CDOT COGNITIVE ROADSIDE DEVICE EVALUATION STUDY

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TABLE OF CONTENTS

STUDY BACKGROUND **1**
DEVICE INFORMATION **3**
STUDY METHODOLOGY **5**
Evaluation Methodology 5
Site Selection & Participant Recruitment 7
Data Collection 7
Law Enforcement Collaboration 8
IRB Approval 8
ANALYSIS **9**
Cognivue Thrive Device 9
'Ground Truth' Measurement of Impairment 9
Size & Representativeness of Sample 9
LESSONS LEARNED TO GUIDE FUTURE STUDIES **17**
KEY ISSUES **19**
Technology Issues 19
Legal & Legislative Issues 22
CONCLUSIONS **25**
RECOMMENDATIONS **26**
CONTRACTOR INFORMATION **27**
Traffic Injury Research Foundation, USA, Inc. (TIRF USA) 27
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The CFSRE/NMS Labs team consists of Dr. Barry Logan and Ms. Amanda Mohr. 30
ACKNOWLEDGMENTS **33**
SME Experts 33
REFERENCES **35**

LIST OF TABLES

Table 1 | Drugs Tested in Blood Samples 6
Table 2 | Summary of Data 10
Table 3 | Cognivue Thrive Results vs Drug Testing 10
Table 4 | Type of Drug Detected vs Cognivue Thrive Results 11
Table 5 | AUC Results 11
Table 6 | Odds Ratios for Blood Sample and Cognivue Thrive Agreement 15

LIST OF FIGURES

Figure 1 | Cognivue Thrive Device 4
Figure 2 | Drugs ROC Curve 12
Figure 3 | Cannabis ROC Curve 12
Figure 4 | Cannabis >= 5 ng/mL ROC Curve 13
Figure 5 | Amphetamine ROC Curve 13
Figure 6 | Other Drugs ROC Curve 14

EXECUTIVE SUMMARY

The legalization of recreational cannabis has affected rates of drug-impaired driving in several jurisdictions, including Colorado. Most often this change has been associated with increases in impaired driving fatal crashes as well as arrests for driving under the influence (DUI) post-legalization (1,2,3). In light of a growing, national trend towards the legalization of cannabis for both recreational and medicinal use, as has occurred in Colorado, new and more efficient strategies are needed to enable police to detect impaired drivers under the influence of all categories of drugs.

However, the detection of drug-impaired drivers in much more complex because, unlike alcohol, drugs do not have a clear concentration-effect response, meaning that not all drivers may be impaired at the same drug level. Impairment by drug is influenced by several biological factors and user characteristics which is the primary problem with the setting of per se limits in these cases. This also means it is flawed to rely solely on the measurement of a drug level in saliva or blood because this measure cannot provide conclusive evidence of impairment. The use of per se limits for cannabis is particularly problematic because while some research shows cannabis does impair driving at the population level, these findings cannot be generalized to specific individuals.

For this reason, the identification and validation of accurate and reliable technology which law enforcement can use to detect drug impairment in drivers as a screening tool could augment detection strategies and produce greater efficiencies as well as cost-efficiencies.

Pursuant to House Bill 22-1321, the purpose of this project is to investigate and evaluate the viability of a device capable of assessing cognitive and physical impairment of motorists due to drugs other than alcohol during roadside sobriety investigations. The knowledge and learning gained through this exploratory study can provide a foundation to inform a possible future, larger-scale pilot study to evaluate such devices that show promise for detecting impairment due to drugs when administered at the roadside.

The device selected by CDOT for testing in this study was the Cognivue Thrive. It is a computerized screening tool that measures cognitive function and which could be used to indicate drug impairment when performance deviates from normal testing metrics. The results provided by Cognivue include 28 individual scoring variables, each of which is compared to a normative range based on age. An assessment of whether drivers were impaired or not impaired is provided.

To evaluate the device, an experimental research design was used which involved testing participants with the Cognivue Thrive device, and following this, a blood test. The purpose was to compare the Cognivue Thrive test results with the blood sample results for each study participant. The ‘ground truth’ of impairment was determined by the blood test results. However, it is recognized that the presence of drug indicators in blood is not a perfect measurement of impairment. At an individual level, impairment from drugs is dependent on several factors including dose, method of ingestion, product formulation, biological characteristics, and frequency of use.

Interpretation of the analysis must also consider that the accuracy of the device may differ by age group, but this could not be assessed with the current sample which had few participants of 30 years of age or older. Additionally, the total sample size of 149 is relatively small for providing conclusive results.

The results showed that when drugs were detected in the blood sample there were more subjects judged to be non-impaired than impaired by the device. This would indicate a substantial number of false negatives identified by the device, if the detection of drugs in the blood sample meant the subject was truly impaired. As mentioned above, this result is perhaps not surprising given that detecting the presence of drugs does not necessarily mean the subject was impaired at the time the blood was drawn.

The results for subjects in which no drugs were detected in the blood sample were more difficult to explain. For this category, roughly equal numbers of subjects were judged impaired as were judged non-impaired by the device. This means there were a substantial number of false positives. It is possible some of these subjects judged impaired by the device have a mild cognitive deficit or condition that made performance on the tests difficult. It may also be that some of the exercises on the device are not as useful for detecting impairment in the young population that participated, or, that the way the various scores were combined to assess impairment needs adjusting for a young population.

It can be concluded that the device shows promise for detecting drug-impaired drivers. However, much more research is needed using alternative study designs and with a larger sample size that better reflects the driving population, notably with respect to age.

Additionally, a number of key policy and legislative issues as well as implementation caveats were identified and are discussed in the main body of the report, including:

Technology Issues

1. Law Enforcement agencies need robust, efficient, practical tools to detect drug impairment among drivers at roadside.
2. Law Enforcement officers without DRE or ARIDE training may generally have greater difficulty in determining when such a screening device should be employed or with whom due to the complexity of drug impairment.
3. The availability of a technology or device to screen for impairment reduces the perceived subjectivity of a DRE evaluation.
4. There is some concern that impaired drivers may have difficulty following instructions to use the testing device or be unwilling to do so.
5. Persons who consume certain drugs daily may have a higher tolerance and may not be readily identified as impaired by a new technology.
6. It may be challenging to identify a cognitive testing device that can identify impairment from a broad cross-section of drugs.
7. When devices of this nature are used, there needs to be acceptance from both the scientific and legal communities.

8. A new technology that could be used by non-DRE-trained officers could increase the enforcement of drug-impaired driving laws.
9. Protocols for the use of new technologies must be developed to guide their implementation in police agencies.
10. Law enforcement officers may be reluctant to use the technology to provide the foundation for an arrest without robust research in support of the validity and reliability of the device.
11. Results from a technology that did not require a blood test for confirmation would create efficiencies in the impaired driving system.
12. The use of green labs to conduct further research on the validity and reliability of a cognitive testing device to detect drug impairment would pose some challenges.
13. With respect to use at roadside, this device would require an individual's focused attention which would require a controlled environment with minimal distractions.

