples provided by suspected drug-impaired drivers?

A variety of drugs are detected in drug-impaired drivers, either alone or in countless combinations. However, it is not efficient or practical to test for many different types of drugs. As such, it is important that drugs included in a standard test of samples should be reflective of the drugs that are most prevalent among an impaired driver population in a given jurisdiction. For example, data from the reports from the National Roadside Surveys (2007 and 2013–2014) in the United States revealed that the predominant drug detected in drivers was THC.[3] Other important drug classes included methamphetamine, amphetamine, cocaine, opioids, and benzodiazepines. However, the drugs required for analysis are not consistent across jurisdictions and geographical differences may affect the drug test panel. Furthermore, monitoring of new seized substances assists the laboratory in potentially identifying impairing drugs in the driving

population. Because the drug test profile may change rapidly it is important to ensure laboratories are equipped and prepared to routinely implement adjustments required.

Guidance regarding laboratory recommendations for Tier I and Tier II test panels were published in 2013, and recently updated in 2017.[4] Principal changes in laboratory specifications included the removal of butalbital, phenobarbital, and phencyclidine from Tier I (mandatory) to Tier II (optional) due to changes in prevalence. In addition, buprenorphine, fentanyl, tramadol, and their metabolites were moved from Tier II to Tier I due to their increased prevalence and concerns about their potential to cause impairment. Other additions were made to the list of Tier II compounds, including fentanyl analogs, mitragynine, novel opioids, atypical antipsychotics, and novel benzodiazepines. In addition, screening and confirmatory cut-offs for the oral fluid scope were further refined.

2.   What are the recommended analytical cut-off values for screening and confirmatory testing of drugs?

One of the main challenges in drug-impaired driving cases is the variation between laboratory testing levels. Different cut-offs lead to different interpretations of results producing inconsistency between jurisdictions. Lower concentrations may result in drivers testing positive in one area of the country, whereas the same driver may test negative in another jurisdiction. Of concern, cut-off values that are too high can result in impaired drivers avoiding detection. These variations across laboratory protocols make it difficult to draw conclusions regarding the number of drivers under the influence of drugs and whether in fact they are impaired.

There are several benefits in applying standard cut-off concentrations in casework, which include:

- Fair treatment of all drivers.
- Ability to compare data across geographical areas and jurisdictions,
- Ensure that drugs which are known to cause impairment are included (drugs with strong pharmacological effects as described in peer-reviewed traffic safety literature), and
- Public confidence in the results obtained by the laboratory.

3.   What are the best practices for laboratories to handle and analyze sample matrices (urine, blood, saliva) for drug-impaired drivers?

Urine is the least preferred matrix for drug-impaired driving cases because its window of drug detection may greatly exceed the window of drug impairment and generally the parent drug is not detected. Sample matrices such as blood and oral fluid specimens are preferable as both offer the possibility of documenting drug intake proximal to the incident. Therefore, it is important to determine the best practices that define which matrix should be used by laboratories in order to receive the most reliable results. Furthermore, consistency in the types of samples collected for certain substances would help establish a standard matrix for commonly detected substances.

Best practices that establish a standard laboratory protocol is also an important research need. Variations in laboratory protocols for sample preparation and measurement exist and may lead to discrepant results. For example, sample preparation methods such as urine hydrolysis and precipitation methods for whole blood may not be carried out in every facility. Moreover, the detection levels of the parent drug, as opposed to metabolites, may differ between laboratories. As such, consistency and proficiency of laboratory protocols will better ensure that the conclusions drawn from drug tests can be used to reliably and efficiently identify drug-impaired

drivers. Notably, an increasing number of laboratories are participating in external proficiency programs, and inspections to acquire certification.

4. What are appropriate best practices to manage higher testing demands that acknowledge the resource and training capacity that currently exists within laboratories?

Immunoassay screening, followed by mass spectral qualitative or quantitative confirmation of drugs in blood and urine have been the gold standard for over 50 years. However, increased testing demands as a result of the legalization of marijuana in numerous jurisdictions, and the rise of novel psychoactive substances require best practices to manage these testing demands in consideration of limited laboratory resources and training capacity.

Alternative technologies, such as liquid chromatography coupled with mass spectrometry (LC-MS) or time-of-flight mass spectrometry (LC-TOF-MS) instruments have certain advantages over traditional immunoassay screening. Both instruments allow for the ability to detect a wide range of unknown substances, and LC-TOF-MS allows for retrospective analysis as new information arises from the drug-impaired driving investigation. However, these technologies have higher initial costs and require greater investment in training personnel.[5]

As such, research is needed to determine best practices to manage higher testing demands that outline how these alternative technologies can be used to complement traditional immunoassays. Routine analyses that are best suited for immunoassays should be outlined, and instances where LC-MS or LC-TOF-MS can be implemented for complex analyses should be noted. This can provide laboratories with a sufficient protocol that also acknowledges laboratory resource and training limitations. Additionally, best practices should also provide an optimal protocol for instances where the complete adoption of these alternative technologies is feasible. Adoption of these protocols to manage testing demands will ensure uniformity of analysis techniques and allow for the consistent detection of a wide range of unknown substances.

5. What mechanisms help jurisdictions efficiently share new knowledge and learning that builds on experiences and allows jurisdictions to benefit from new knowledge more rapidly?

Drug-impaired driving research is being conducted at an unprecedented pace, and it is essential that knowledge generated from these research efforts is shared between jurisdictions in the most efficient manner to inform the development of evidence-based drug-impaired driving strategies across jurisdictions. Resources for road safety stakeholders that compile and synthesize the latest information in an accessible format is a key aspect of effective knowledge transfer. An example of this is the DIDLC[6] created by the TIRF. The DIDLC is a web-based user-friendly resource for government, researchers, practitioners, and other road safety stakeholders that facilitates the knowledge transfer process by consolidating the latest research about the drug-impaired driving problem and to address the development of effective strategies. Resources on topics such as prevalence, the effects of drugs on driving, and the tools and technologies used to detect drugs in drivers are available to download on the DIDLC website.

The ability to share and implement new knowledge is essential to tackle this issue and research to highlight effective knowledge transfer models that enable the efficient sharing of information and experiences between jurisdictions is imperative for the development of evidence-based policy. Moreover, standardization of research parameters is much needed to track outcomes and inform the development of effective countermeasures. Mechanisms to

facilitate such coordination can have substantial benefits and are essential to progress to reduce drug-impaired driving.

NOTES

1. Farrell et al., 2007.
2. Logan et al., 2013, 2017.
3. Compton and Berning, 2009; Berning et al., 2015.
4. Logan et al., 2013, 2017.
5. Busardò et al., 2017.
6. www.druggeddriving.tirf.ca.

Supervision

CONTEXT OF THE ISSUE

The main objective of community supervision of drug-impaired drivers is to hold them accountable for their behavior and encourage them to adopt attitudes and behaviors that discourage repeat impaired driving offenses. This is accomplished through the application of conditions of supervision, rehabilitative strategies, and the use of graduated responses. Current thinking within corrections and supervision agencies is to place greater emphasis on behavior change strategies rather than the more recent primary focus on compliance with court or probation conditions.

It is widely recognized that impaired driving offenders[1] are a heterogeneous population, and not all offenders require the same intensity of supervision. Research also shows that over-servicing offenders, by using stricter conditions of supervision than required, can be detrimental. A more efficient use of resources is to allocate them to offenders who pose a higher risk of re-offending, and to minimize interventions for offenders who are unlikely to re-offend. The importance of assessment, followed by monitoring of progress towards behavioral goals and objectives, and re-adjusting as needed, is a proven approach. In addition, conditions of supervision should be tailored to individual offenders, and strategies utilized to manage first offenders are distinct from those used to manage repeat offenders.

Research has also provided insight into effective practices to reduce recidivism which include the appropriate level of engagement with offenders based on their risks and needs, the frequency of contact with them as well as the location of contact (e.g., home, work, and probation office). The content of these contacts and the use of drug testing are equally important components. For example, strategies used to supervise addicts are not the same as those used with substance abusers.

Finally, while much is known about effective supervision strategies for alcohol-impaired drivers, as well as drug-using offenders, much less is known about the characteristics, risks, and needs of drug-impaired drivers. As such, research is needed to answer important questions related to the optimal use and focus of interventions for this population of offenders.

RESEARCH NEEDS

Priority research needs related to the supervision of drug-impaired drivers are described below according to chronological flow of a drug-impaired driving case. The most salient research questions are highlighted, but do not constitute an exhaustive list. Each research need is presented and the rationale for prioritizing it is noted.

1. **What is the criminal profile of drug-impaired (marijuana) drivers, and what is their level of criminal involvement or "sophistication?"**
    A better understanding of the criminal profile and the criminal sophistication of drug-impaired drivers is necessary to identify the most appropriate and effective supervision strategies for this population. For example:

- Are these offenders more likely to have other criminal history or traffic offenses compared to alcohol-impaired drivers?
- Do the driving records of these offenders reveal different types of violations or infractions than those of alcohol-impaired drivers?
- Are these offenders more likely to re-offend than alcohol-impaired drivers?
- Does this population present with more deficits that require attention?

Answers to these questions can help to determine the most appropriate assessment instruments for this population, as well as the most appropriate level of supervision that is required. These are important issues to address to reduce recidivism risk. Answers to these questions can also prevent over-servicing offenders that are deemed to be low risk, as this can be detrimental to supervision and hinder behavioral change goals and objectives. This knowledge will help to redirect limited resources to focus on offenders who pose the greatest risk of recidivism and minimize interventions for offenders with low risk of re-offending. However, careful classification of offenders is essential to the delivery of appropriate supervision, as those with polysubstance abuse may be miscategorized based on violations.

Furthermore, knowledge of criminogenic needs, such as criminal thinking, criminal associates, and other risk factors and characteristics of drug-impaired drivers is essential to supervision efforts and can offer insight into underlying factors that contribute to the offenders' criminal behaviors. Assessing the criminogenic needs of offenders is important to identify and prioritize the response to such needs. Future studies are needed to explore the criminogenic needs of drug-impaired drivers and determine if these needs are more or are less pronounced as compared to other types of offenders.

In addition, it is important to determine if there is a sub-population of "high-risk"[2] offenders that pose a greater risk that others. A subpopulation of high-risk drug-impaired drivers pose a more substantial threat to public safety, particularly those that are polysubstance users. Identifying the characteristics of those drug-impaired drivers that have the greatest risk of re-offending can greatly aid in prevention efforts and inform the allocation of resources. As such, research is needed to determine whether drug-impaired drivers are a homogenous or heterogeneous group, and whether the risk posed by this population is generally similar, or whether some offenders pose a much greater risk than others, as is the case with alcohol-impaired drivers.

Ultimately, this research is essential to better understand the supervision needs of drug-impaired drivers and assess the level of risk they present. Answers to these questions can help to increase preventative efforts and facilitate the early identification of high-risk offenders and interrupt the path to repeat offending. This knowledge can also enable the efficient allocation of resources and ensure that the necessary resources are directed towards offenders with a higher risk of re-offending.