Legal & Legislative Issues

1. A state agency would have to be granted authority to permit the approval of a new technology and to develop rules to manage its application and use.
2. Drug-impaired driving laws would need to be revised to include a protocol for this type of cognitive testing and to compel impaired drivers to comply with testing.
3. Legislation would have to specify whether devices are to be used as a basis for an arrest decision at roadside or used post-arrest as confirmatory evidence of impairment for court purposes.
4. The ability to clearly quantify the magnitude of impairment measured by a device is essential to its successful implementation.
5. A per se limit for drugs that can be correlated with a device result may not be possible at this time. In this event, important questions must be answered with respect to how device results relate to the quantification of impairment.
6. It will be critical that results of the device with respect to level of impairment can be clearly articulated for a lay audience.

STUDY BACKGROUND

The legalization of recreational cannabis in many jurisdictions has impacted rates of drug-impaired driving. Several jurisdictions, including Colorado, have reported increases in impaired driving fatal crashes as well as arrests for driving under the influence (DUI) post-legalization (1,2,3). This has generally raised the profile of drug-impaired driving as a priority road safety issue and resulted in greater attention to it. It has also prompted new initiatives designed to better understand and address this problem.

Enforcement has been a key feature of road safety strategies because strong enforcement of drug-impaired driving laws and the consistent detection of impaired drivers on the road underpins the desired general and specific deterrent effects of laws. At the same time, law enforcement agencies have faced new challenges in training and maintaining enough law enforcement officers with Drug Recognition Expert (DRE) training to keep pace with the drug impaired driving problem. It is one of the most demanding and complex certifications to attain in policing. While most officers may begin their career in traffic, they often rotate through several different roles within policing as they gain experience, meaning turnover is substantial and police agencies must continuously recruit and train for this specialized traffic role.

Among drugs detected in the driving population, cannabis has been the most prevalent (4), although depressants, stimulants and narcotic analgesics are also common. As such, cannabis poses particular concern given its association with a moderate crash risk (5,6,7,8,9). But many other drugs also have varying degrees of impairment, making them equally concerning, although much less is known about them, and available research evidence is, to date, limited.

Nonetheless, considering a broader, national trend towards cannabis legalization of both medicinal and recreational use, as is the case in the state of Colorado, new and efficient strategies to detect drug-impaired driving, including all categories of impairing drugs, are needed. However, unlike alcohol, research regarding the impairing effects of Tetrahydrocannabinol THC (one of the identified active psychoactive ingredients of cannabis) and other drugs on driving is much more complex because these drugs do not have a clear concentration-effect response. This makes it more challenging to conclude if a driver is impaired using saliva or blood testing alone.

To date, jurisdictions have adopted a variety of legal approaches to tackle the drug-impaired driving problem. Whereas some jurisdictions have opted for zero-tolerance laws, others have relied on behavioural measures of impairment, and still others have instead implemented specific per se limits in law. Per se limits for drugs, particularly cannabis, are problematic given that the level of impairment varies considerably across individuals. While research

suggests there is an impairing effect evident at the population level, it cannot be generalized to specific individuals (10).

As such, the availability of accurate and reliable technology which law enforcement can use to detect the presence of drugs in drivers, like the use of preliminary breath testing devices to detect alcohol, could augment detection strategies and produce greater efficiencies as well as cost-efficiencies. Presently, law enforcement agencies often rely on the capacity of DREs to conduct evaluations to determine the category of drug(s) which are the source of impairment, and this determination should be supported by toxicological analysis if the evaluated party provides a toxicological sample. But as noted previously, a primary challenge for law enforcement is maintaining an adequate number of DRE officers available to respond to investigation requests in a timely manner. Colorado currently has 122 certified DREs.

The purpose of this project is pursuant to House Bill 22-1321. It is focused on investigating and evaluating the viability of a device capable of assessing cognitive and physical impairment of motorists due to drugs other than alcohol during roadside sobriety investigations. This exploratory study serves to inform a possible future pilot study, larger in scale, through lessons learned to evaluate such devices that show promise for detecting impairment due to drugs when administered at the roadside.

The remainder of this report includes the following sections:

- **Device Information** describes the device selected for testing by CDOT.
- **Study Methodology** describes the study design, site selection and participant recruitment, data collection approach, police collaboration and Institutional Review Board (IRB) approval.
- **Analysis** provides a summary of the data collected and presents the analysis results.
- **Lessons Learned to Guide Future Studies** discusses the lessons learned during the execution of the project that will benefit future studies to evaluate similar devices.
- **Key Issues** discusses important points raised by Subject Matter Experts convened as part of the project related to technology, implementation & research, and legal & legislative issues.
- **Conclusions** summarizes the key findings and recommendations from the project.
- **Contractor Information** describes the experience and qualifications of the contractor team that undertook the study.

DEVICE INFORMATION

The device tested was selected by CDOT and is the Cognivue Thrive. The legislative intent of HB 22-1321 was to investigate devices that can assess cognitive and physical impairment of motorists to conclude the presence of drugs other than alcohol during roadside sobriety investigations. Due to the time limits of the study and the CDOT's difficulty in finding a qualified research group with the capabilities of doing the study, only one device was selected. The objective of this study was not to compare devices but to ascertain if a device could be used at roadside. The Cognivue device met the parameters of the study due to its portable size, ease of operation, FDA approval, and its ability to obtain data on an individual's cognitive and physical ability. It is a computerized screening tool that measures cognitive function which could be used to indicate drug impairment when performance deviates from normal testing metrics. The Cognivue technology is based on the science of adaptive psychophysics. In psychophysics, experiments seek to determine whether the subject can detect a stimulus, identify it, differentiate between it and another stimulus, or describe the magnitude or nature of the difference.

The Cognivue Thrive test consists of six, one-minute separately scored sub-tests of three key cognitive domains and two speed parameters. The device measures tracking movement, vision, perception and memory of letters, words, and shapes. The battery of testing includes perceptual processing and memory testing and consists of four domain specific tests of higher visual processing abilities and patient must differentiate between perceptual stimuli.

The device is FDA-approved under Device Class 2, registered establishment name COGNIVUE, INC. and registered establishment number 3014389576.

As shown in Figure 1, the device resembles a laptop and weighs less than eight pounds. It is important to note that the Thrive device was not designed for roadside testing of potentially impaired drivers, and this was clearly indicated by the manufacturer when they were approached to secure devices for this study. As such, the evaluation of the device did not consider ease of use for administering to drivers at the roadside, and in its current form, the technology is not practical for roadside testing purposes.

Figure 1 | Cognivue Thrive Device

STUDY METHODOLOGY

Evaluation Methodology

An experimental research design was used in this study which involved an experimental group of individuals who were deemed impaired and a control group of individuals who were deemed sober. Each potential study participant first performed a preliminary breathalyzer test (PBT) and anyone with a breath alcohol concentration (BAC) result of .08 or greater was excluded from the study. Then potential participants submitted to an oral fluid drug test so researchers could assign them to the experimental or control group. The saliva test panel consisted of THC, cocaine, amphetamines, methamphetamines, benzodiazepines, opiates, and methadone. The goal was to recruit a balance of participants testing positive and negative. Minors (persons under 18 years of age) and pregnant women were excluded as they represent vulnerable populations.