2. Are interventions that have been proven effective in reducing recidivism among alcohol-impaired drivers also effective with drug-impaired drivers?
Effective interventions to reduce recidivism employ an appropriate level of engagement with offenders based on their risks and needs. This also determines the frequency of contact with them as well as the location of contact (e.g., home, work, and probation office). The content of these contacts and the use of drug testing are equally important components, and there are different approaches to supervising substance abusers as opposed to addicts.

However, while much is known about effective supervision strategies for alcohol-impaired drivers, as well as drug-using offenders, it is unknown whether similar or different types of interventions are needed for drug-impaired drivers.

At present, many drug-impaired drivers participate in interventions developed for alcohol-impaired driving, although little is known about the effectiveness of these tools with a drug-impaired driving population. Research is needed to evaluate the effectiveness of alcohol-impaired driving interventions with drug-impaired drivers, as this will provide an important starting point to inform the development of effective interventions for drug-impaired drivers.

3. Are marijuana-impaired drivers polysubstance users? In particular, what is the frequency of alcohol use among this population, and how often do they use alcohol in combination with marijuana when driving?

Marijuana and alcohol are often used in combination. In addition, many drug-impaired drivers that are arrested have also consumed alcohol in conjunction with more than one drug. According to the experiences of many DREs, many drug-impaired drivers appear to be polysubstance users which makes them a greater risk on the road. More research is needed to understand the prevalence of polysubstance use among drug-impaired drivers and, in particular to determine the frequency with which drivers combine marijuana with alcohol as research suggests that the effects of alcohol are additive when marijuana is consumed.

Knowledge of these behaviors can inform enforcement and supervision efforts, and tailor intervention strategies to better address the prevalence of this behavior. Increased awareness about patterns of use can also help supervision officials assess the level of risk and potential of re-offending.

4. What is the frequency of use of marijuana by marijuana-impaired drivers between arrests?

Similarly, research investigating the frequency of marijuana use by marijuana-impaired drivers between arrests is essential to develop effective intervention strategies for drug-impaired drivers. Research is needed to gauge the frequency of marijuana use in this population and determine the most effective drug testing protocol as part of supervision strategies.

This knowledge can enable supervision officials to formulate effective interventions to ensure drug testing can detect current use, deter future use and support sobriety. Ultimately, these findings can facilitate the development of intervention strategies for marijuana-impaired drivers that effectively reduce the likelihood of re-offending.

NOTES

1. The term offender is used throughout this report as a convenient, yet general descriptive label that includes those arrested and supervised pre-trial, during diversionary status, on probation, or released on parole.
2. Offenders that are at high risk of repeat drug-impaired driving offenses.

Treatment

CONTEXT OF THE ISSUE

A driving while impaired violation is a strong marker of risk for recidivism,[1] fatal crashes,[2] social marginalization and disadvantage,[3] and all-cause mortality.[4] Hence, provision of effective remediation to prevent recidivism represents not only a traffic security imperative, but an important public health strategy as well. Most jurisdictions have a driving while impaired recidivism prevention strategy in place, frequently as a facet of the relicensing of drivers following a violation. Their content and orchestration are both varied and usually multifaceted. In broad strokes, programs can involve an assessment of drivers to detect substance misuse and other risk factors of recidivism as well as to guide individualized prevention planning, mandated, or voluntary programs designed to assist drivers to decouple substance misuse from driving via technology (e.g., interlock, transdermal alcohol monitoring), or referral to psychosocial interventions that target behavioral change related to substance misuse and driving while impaired behavior.[5] This chapter focuses on research needs regarding psychosocial interventions (i.e., treatment) for driving while impaired, and driving while impaired by drugs specifically.

For several reasons, driving while impaired by alcohol has traditionally been the violation for which most offenders have been detected, prosecuted, and subsequently mandated to remedial relicensing programs. Indeed, the global burden on health associated with driving while impaired by alcohol[6] appears at present to be significantly greater than that related attributable to driving while impaired by drugs.[7] At the same time, there is growing awareness that the heterogeneity in psychoactive substance use patterns observed in the general population generalizes to the driver population.[8] Some evidence indicates that polysubstance misuse increases recidivism risk.[9] Moreover, legalization of cannabis in a growing number of North American jurisdictions is fueling more vigorous detection and prosecution for driving while impaired by cannabis. This development will intensify the heterogeneity in the characteristics of drivers confronting clinicians in recidivism prevention settings, and task the research community to identify evidence-informed treatments to reduce the risk of driving while impaired by drugs recidivism.

The consensus regarding psychosocial driving while impaired prevention programs is that they can be modestly beneficial to reduce recidivism.[10] Given the historical focus in the treatment evaluation literature on prevention of driving while impaired by alcohol recidivism however, the evidence for their effectiveness for preventing driving while impaired by drugs recidivism is scant. At the same time, research into the benefits of specific treatments in the driving while impaired by alcohol field has been is been dogged by vexing methodological and conceptual challenges, and that are likely to be exacerbated in research about treatment of driving while impaired by drugs. For instance, among the 42 studies reviewed in a recent systematic review of driving while impaired recidivism interventions,[11] less than 25% used a methodology (i.e., experimental or randomized controlled trial) that would allow causal inferences about the effect of treatment exposure on outcomes. Thus, while potentially suggestive, most treatment evaluation studies of driving while impaired do not meet the recognized threshold for providing minimal evidence of clinical benefit. In naturalistic studies testing specific driving while impaired interventions in more realistic contexts, the need for accounting for the impact from non-random effects that influence the outcome of offenders are frequently ignored.

The established heterogeneity in the characteristics of alcohol-impaired driving offenders[12] will be magnified in those of driving while impaired by drugs, thus posing additional challenges for clinicians with respect to assessment and treatment assignment. The drivers detected for driving while impaired by drugs in many cases will present with patterns of substance misuse, behavioral risk-taking, and dysregulation in associated neurobiological systems that are meaningfully distinct from those seen in drivers detected primarily for driving while impaired by alcohol.[13] Whether treatments that are effective for reducing recidivism in driving while impaired by alcohol will generalize to driving while impaired by drugs is unknown. What seems to be clearer than ever however is that no one treatment for reducing driving while impaired recidivism can be expected to be sufficiently effective for offenders presenting for remediation.[14]

This chapter considers a number of research needs for the development of evidence-informed treatment of drug-impaired driving offenders, especially in light of what can be gleaned from the alcohol-impaired driving research literature. Driving while impaired with cannabis is a particular focus here, given the prevalence of cannabis use in the general and driver populations[15], and the trend towards legalization. Below, research needs that are salient to the above discussion are presented, followed by consideration of how research might be designed to address these needs.

RESEARCH NEEDS

The research needs associated with the priority area of treatment are listed in the following section according to chronological flow of a drug-impaired driving case. The most salient research questions are highlighted, but do not constitute an exhaustive list. Each research need is described in addition to the rationale for prioritizing each question.

1.   Have treatment programs for drug-impaired driving offenders been evaluated for effectiveness?

Studies evaluating specific treatments for reducing recidivism among drivers impaired by drugs, and particularly by marijuana, are presently rare, but their number can be expected to grow exponentially. In general, determining whether a treatment is beneficial starts with efficacy research, which tests a treatment under ideal conditions (i.e., set forth by the experimenter). Randomized controlled trial (RCT) methodology is the preferred approach in efficacy research, and involves random assignment to different treatment conditions (e.g., experimental treatment versus comparator or control treatment), and monitoring of interventions for their fidelity to their prescribed application. These features protect against most threats to internal validity (e.g., case mix, history, self-selection, time, and inadequate treatment implementation) necessary to establish a causal link between the treatment exposure and outcomes.[16]

Nevertheless, RCTs of treatments to reduce driving while impaired by alcohol recidivism are rare[17], with the result being that much of the evidence underlying current treatments for reducing recidivism is based upon studies with methodologies (e.g., quasi-experimental, natural experiments) that do not allow inferences of causality between treatment and a positive outcome. To our knowledge, RCTs of treatments have not been applied for testing treatments for driving while impaired by drugs, and by marijuana specifically. As the traffic safety research community attempts to identify treatments with the potential to reduce recidivism of driving while impaired by

cannabis, more use of RCT methodology than has historically been the case, despite being demanding to design, execute[18] and report (see Consort Statement for details[19]), is clearly needed.

While efficacy research examines whether a treatment works under ideal conditions, effectiveness research looks at how that evidence translates into the real world. This is obviously critical to evidence-informed treatment, as a treatment that cannot show effectiveness outside the laboratory for any number of reasons (e.g., not deployable with adequate fidelity[20] or effects are clinically meaningless) is simply not useful. In general, treatment effectiveness studies follow efficacy studies, which represents the typical "bench-to-practice" order of translational clinical science.[21] Effectiveness research may or may not use randomization, but randomization of offenders to different treatments is often not feasible. In such cases, naturalistic studies using non-randomized methodologies (e.g., nonequivalent comparison group experiment design or quasi-experiments) are frequently used to evaluate the impact of different programs in the field. However, inferences of treatment effectiveness in this context can be significantly compromised by non-random factors that are frequently encountered in driving while impaired remediation settings and that are likely to influence outcomes, such as court-mandated and administrative relicensing assignment to different programs based upon BAC at arrest or results of risk assessments. With few exceptions,[22] these factors are often not often considered in the driving while impaired treatment effectiveness research but can significantly bias the results. Their effects are further complicated by the introduction of new and unpredictable legal and administrative dispositions regarding mandated referral of drug-impaired driving offenders to treatment. Relatively new statistical methods (e.g., regression discontinuity design) are capable of accounting for these threats,[23] but they remain underutilized in impaired driving treatment research.

In summary, both treatment efficacy and treatment effectiveness are important to establishing the benefits in the field for the treatment of drug-impaired drivers. Efficacy studies have traditionally been rare in the impaired driving field, while effectiveness studies, though more numerous, have been challenged by real-world conditions that limit inferences concerning treatment benefits. Going forward, RCTs are needed to identify efficacious treatments for reducing recidivism among drug-impaired driving offenders, and well-designed effectiveness studies are equally needed to understand how these treatments translate into improving the real-world outcomes from recidivism prevention and relicensing programs.

2.   Have clinically relevant subgroups among drug-impaired drivers been identified?

Marked heterogeneity is observed in characteristics, and treatment outcomes, in the alcohol-impaired driving population. Accordingly, an enduring hypothesis in this treatment field is that effective matching of driving while impaired treatment to the needs of individual offenders can improve outcomes.[24] One research approach to this hypothesis involves the identification of homogeneous offender subtypes, or typologies who do well when exposed to specific interventions.[25] Studies to identify these typologies have predominantly relied on cross-sectional study designs, psychometric measurement, and statistical methods like cluster analysis.[26] While these approaches are relatively easy to undertake, the resulting typological formulations have varied significantly between studies, including their number and constituent dimensions[27] and have provided limited insight into possible mechanisms underlying maladaptive behavior. These shortcomings are likely to be magnified when considering the added heterogeneity in the drug-impaired driving case mix.