Selected participants then completed testing with the Cognivue Thrive device, and following this, provided a blood sample, collected by a trained phlebotomist. The purpose was to compare results from blood samples with test results from Cognivue Thrive for each study participant.

Blood samples were analyzed by NMS Labs staff for testing and confirmation. Samples were initially screened using immunoassay technology, including the National Safety Council Alcohol, Drugs, and Impairment Division (NSC-ADID) Tier I scope. Any sample that screened positive for one or more drugs was sent on to confirmatory testing which was performed using liquid chromatography tandem mass spectrometry (LCMS-MS) and was quantitative in purpose. Blood samples were tested for the following drugs:

Table 1 | Drugs Tested in Blood Samples

DRE category; cannabis	DRE category; CNS depressants
THC	Nordiazepam
Carboxy-THC	Oxazepam
11-OH-THC	Temazepam
DRE category; CNS stimulants	Carisoprodol
Methamphetamine	Meprobamate
Amphetamine	Zolpidem
MDMA	Alprazolam
MDA	Alpha-Hydroxyalprazolam
Cocaine	Clonazepam
Benzoylecgonine	7-Aminoclonazepam
Cocaethylene	Lorazepam
	Diazepam
DRE category; narcotic analgesics	
Codeine	Methadone
6-Acetylmorphine	Morphine
Buprenorphine	Oxycodone
Norbuprenorphine	Oxymorphone
Fentanyl	Tramadol
Hydrocodone	O-desmethyltramadol
Hydromorphone	

The methodology for analyzing the data and assessing the capability of the tested device to identify drug-impaired and non-drug impaired participants was Receiver Operating Characteristic (ROC) curve analyses to calculate Area Under the Curve (AUC). The AUC enables an assessment of the sensitivity (correctly identifying a drug-impaired participant) and specificity (correctly identifying a NON-drug impaired participant) simultaneously.

Information on each participant's age and biological sex was also collected to assess whether these factors affected the accuracy of the device in detecting impairment. This data was

analyzed using logistic regression to estimate the Odds Ratios (ORs) of both false positives and false negatives based on the collected information.

Site Selection & Participant Recruitment

The identification of a study site for the recruitment of participants and administering of all tests was conducted in close consultation with CDOT and the Boulder Police Department. Criteria for study site selection included:

- Provides a safe environment for study team and participants
- Is well-lit
- Provides a high-volume of passing pedestrians
- Provides space for two RVs that can provide a warm, quiet and comfortable environment for participants

The selected venue was between 11th and 12th streets on College Street in Boulder, CO 80302. Data collection took place from April 11 to 14, 2023 between the hours of 3:00 pm and 9:00 pm.

Participants were informed that test results would not lead to legal consequences given that collection of these data took place as part of a research effort, rather than a legal police enforcement initiative. All subjects were offered an incentive of $150 for their participation.

Data Collection

The protocol for data collection included the following steps:

The study director invited a passing individual to learn about the study.

The study director briefly described the study, asked the individual to participate, explained the $150 incentive for those deemed eligible based on the breath and saliva tests, and guided those who agreed to one of the interviewers. If the individual chose not to participate, the study director thanked them for their time. Individuals were asked their age and pregnancy status and those under 18 years of age or who were pregnant were excluded from the study. Persons who were visibly impaired or whom the study director or any member of the research team felt did not have the capacity to provide valid informed consent were excluded from the study.

The interviewer collected the following data using a tablet.

Participant profile: The interviewer recorded the age and observed gender of the participant.

Breathalyzer: The interviewer administered an approved preliminary breath test (PBT) to identify participants not eligible to participate due to alcohol consumption.

Oral fluid test: The interviewer administered the oral fluid test according to manufacturer specifications. The interviewer entered if the result was positive or negative for drugs, as well as positive or negative for cannabis specifically.

Cognivue Thrive test: The interviewer explained the steps to administer the Thrive test and prepared the device by entering the subject ID number so results could be linked to other collected data. The participant performed the test, which took approximately 5 minutes.

Blood sample: The phlebotomist collected a blood sample and labeled it with the subject ID **number.**

Payment: The interviewer thanked the participant, provided the incentive, and sent them on their way. In case it became clear during the interview that the participant was impaired, the interviewer inquired about how they would be travelling to their next destination. If the participant intended to drive, alternative transportation arrangements were made (e.g., taxi or Uber/Lyft is ordered) by the study director.

Completion: The interviewer properly stored all information captured before indicating to the study director they were ready for the next interview. The study director then guided the next available participant to the interviewer and the process began again.

Law Enforcement Collaboration

The role of law enforcement was restricted to providing security for the team and participants. Off-duty officers were present in the general vicinity, as would be common in any high-traffic area during evening hours, but were not present as potential participants were approached, nor were they were involved in the study. Participants were not identified to off-duty officers, and officers were not privy to test results as this would oblige them to fulfill their duties as officers of the law.

IRB Approval

Written IRB approval was obtained from WCG IRB (https://www.wcgirb.com/about/) to ensure Human Subjects Research protections were observed. The IRB tracking number is 20231077.

ANALYSIS

Prior to presenting study results, several important caveats are discussed.

Cognivue Thrive Device

The results provided by Cognivue include 28 individual scoring variables, each of which is compared to a normative range based on age. Based on these data, an assessment of impaired or not impaired is also provided. For the purposes of comparison with the blood samples, it is this singular assessment of impaired or not that was used. How the individual scores are combined to reach this assessment is unknown to the project team and the evaluation could not assess the accuracy of these individual scores in assessing impairment.

'Ground Truth' Measurement of Impairment

To assess the ability of the device to detect impairment from drugs it is necessary to have a 'ground truth' assessment of drug-related impairment. For this study 'ground truth' was determined by testing the blood samples for drugs. However, the presence of drug indicators in blood is not a perfect measurement of impairment. Unlike alcohol, drugs do not typically have a clear concentration-effect response which makes conclusions about impairment more complex. At an individual level, impairment from drugs is dependent on several factors including dose, method of ingestion, product formulation, biological characteristics, and frequency of use.

Size & Representativeness of Sample

While the study attempted to recruit participants representing a cross-section of age cohorts, the demographics of pedestrians in the study area resulted in a sample which was heavily skewed towards younger participants, with all but 15 of the 149 subjects included for analysis being less than 30 years old. Interpretation of the analysis must consider that the accuracy of the device may differ by age group, however this could not be assessed with the current sample. Additionally, the total sample size of 149 is relatively small for providing conclusive results. It does, however, provide an initial indication as to whether a correlation may exist between device results and forensic analysis. In addition, several 'lessons learned' also emerged through the implementation of this pilot project which can both inform and guide future, larger-scale studies of this nature.