A potentially more clinically meaningful approach, and one being actively pursued in the related addiction field, involves identification of phenotypes. Individual members of a phenotype show common:

- Maladaptive behavioral manifestations;
- Prognostic severity;
- Personality, cognitive, neurobiological, and physiological features that plausibly explains maladaptive behavior; and
  - Selective responsivity to specific interventions.[28]

Implicit in this approach is that the research will have to extend beyond empirical statistical approaches (e.g., cluster analysis) to identify candidate phenotypes, and use multiple methods triangulation[29] (e.g., genetic, neural, and hormonal measures) to gain additional explanatory insight than that provided by self-reported psychometric measures that are predominant in traffic safety research. Data are beginning to emerge in support of

- The genetic[30], neural,[31] and hormonal[32] substrates of driving while impaired propensity;
  - Behavioral phenotypes within the driving while impaired population;[33] and
  - Selective treatment responsivity based upon genotype.[34]

In sum, the connection between genotype, externalizing behavior and drug misuse will be increasingly difficult to avoid when targeting the different mechanisms underlying drug-impaired driving, and the design of treatments capable of interrupting them.[35]

3. What role does dynamic decision-making play in drug-impaired driving offenders?

Alcohol use disorder is over-represented in the driving while impaired by alcohol population. This longstanding observation has focused recidivism prevention efforts on detection and treatment of alcohol use disorder (AUD). Lack of control over alcohol, a key symptom of AUD, invariably results in episodes when acute intoxication is present in a security sensitive situation (i.e., when an individual has access to a vehicle and the inclination to drive it). Nevertheless, it is increasingly clear that a substance use disorder is neither a necessary precondition nor sufficient explanation for engagement in driving while impaired behavior. Other patterns of alcohol misuse, such as binge and heavy drinking are involved in the majority of driving while impaired events.[36] In such cases, risky impaired driving behavior may emerge from a more complex cascade of individual and environmental interactions[37] that begin when drivers are in a sober state and persistently engages in poor planning and risky decision-making (e.g., deciding to drive to a venue where heavy drinking is likely to occur), and ends when after excessive drinking, drivers fail to accurately evaluate their level of intoxication (e.g., "I feel fine to drive") and demonstrates impulsive (e.g., "I only have two kilometers to drive") and risky decision-making (e.g., "I need my car at home tomorrow morning so I'll take the risk"). Deficits have been observed in executive control, decision-making, and emotional processing in sober alcohol-impaired driving samples[38], while there is evidence for individual differences in subjective responses to alcohol intoxication and susceptibility to alcohol-related disinhibition.[39]

Despite these recent discoveries and the dynamic processes revealed, few studies have holistically examined these processes in the context of impaired driving by alcohol recidivism and treatment approaches that could interrupt them (i.e., targeted treatment).[40] Alcohol-impaired driving research, and even the embryonic driving while impaired by drugs literature,[41] continues to favor correlational psychometric studies that explores static sociodemographic and personality links to impaired driving status in sober offenders (i.e., driving while impaired recidivist versus 1st offenders versus nonoffenders), an approach that offers limited explanatory insight into the processes influencing engagement in persistent impaired driving behavior or into how targeted treatments may be designed. While psychopharmacological studies have investigated the effects of acute drug intoxication on the psychomotor and cognitive capacities required for driving,[42] no studies to our knowledge have examined the role of drug intoxication from a holistic, dynamic decision-making perspective. Given the use patterns and specific psychoactive effects of different drugs, and especially marijuana, the generalizability of cognitive and decision-making findings from studies of alcohol-impaired driving offenders to drug-impaired driving offenders is far from certain.[43] In sum, research into interactions between individual differences, marijuana and drug intoxication, and drug-impaired driving related decision-making processes is needed to inform development of targeted treatment.

4. What sex and gender effects exist in the treatment of driving while impaired by drugs and by cannabis specifically?

The overrepresentation of male alcohol-impaired driving offenders in the traffic safety literature is enduring. Nevertheless, evidence for sex differences in the psychosocial,[44] personality,[45] and even neural characteristics[46] of drivers who engage in alcohol-impaired driving behavior has not been found. Research into sex effects in treatment outcomes for alcohol-impaired driving recidivism remains rare. Both sex and gender effects are associated with marijuana use and patterns of consumption, behavior- and health-related impacts, and treatment outcomes.[47] Hence, research into sex and gender effects in the treatment of drug-impaired driving, and marijuana specifically needs to be prioritized to avoid the gaps that exist in the alcohol-impaired driving treatment literature.

NOTES

1. Rauch et al., 2010; Ahlin et al., 2011.
2. Brewer et al., 1994.
3. Karjalainen et al., 2014.
4. Impinen et al., 2010.
5. NHTSA, 2010.
6. GDB, 2016.
7. Romano et al., 2014.
8. Kriikku et al., 2015; Ojaniemi et al., 2009.
9. Impinen et al., 2009.
10. Miller et al., 2015; Wells-Parker et al., 1995.
11. Miller et al., 2015.
12. Nochajski et al., 2006.
13. Brown et al., 2016.
14. Scherer et al., 2015.
15. Li et al., 2012; Johnson et al., 2012; Cook et al., 2017; Valen et al., 2017; Hasin, 2018.