Table 2 contains a summary of the data analyzed. Note that a total of four subjects were excluded due to a blood sample showing a BAC of .08 or greater. These subjects were not included to avoid situations where there may have been an impairment due to alcohol consumption. The sample is well balanced by biological sex. Cannabis was the most frequent drug detected in the blood samples.

Table 2 | Summary of Data

Variable	Count	min	max	mean
Age	149	18	73	22.7
Biological sex	M – 80 F – 69			
Cognivue Thrive result	Impaired – 61 Not Impaired – 88			
Drug detection	Positive – 86 Negative – 63			
Cannabis detection	Positive – 73 Negative – 76			
Amphetamine detection	Positive – 19 Negative – 130			
Other drug detection	Positive – 8 Negative – 141			

Table 3 presents the number of subjects deemed impaired from the Cognivue Thrive test and how many tested positive for any drug from the blood sample. A total of 61 subjects were judged to be impaired according to cognitive test results. Of these, 29 had at least one drug detected in their blood sample and 32 had none. A total of 88 subjects were judged to be non-impaired, and of these, 57 had at least one drug detected and 31 had none.

Table 3 | Cognivue Thrive Results vs Drug Testing

Cognivue Result	Drug Positive	Drug Negative	Total
Impaired	29	32	61
Not impaired	57	31	88

Table 4 shows the number of participants judged to be impaired and non-impaired from the Cognivue Thrive test, for each category of drugs detected in the blood samples, including none. The results showed:

- For subjects with no drugs detected, roughly equal numbers were judged impaired (32) and non-impaired (31)
- For subjects with at least one drug detected, more subjects were judged non-impaired (57) than impaired (29)
- For subjects where cannabis was detected, more subjects were judged non-impaired (48) than impaired (25)
- For subjects with a cannabis result greater or equal to 5 ng/mL of Delta-9 THC, more subjects were judged non-impaired (23) than impaired (9)

- For subjects where amphetamine was detected, more subjects were judged non-impaired (12) than impaired (7)
- For subjects where a drug other than cannabis or amphetamine was detected, more subjects were judged non-impaired (4) than impaired (3)

Table 4 | Type of Drug Detected vs Cognivue Thrive Results

Blood Sample Results	Cognivue – Impaired	Cognivue – Non-Impaired	Total
No drugs detected	32	31	63
At least one drug detected	29	57	86
Cannabis detected	25	48	73
Cannabis detected; Delta-9 THC > 5 ng/mL	9	23	32
Amphetamine detected	7	12	19
Other drug detected	3	4	7

Receiver Operating Characteristic (ROC) curve analyses were undertaken to calculate Area Under the Curve (AUC). The AUC enables an assessment of the sensitivity (correctly identifying impairment) and specificity (correctly identifying non-impairment) simultaneously. While determining the acceptability of a test from the AUC score is subjective, general guidance is that a score of 0.7-0.8 is acceptable and above 0.8 is very good. For tests in which maximizing true positives and minimizing false negatives is vital, high AUC score thresholds are desired.

Table 5 shows the AUC and standard error of AUC for each category of drugs detected in the blood samples, including none. Figures 2 to 6 show the ROC curves from which AUC is determined. For all drug categories, the values of AUC range from 0.41 to 0.50 indicating that the determination of impairment from the cognitive device is not satisfactory.

Table 5 | AUC Results

Drug Type	AUC	Standard Error
At least one drug detected	0.41	0.04
Cannabis detected	0.43	0.04
Cannabis detected; Delta-9 THC > 5 ng/mL	0.44	0.03
Amphetamine detected	0.49	0.03
Other drug detected	0.50	0.02

Figure 2 | Drugs ROC Curve

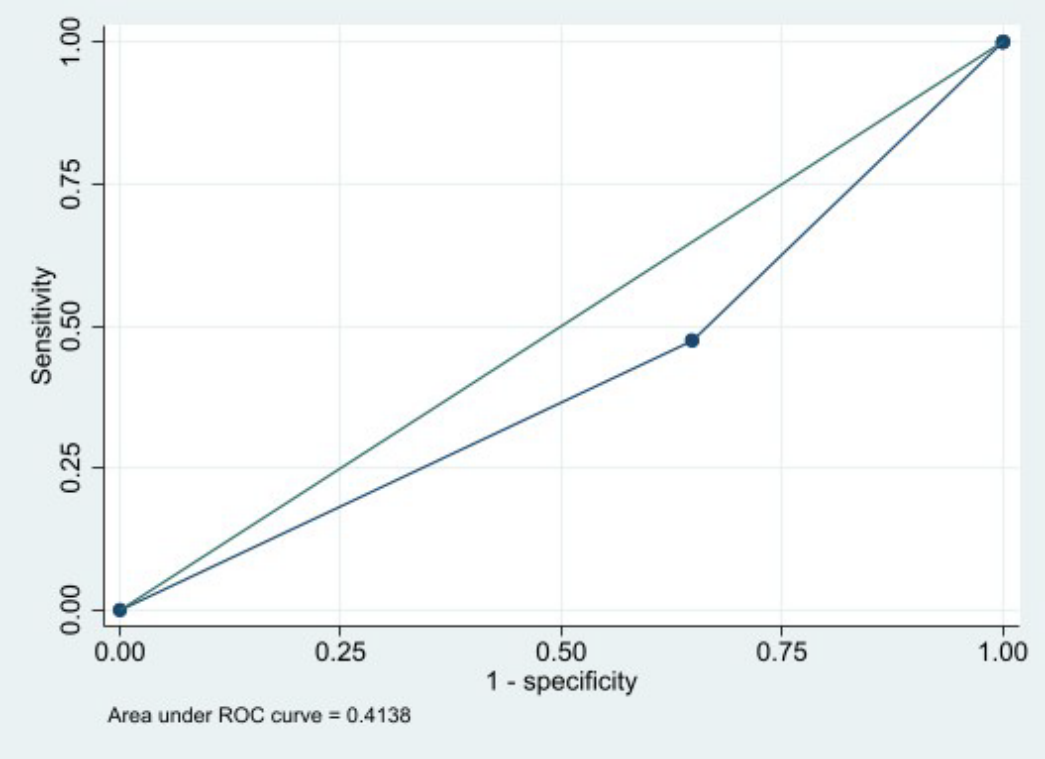


Figure 3 | Cannabis ROC Curve

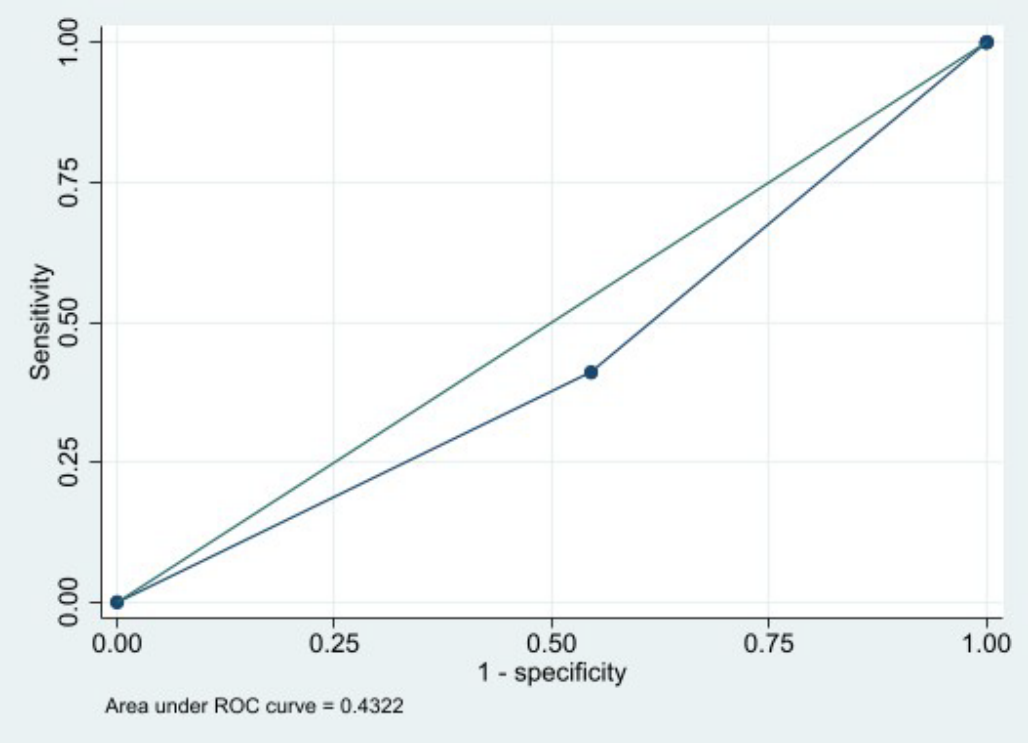


Figure 4 | Cannabis >= 5 ng/mL ROC Curve

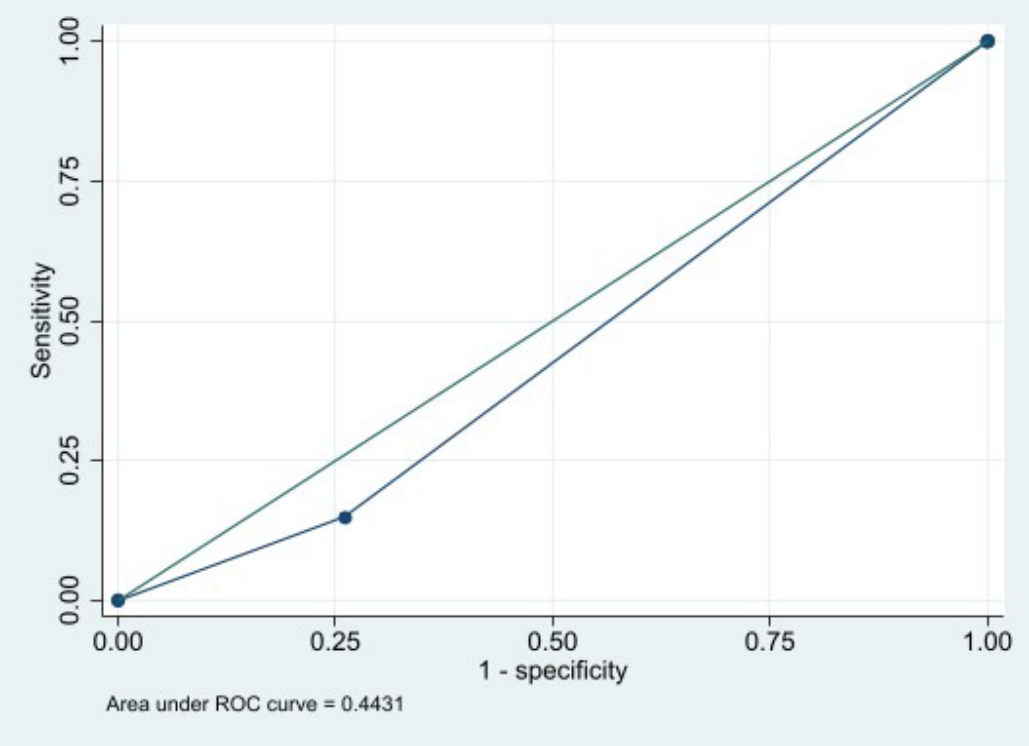


Figure 5 | Amphetamine ROC Curve

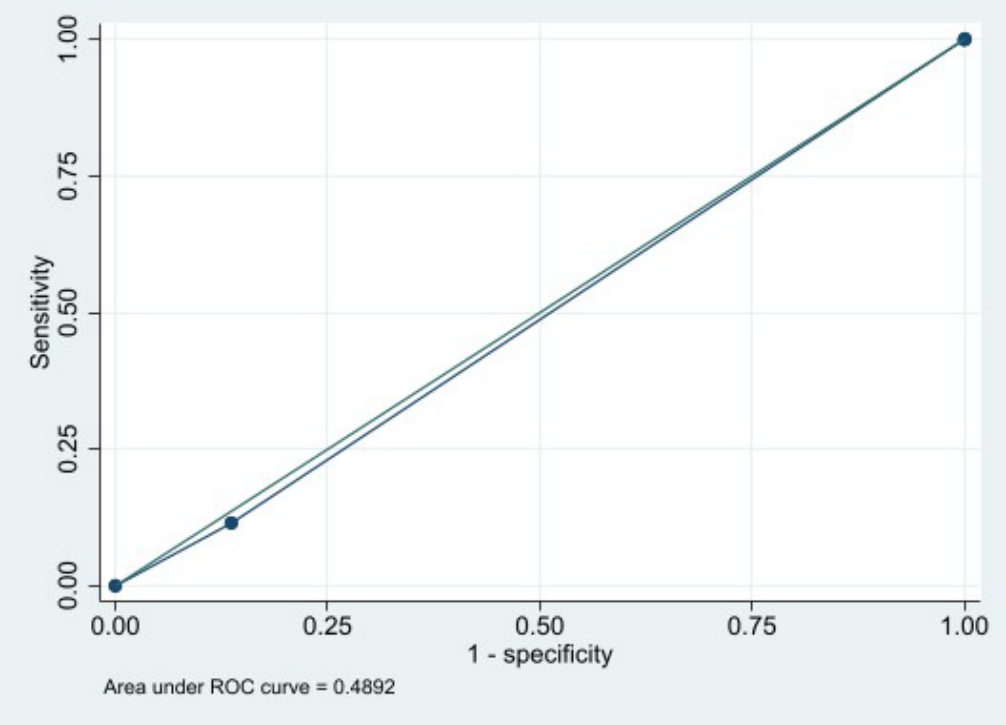
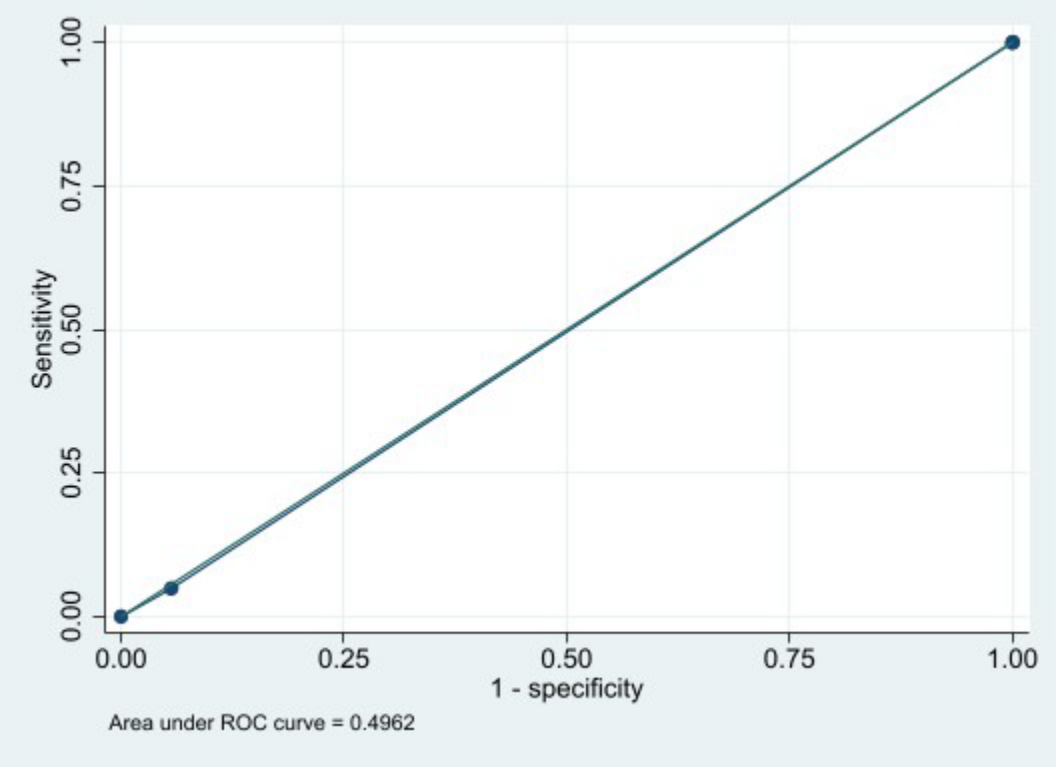


Figure 6 | Other Drugs ROC Curve



Logistic regression models were estimated to assess if subject biological sex or age impacted the likelihood the Cognivue Thrive judgement of impairment would agree with the blood sample results. For each subject, 'agreement' was set equal to 1 if the drug in question was detected in the blood sample and the cognitive screening indicated impaired, or, if the drug in question was not found and the cognitive screening indicated non-impaired. If this was not the case, 'agreement' was set to 0. The Odds Ratios from these models are shown in Table 5. Being female and aged between 18 and 21 were set as the base values for these variables so have an Odds Ratio of 1. For males and being of age 22+, if the Odds Ratio is less than 1 this indicates a lower likelihood of 'agreement', and if greater than 1, a higher likelihood.

The results are inconsistent in that the estimated Odds Ratios for being male or 22+ are not consistently greater or less than 1. Few models produced statistically significant results with only cannabis detected with >-5 ng/mL and 'other' drugs showing statistically significant results for males being less likely to be in 'agreement'. However, even these statistically significant results should be considered in light of the small sample size. Based on these results it cannot be conclusively determined that biological sex or age affected the rate of agreement between the Cognivue device and the blood samples.

Table 6 | Odds Ratios for Blood Sample and Cognivue Thrive Agreement

Blood Sample Results	Biological Sex Odds Ratio (p-value)	Age Odds Ratio (p-value)
At least one drug detected	Female – 1.0 Male – 1.02 (0.95)	18-21 – 1.0 22+ – 1.82 (0.12)
Cannabis detected	Female – 1.0 Male – 0.89 (0.73)	18-21 – 1.0 22+ – 1.15 (0.71)
Cannabis detected; Delta-9 THC > 5 ng/mL	Female – 1.0 Male – 0.55 (0.08)	18-21 – 1.0 22+ – 0.77 (0.50)
Amphetamine detected	Female – 1.0 Male – 0.96 (0.91)	18-21 – 1.0 22+ – 0.80 (0.55)
Other drug detected	Female – 1.0 Male – 0.46 (0.02)	18-21 – 1.0 22+ – 0.79 (0.54)

LESSONS LEARNED TO GUIDE FUTURE STUDIES