16. Ouimet et al., 2011.
17. Miller et al., 2015.
18. Sargent, 2010.
19. Boutron et al., 2008.
20. Miller et al., 2014.
21. Mercer et al., 2007.
22. Flam-Zalcman et al., 2013.
23. Shadish and Cook, 2009.
24. Impinen et al., 2009; Miller et al., 2015; Wells-Parker et al., 1995; Nochajski et al., 2006; Brown et al., 2016; Scherer et al., 2015; Ball et al., 2000; Wells-Parker et al., 1990; LaBrie et al., 2007.
25. LaBrie et al., 2007; DeMichele et al., 2013; Hillemacher et al., 2008; Donovan et al., 1990; Saltstone et al., 1989; Ulleberg, 2001.
26. Ball et al., 2000; Wieczorek et al., 1992; Wells-Parker et al., 1986; Nolan et al., 1994; Ulleberg et al., 2003; Donovan, 1993; Okamura et al., 2014; Lastovicka et al., 1987.
27. C'de et al., 2001; Fernandes et al., 2007; Fernandes et al., 2010.
28. Waite et al., 2014; O'brien et al., 2006; Claus et al., 2012; Hutchinson, 2008.
29. Mercer et al., 2007.
30. Beaver et al., 2012; Anum et al., 2014; Quinn et al., 2013.
31. Dedovic et al., 2016.
32. Couture et al., 2015; Eensoo et al., 2004.
33. Brown et al., 2016.
34. Eensoo et al., 2018.
35. Tomko et al., 2016.
36. Flowers et al., 2008.
37. Beaver et al., 2012; Kusev et al., 2017.
38. Brown et al., 2016; Couture et al., 2015; Bouchard et al., 2012.
39. Quinn et al., 2011; Quinn et al., 2016; Fillmore et al., 2009; Marczinski et al., 2007.
40. Aharoni et al., 2013.
41. Richer at el., 2009.
42. Bondallaz et al., 2016; Desrosiers et al., 2015.
43. Sewell et al., 2009; Busardò et al., 2017.
44. Elliott et al., 2006.
45. Brown et al., 2015.
46. Dedovic et al., 2016.
47. Cooper et al., 2018; Cuttler et al., 2016.

Public Policy

CONTEXT OF THE ISSUE

The identification of policy priorities and development of public policy on drug-impaired driving is often created more swiftly than research is conducted. In many instances there is not sufficient science to support public policy decisions at the time they are made. Research examining the effects of the legislation to decriminalize or legalize marijuana and investigating the most effective implementation strategies are needed to direct the development of sound public policy.

Developing public policy without adequate research creates the possibility for unintended consequences resulting from policy implementation. Moreover, in the absence of comprehensive data about drug-impaired driving, the magnitude of the problem cannot be adequately conveyed to policymakers. Therefore, the development of sound public policy necessitates the dissemination of existing and new research initiatives in conjunction with comprehensive data collection in order to provide a foundation of scientific evidence to inform public policy.

RESEARCH NEEDS

The research needs associated with public policy are listed in the following section according to chronological flow of a drug-impaired driving case. The most salient research questions are highlighted, but do not constitute an exhaustive list. Each research need is described in addition to the rationale for prioritizing each question.

1. What are the social policy considerations of decriminalizing marijuana without legalization?
As jurisdictions consider the costs and benefits associated with enacting new legislation for marijuana, it is essential for research to address the social policy considerations of the decriminalization of marijuana without legalization to allow jurisdictions to make an informed decision whether to decriminalize or legalize marijuana. Research is needed to determine the social implications associated with decriminalized marijuana, such as how the legislation may affect usage rates, and if decriminalization reduces the social costs associated with the criminality of the drug.

Ultimately, research to identify social policy considerations related to marijuana decriminalization can serve to highlight important issues so that they can be addressed during the development and implementation of a legal and regulatory framework for the decriminalization of marijuana.

2. What is the effect of decriminalizing or legalizing marijuana on drug-impaired driving?
Due to legislation to decriminalize or legalize marijuana, road safety is a primary public policy implication, and a legal and regulatory framework that addresses these concerns is essential. However, in order to understand the effects of decriminalized or legalized marijuana on road safety in general, research must address the effects of these strategies on the prevalence of drug-impaired driving. As a precursor to this research, more robust and better data are

paramount to create a strong foundation to increase knowledge and understanding of this issue. Improvements to data collection that establish universal definitions for key variables and set essential outcome and process indicators can facilitate research to determine the effect of legalization. It can also provide the opportunity to compare the impact across respective countries. Possible measures to consider include: deaths, injuries, arrests, convictions, number of drug-impaired drivers, number of drug-positive drivers, number of drivers, total population.

3. Does legalizing marijuana reduce the black market for this drug or does it increase the market for other drugs? Similarly, does the legalization of marijuana affect the usage rates of other drugs?

Often, one of the main objectives of legislation to legalize marijuana is to reduce the black market for this drug. However, experiences from Washington and Colorado suggest that this is not the case. To gain insight into the effects of legalization on the black market for marijuana and its associated criminal impacts, research is needed to examine what aspects of the legislative design incentivizes or deters the continuation of the black market.

Much less is known about the effects of legalizing marijuana on the usage rates of other drugs. There is currently no consensus, as some research suggests that legal marijuana increases rates of drug abuse, whereas other research fails to find an effect of legalized marijuana on drug use. Therefore, it is essential for research to explore whether the commercial availability of legal marijuana increases the availability of other drugs, and incites increased rates of drug abuse, or if legal marijuana decreases the consumption of other drugs, such as alcohol.

This research is essential to anticipate the additional unintended social impacts and potential negative effects that legal marijuana can have on public health. Ultimately, answers to these research questions can provide policymakers with a comprehensive list of considerations that can be used to develop sound public policy.

4. Does legalization of marijuana affect the rates of crimes and homelessness near dispensaries?

The effect of marijuana cultivation plants and dispensaries on communities is a highly debated topic. Research is needed to determine how the legalization of marijuana affects the rates of crime and homelessness near cultivation plants and dispensaries. Studies that have examined the effects of a dispensary in a community often demonstrate elevated crime rates; however, there are also findings to suggest that dispensaries tend to be located in areas that already have higher crime rates.