The current study was an important first step towards understanding the potential role of cognitive testing devices in detecting drug-impaired driving. It provided much valuable information to inform next steps to build upon the available body of knowledge regarding this topic and guide future exploratory research. Based on experiences from this current study, it appears there are potentially two methodological approaches which can provide more in-depth information to guide determinations about the validity of cognitive testing devices to detect drug-impaired drivers and continue this program of research.

One approach is to utilize a population of arrested impaired drivers as a study sample. This could be achieved by conducting roadside studies in which drivers are stopped by police as part of a Sobriety checkpoint operation. Post-arrest and following the DRE evaluation by law enforcement, researchers could invite subjects to participate in testing using the Cognivue Thrive or a similar device. Advantages of this type of study is that the study population mirrors the driving population police will encounter on the roadway, and a broader cross-section of age cohorts could be tested. While the current study recruited subjects in the field, it is unknown whether participants were in fact drivers or had a valid license, and the ages of participants were mostly under 30 years old. As such, it cannot be determined whether the study population was consistent with the driving population in Colorado or whether different age cohorts performed differently on the device. This is an important issue because there is a growing population of aging drivers on the road, and the recruitment of older pedestrians for this study was limited.

A second approach involves recruiting participants from volunteers in a green lab training exercise. An advantage to this approach is having a fixed location where recruitment of study participants could be done in advance and more information about use characteristics and history could be collected. This could also enable more data collection points over a longer period of time as well as help facilitate the recruitment of older individuals. However, one potential limitation of this approach is that the dosing of subjects in the green lab exercise may not mirror real-world levels which are more consistent among a drug-impaired driver population. Ethical approvals to dose participants to higher levels may not be obtained. In addition, some research suggests that participants titrate their dose as they consume it to achieve the desired high, so dosing may not have the desired effect.

This study also generated additional and practical lessons learned that can inform a future, larger-scale study to evaluate the ability of similar devices to detect drug impairment. The practical issues identified warrant consideration with respect to logistical features of study designs.