To this end, more research to determine the effect of legalization on crime rates and homelessness in the vicinity of these facilities is essential to determine the societal impact that legalized marijuana has on these communities, and how the legalization of marijuana may exacerbate impacts on communities that may already have high rates of crime and homelessness.

Public Education and Awareness

CONTEXT OF THE ISSUE

Public awareness of marijuana is characterized by misperceptions and unanswered questions. There are widespread misperceptions about marijuana usage, the effects of marijuana on driving, the laws that exist to prevent marijuana-impaired driving, and the ability of police to enforce those laws. It is a common misperception that marijuana is not harmful, and it is often reported that marijuana is perceived as a healthy, organic, medicinal, and natural herb. This misperception has important implications for healthcare, as the risk of negative public health effects related to marijuana use can place a substantial burden on emergency room and other health-related services.

The effects of marijuana on driving ability are also misunderstood. It is a common misperception among users that they are a "better" driver after consuming marijuana. Results from the Traffic Safety Culture Index by the AAA Foundation for Traffic Safety reported that just over half of respondents believed that using marijuana within 1 h of driving increased crash risk.[1] This misperception has important implications for road safety, as the lack of awareness about the impairing effects of marijuana on driving can directly impact the rates of drug-impaired driving and drug-related crashes.

Misperceptions also exist about legislation related to marijuana and driving. It has been reported that drivers have little knowledge of per se laws for marijuana.[2] Moreover, drivers tend to believe that police officers do not have the tools to test marijuana-impaired drivers and do not have the ability to remove them from the road.[3] This misperception has important implications for enforcement, as the lack of knowledge about the laws and police investigative powers can erode the deterrent effects of laws and may encourage increased levels of drug-impaired driving among potential offenders.

States that have made the move to legalize some form of marijuana have underscored the importance of public education in advance of legalization. Public education campaigns that are delivered in advance of any changes to the regulatory framework, and as often as possible, can ensure that the public has time to establish a knowledge base on this issue and misperceptions are addressed. It is beneficial for public education campaigns to use a positive approach and emphasize driving sober instead of telling drivers "don't drive high." Messaging should emphasize the impairing effects and risks associated with marijuana and driving as well as underscore the risk of mixing marijuana with alcohol or other drugs and driving. Finally, messaging should also underscore that although it may be legal to possess marijuana, it is not legal to use marijuana while driving. Messages that are targeted towards youth and high-risk populations will help key lessons resonate with these specific groups. However, it is important to ensure that messages do not inadvertently encourage persons who may not otherwise use marijuana,[4] and who may be pre-disposed to substance misuse or abuse, to initiate use. Comparisons with alcohol impairment are also discouraged in light of evidence that these drugs have different effects and are metabolized differently.

Finally, guidance regarding ways to safely use marijuana can help consumers, in addition to detailed information about the effects depending on concentration and form of consumption. High-risk subgroups, such as adolescents, can benefit from guidance, support strategies and coping skills. Awareness about the availability and usage of technologies to detect marijuana-impaired driving is also much needed.

RESEARCH NEEDS

The research needs associated with the priority area of public education and awareness are listed in the following section according to chronological flow of a drug-impaired driving case. The most salient research questions are highlighted, but do not constitute an exhaustive list. Each research need is described in addition to the rationale for prioritizing each question.

1. How does public education affect rates of marijuana consumption among youth and adults?

The rates of marijuana consumption among youth and adults can be affected by several factors. As consumption rates are monitored for the effects of legalization on usage, it is also imperative that research examines the effects of public education on the rates of consumption. As such, research is needed to understand how a variety of educational strategies can reduce rates of consumption of youth and adults, and which educational strategies resonates with each age group.

Ultimately, the findings from this research can help design and tailor educational approaches that effectively reduce marijuana consumption. Furthermore, these findings can facilitate targeted public education campaigns with messages that are adapted to the intended audience.

2. What types of messages are most effective to prevent people from driving when they are impaired by marijuana?

Messages surrounding marijuana use and driving that focus on the impairing effects of the drug will help the public manage and reduce the risk of driving while impaired. Messages that are mindful of the desired outcome behavior are essential to the success of public education campaigns, and therefore messages that address common questions such as "how much marijuana is safe to consume and drive?" or "how long after consuming marijuana can you drive?" should be considered with outcomes in mind.

As such, research is needed to determine the most effective messaging to convey the impairing effects of marijuana on driving. However, it will be important that these messages are in line with personal experience, otherwise the public may not find these messages relatable. Other issues such as the use of marijuana and alcohol while driving also require attention as questions about the combined effects of these two substances may not be top of mind for the public.

This research is essential to inform public education and awareness campaigns, and the approach to addressing this question will largely determine the attitudes and strategies that the public adopts towards marijuana and driving.

3. What types of messaging are most recognized by the public and most effective in changing behavior?

The types of messages surrounding public education campaigns and their effects on behavior change have a significant impact on the prevalence of marijuana-impaired driving. It is essential that research is undertaken to determine what types of messages are most successful at reaching the public, and the effectiveness of messages in changing behavior. It must be underscored that the content, tone, and style of messages, as well as their delivery, play a significant role in terms of whether messages resonate with the public's experiences, and motivate them to change their behavior accordingly. Moreover, an understanding of public knowledge, attitudes and beliefs towards marijuana and driving is essential to inform education campaigns that

shape and reinforce social positive norms. If public attitudes regarding drug-impaired driving are unclear, then social norming may not be appropriate and may not have the intended effect.

Ultimately, this research can provide an evidence-based compilation of available educational campaigns, which is an important step towards developing key messages to form a collection of general and uniform educational messages that can be used nationally, jurisdictionally, and locally.

NOTES

1. AAA Foundation for Traffic Safety, 2017.
2. Arnold and Tefft, 2016.
3. Desjardins, 2018.
4. Werb et al., 2011.

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APPENDIX

Traffic Safety Implications of Increasing Cannabis Use

*Agenda for Mid-Year Meeting of the Alcohol,
Other Drugs, and Transportation Committee*

THURSDAY, AUGUST 10, 2017, 8:30 a.m.–5:00 p.m.

7:30 am – 8:30 am	**Breakfast (Main House)**
8:30 am – 8:45 am **[15 min]**	**Welcome and Opening Remarks (Carriage House)** **Richard Compton, Chair, Mid-Year Meeting Planning Team**
8:45 am – 10:00 am **[75 min]**	**Session 1: Driving Impairment and Crash Risk Due to Marijuana Use** **Session Lead: Richard Compton** **Overview of Topic - Richard Compton** (20 min) Discussion & Recommendations (55 min)
10:00 am – 11:15 am **[75 min]**	**Session 2: Is Law Enforcement Prepared to Deal with Increased Exposure of Marijuana Impaired Drivers?** **Session Lead: Jana Price** **A professional view - Keith Williams** (10 min) Discussion & Recommendations (65 min)
11:15 am – 11:30 am **[15 min]**	**Morning break**
11:30 am –12:45 pm **[75 min]**	**Session 3: Are Prosecutors and Judges Prepared to Deal with Increased Exposure of Marijuana Impaired Drivers?** **Session Lead: Heidi Coleman** **A professional view - Judge Mary Jane Knisely (MT)** (20 min) **DA Hoon Chang (CA)** Discussion & Recommendations (55 min)
12:45 pm – 1:45 pm	**Lunch (Main House)**
1:45 pm – 3:00 pm **[75 min]**	**Session 4: What do Toxicologists Need?** **Session Lead: Richard Compton** **Overview of topic – Barry Logan** (10 min) Discussion & Recommendations (65 min)
3:00 pm – 3:15 pm **[15 min]**	**Afternoon break**
3:15 pm – 4:30 pm **[75 min]**	**Session 5: What information do Drivers Need to Know About Use of a Legal Substance (Marijuana and Impaired Driving?** **Session Lead: Anne McCartt** **Overview of topic - Angela Eichelberger** (20 min) **Jake Nelson** Discussion & Recommendations (55 min)
4:30 pm – 5:00 pm **[30 min]**	**Wrap-up and Plans for Friday**
5:30 pm - 7:30 pm	**Networking Reception & Lobster Bake Dinner (Main House)**

FRIDAY, AUGUST 11, 2017, 8:30 a.m.–12:00 p.m.

7:30 am – 8:30 am	**Breakfast Served (Main House)**
8:30 am – 8:45 am **[15 min]**	**Welcome and Plans for Day 2 (Carriage House)** **Richard Compton**
8:45 am – 9:45 am **[60 min]**	**Session 6: How Might State's Need to Revise their Impaired Driving Statutes to More Appropriately Deal with Drug-Impaired Driving?** **Session Lead: Tara Kelley-Baker** **Comments on Legislation: Darrin Grondel (WA)** (20 min) **Ed Wood (CO)** Discussion & Recommendations (40 min)
9:45 am – 10:00 am **[15 min]**	**Morning break**
10:00 am - 11:00 am **[60 min]**	**Session 7: Data and Research Needs** **Session Lead: Marie Claude Ouimet** (15 min) Discussion & Recommendations (45 min)
11:00 am – 12:00 pm **[60 min]**	**Prioritize Data and Research Needs, Consider Recommendations, Possible Plans for a Circular or Paper** **Session lead – Anne McCartt**
12:00 pm	**Day 2 Closing and Meeting Wrap-up** **Adjourn**

Alcohol, Drugs & Driving Committee (ANB50)

Transportation Research Board

Agenda: Marijuana & Driving Workshop

Presiding Officers:

Robyn D. Robertson, President & CEO, Traffic Injury Research Foundation

Dr. Tara Kelley-Baker, Data and Information Group Leader, American Automobile Association Foundation for Traffic Safety

Speakers and Presentation Titles

1) Presentation title: Cannabis impairment & crash risk

   Presenter: Dr. Richard Compton, Director, Office of Behavioral Research, National Highway Traffic Safety Administration

2) Presentation title: Evaluation of recidivism risk following detection of cannabis impaired driving and strategies for selective prevention

   Presenter: Dr. Thomas G. Brown, Director and Principal Investigator, Addiction Research Program & Director, Policy and Knowledge Exchange, Research Centre of the Douglas Mental Health University Institute
   Assistant Professor, Department of Psychiatry, McGill University

3) Presentation title: Drug-impaired driving enforcement: Experiences from the Field

   Presenter: Constable William Hand, Waterloo Regional Police Service, Investigative Services Traffic, DRE Instructor

4) Presentation title: Supervision and Treatment of Drug-Impaired Drivers: Looking Forward

   Presenter: Mack Jenkins, Chief Probation Officer (ret), San Diego County Probation

5) Presentation title: Driving in the Age of Legalization

   Presenter: Jacob Nelson, Director of Traffic Safety Advocacy & Research Director of Traffic Safety Advocacy & Research for Director of Traffic Safety Advocacy & Research for AAA

Additional description: Workshop presentations will be brief and designed to set the stage for facilitated discussion to further explore and prioritize research needs in relation to each topic.

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, non-governmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Marcia McNutt is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. John L. Anderson is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

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