1. Measures of point in time impairment are critical as device data are collected. The assessment of impairment solely through blood samples provides a better measure of drug presence than drug-impairment. Given the lingering presence of drugs in the body after impairing effects have subsided, the use of a DRE evaluation of behavioral impairment can aid in more conclusive determinations with respect to actual level of impairment among study participants.
2. A larger scale study would benefit from a longer study period than the current project. Depending on the scale, a timeline between one to three years would be appropriate. This longer timeframe would allow for the recruitment of a larger number of participants which could provide more robust findings. A longer study period would also enable adjustments to the study design that are not working as well as anticipated, for example, recruitment strategies to ensure a diverse study population. Additionally, multiple devices could be tested and compared during a longer study period.
3. Recruitment of subjects over age 30 was more challenging. It is possible a higher-valued incentive may have resulted in more older age cohorts participating. Similarly, the presence of a more structured environment such as a DUI checkpoint or a green lab training facility with scheduled timeslots for participation may also increase participation.
4. The recruitment of subjects in an outdoor environment should include a plan to keep subjects warm and dry if inclement weather occurs and subjects are waiting outside prior to testing being conducted.
5. A female taxi or Uber/Lyft driver should be available in the event a female test subject is impaired and requires a ride to a safe location. Personal safety is an important concern among women, and they may not be comfortable with a male driver if they are impaired.
6. Water should be available and offered to test subjects 10 minutes prior to taking a blood sample to ensure hydration is adequate for the collection of biological samples.
7. Restroom facilities should be accessible to participants.
8. The presence of visual identifiers for the study team (e.g., signage, name badges, shirts, or jackets) can provide additional credibility to signal to participants the study is being conducted on behalf of a recognized authority/entity. This may help to facilitate recruitment of older age participants.
9. Although not an issue for the current study, populations that are less skeptical about science may be more willing to participate in a research study whereas those more skeptical about research may require more information and assurances.

KEY ISSUES

There were also a variety of policy and legislative issues as well as implementation caveats that emerged from this study which warrant consideration. Notably, the research team consulted with a group of key Subject Matter Experts (SMEs) who shared their knowledge and perspectives based on their experiences in different areas of the impaired driving system. This information was useful to identify relevant regulatory and legislative issues which must be addressed as part of future pilot studies to test cognitive or other devices capable of detecting drug-impairment at the roadside.

Subject matter experts who contributed to this study were identified by CDOT and are identified below:

- **Vanessa Beall** - Lab Director at Colorado Bureau of Investigation
- **Lt. Colonel Barry Bratt**, Region One Commander for the Colorado State Patrol
- **Heather Krug**, State Cannabis Sciences Program Manager, Colorado State Public Health Laboratory
- **Allison Rosenthal**, Division of Criminal Justice, Department of Public Safety
- **Ean Seeb**, Senior Policy Advisor on Cannabis to the Governor of Colorado

Two meetings with the SMEs took place in April and May of 2023 to discuss issues related to testing challenges, court challenges, potential needs, and opportunities with respect to device usage, and legislative recommendations to guide future studies. Important discussion points raised during these meetings are summarized below organized according to technology issues, implementation & research Issues, and legal & legislative issues.

Technology Issues

- **Law enforcement agencies are in need of robust, efficient, practical tools to detect drug impairment among drivers at roadside.** While a few cognitive tools are available which can help assess potential impairments, there are currently none that can be used as a fast and reliable screening tool. Notably, the DRE program is an effective tool, but it is not viable at roadside. Instead, suspects must be transported to an environment appropriate to conduct the evaluation, and not only does this delay the collection of evidence; it also imposes considerable staffing and training costs for law enforcement agencies. Of concern, delays between the roadside interaction and DRE testing at the station can result in evidence of impairment being lost. As such, an efficient tool that could be used reliably at roadside would have immense benefits to the enforce drug-impaired driving laws and produce efficiencies in callouts for DREs.

- **Law Enforcement Officers may generally have greater difficulty in determining when such a screening device should be employed or with whom due to the complexity of drug impairment.** Most people have at least some 'life experience' interacting with a person who is alcohol impaired. As such, officers generally have a frame of reference to recognize when a driver may be impaired. But experience with drug-impairment is less common which can make it more difficult for newer officers to recognize these signs and know when to initiate an investigation. While the odor of alcohol is a common, early indicator that police rely on during a stop to determine whether a driver has been drinking and further investigation may be necessary, many drugs do not have an odor which can make detection more challenging for officers to determine whether the use of a screening tool is necessary or justified. Younger and less experienced officers may have limited experience with drug-impaired individuals and may not be familiar with common signs which can indicate drug impairment. While green labs provide experience with cannabis, this is not the case with other drugs. In this regard, Advanced Roadside Impaired Driver Education (ARIDE) trained officers can help fill this gap, but it is a resource issue for police agencies to maintain enough ARIDE officers. For this reason, a roadside testing device could have immense value to aid in the detection of drug-impaired drivers.
- **The availability of a technology or device to screen for impairment reduces the perceived subjectivity of a DRE evaluation.** Although the procedures and protocols of the DRE evaluations have been validated, in and of themselves, there can be a perception that scoring is subjective. A technology that essentially removed the human decision-making part of the process can be valuable to help underscore and demonstrate the objectivity and equity in enforcement actions. Still, it would be most practical to implement a new technology as part of or in tandem with a DRE assessment for logistical reasons. And this would, however, require extensive research and validation of the technology before it could be considered for approval by the International Association of Chiefs of Police (IACP) and National Highway Traffic Safety Administration (NHTSA). This would require a substantial investment of time and resources to achieve.
- **There is some concern that impaired drivers may have difficulty following instructions to use the testing device or be unwilling to do so.** This could be due to impairment, or it could be argued that situational factors (e.g., lighting, noise) affected test results. It could also be a result of a generally uncooperative subject attempting to avoid providing evidence. At present, at least some defense attorneys advise clients to refuse testing since penalties for refusal are administrative or civil in nature whereas penalties for an impaired driving conviction are much more substantial and criminal in nature. There was concern that drivers may also be uncooperative with a cognitive test (i.e., refuse) and not comply with test instructions which would undermine the efficiency of the technology. In this regard, a quiet

environment, such as that used for a DRE evaluation would be necessary, and a protocol to make determinations about what actions constitute 'non-cooperation'.

- **Persons who consume certain drugs daily may have a higher tolerance and may not be readily identified as impaired by a new technology.** Some drugs, such as cannabis, produce a degree of tolerance due to frequent use. As such, chronic or frequent users may not exhibit a sufficient degree of impairment, meaning this population of consumers may not be detected by the technology. However, persons not exhibiting signs of impairment may simply not be impaired making this point moot. More research would be needed to address this issue.
- **It may be challenging to identify a cognitive testing device that can identify impairment from a broad cross-section of drugs.** An important challenge for toxicology labs is that drug-testing protocols are complex, time-consuming, and rely on multiple methods of analysis. On this basis, there is some concern that developing a single, simple test for detecting all types of drug impairment will be difficult to achieve.
- **When devices of this nature are used, there needs to be acceptance from both the scientific and legal communities.** The state will need to conduct test cases to achieve this level of acceptance.
- **A new technology that could be used by non-DRE-trained officers could increase the enforcement of drug-impaired driving laws.** Law Enforcement agencies are continuously challenged to maintain an adequate number of DREs. This is a very demanding certification to maintain, and officers are often rotated through different divisions and roles outside of traffic enforcement. This means law enforcement agencies are constantly backfilling DRE positions and this situation ultimately erodes the deterrent effects of drug-impaired driving laws. The availability of a technology which could be used by non-DRE trained officers would help strengthen the enforcement of drug-impaired driving laws and reduce the resource burden on agencies.
- **Protocols for the use of new technologies must be developed to guide their implementation in police agencies.** Moreover, any protocols must be consistent and compliant with other existing regulations, legislation, and training practices pertaining to impaired driving detection devices.
- **Law Enforcement officers may be reluctant to use the technology as a part of the basis for an arrest without robust research in support of the validity and reliability of the device.** Some officers may be reluctant to pursue drug-impaired driving investigations because officers and their agencies can be subject to civil complaints or lawsuits if DRE calls of a drug-category or impairment generally are not

supported by forensic test results. This is an issue which may be a barrier to the implementation of any new technology.

- **Results from a technology that did not require a blood test for confirmation would create efficiencies in the impaired driving system.** The blood test is particularly challenging since it is invasive and requires a driver's cooperation and compliance which is unlikely to be forthcoming if they are impaired. It is currently estimated that about 50% of drivers in Colorado refuse the test. Many tests report a negative result even when drivers admitted to consuming being on drugs which is often a due to a delay in testing. Blood test results also can require testimony from a toxicologist in court. This suggests additional, validated and less invasive tools are needed to improve the identification of drug-impaired drivers, and tools which could reduce the reliance on blood test results would be invaluable.

  At present, law enforcement agencies have challenges with blood draws because medical facilities are sometimes reluctant to partner with law enforcement agencies to conduct them. This means officers who make arrest in rural areas may have to drive long distances to find a phlebotomist to perform a toxicological test for impairment. Securing services of an independent phlebotomist between 8am and 5pm on weekdays is much easier than evening and weekend nights. To address this issue, some other jurisdictions are certifying officers to draw blood, but this is not permitted in Colorado.

- **The use of green labs to conduct further research on the validity and reliability of a cognitive testing device to detect drug impairment would pose some challenges.** This protocol is available for law enforcement training, but obtaining permission to conduct green labs for research as opposed to law enforcement training is potentially quite challenging with respect to obtaining ethical approval.

- **The Colorado Highway Safety Office (HSO) is actively exploring solutions to make green labs a more viable option for law enforcement and prosecutor training.**

- **Use at roadside:** This device would require an individual's focused attention, therefore will need a controlled environment with minimal distractions. Impaired driving investigations at roadside are done in a dynamic environments; weather, traffic conditions, and the surrounding environment can affect an individual's performance on the testing device. This device is not designed for roadside as it requires an electrical outlet, a stable flat top surface, and an internet connection.

Legal & Legislative Issues

- **A state agency would have to be granted authority to permit the approval of a new technology and to develop rules to manage its application and use.** Rules

would be necessary to define selection criteria and how data from devices is managed, shared and stored. Any criteria, however, should not be so narrow as to limit the consideration of new technologies as they emerge.

- **Drug-impaired driving laws would need to be revised to include a protocol for this type of cognitive testing and to compel impaired drivers to comply with testing.** A primary challenge with any detection tool or technology is they generally require 'cooperation or compliance' by drivers to complete the test. In principle, a drug-impaired driver has little incentive to perform any test since the penalties for refusal are much less than the penalty for an impaired driving charge. There is some anecdotal evidence that proxy indicators used by law enforcement show refusals of blood testing increased after cannabis was legalized in Colorado. It was further noted that some defense attorneys tell clients to refuse as this results in a civil action instead of a criminal action when drugs are detected.
- **Legislation would have to specify whether devices are to be used as a basis for an arrest decision at roadside or used post-arrest as confirmatory evidence of impairment for court purposes.** This is a very important distinction with differing implications for the development of device protocols and the weight of evidence assigned in court cases.
- **The ability to clearly quantify the magnitude of impairment measured by a device is essential to its successful implementation.** Courts generally are more comfortable with a test result number that is understandable and that quantifies the level of impairment in a meaningful way. In this regard, often testimony from law enforcement officers with respect to behavioral impairment in the absence of a forensic test result is insufficient. In other words, it would be important that any result from a new technology can be articulated in court as it relates to a specific level of impairment. However, the complexity of drug impairment is vastly different from a BAC breath alcohol result, and in many instances the science of impairment at an individual level is inadequate currently. This may pose a barrier to the use of a new technology if important questions cannot be answered to achieve the 'beyond a reasonable doubt' evidentiary standard.
- **A per se limit for drugs that can be correlated with a device result may not be possible at this time. In this event, important questions must be answered with respect to how device results relate to the quantification of impairment.**
- **It will be critical that results of the device with respect to level of impairment can be clearly articulated for a lay audience.** For example, many older jurors may be more experienced with the potency of cannabis that was available decades ago. This can affect decisions by juries with respect to how impaired a driver was based on the amount consumed.

CONCLUSIONS

The purpose of the project was to investigate and evaluate the viability of a device capable of assessing cognitive and physical impairment in motorists due to drugs other than alcohol during roadside sobriety investigations. Outcomes of this study are useful to inform additional, future pilot studies that are larger in scale and scope.

The evaluation assessed the performance of potentially impaired versus non-impaired participants based on a comparison of results from the Cognivue Thrive device with drug-screening results in blood samples.

It is the singular assessment of impaired or not from the device that was used. How individual scores measured by the device are combined to reach this assessment is unknown to the project team and the evaluation could not gauge the accuracy of these individual scores in assessing impairment. The 'ground truth' of drug impairment was determined by testing the blood samples for drugs. However, it must be recognized that the presence of drugs in blood is not a perfect indicator of impairment.

Interpretation of the analysis must also consider that the accuracy of the device may differ by age group, but this could not be assessed with the current sample which had few subjects 30 years of age or older. Additionally, the total sample size of 149 is relatively small for providing conclusive results.

The results in Table 4 showed that when drugs were detected in the blood sample there were more subjects judged to be non-impaired than impaired from the device. This would indicate a substantial number of false negatives identified by the device, if the detection of drugs in the blood sample meant the subject was impaired. As previously discussed, this result is perhaps not surprising given that detecting the presence of drugs does not necessarily mean the subject was impaired at the time the blood was drawn.

The results for subjects in which no drugs were detected in the blood sample were more difficult to explain. For this category, roughly equal numbers of subjects were judged impaired (32) as were judge non-impaired (31) by the device. This means there were a substantial number of false positives. It is possible some of these subjects judged impaired by the device have a mild cognitive deficit or condition that made performance on the tests difficult. It may also be that some of the exercises on the device are not as useful for detecting impairment in the young population that participated, or, that the way the various scores were combined to assess impairment needs adjusting for a young population.

It can be concluded that the device shows promise for detecting drug-impaired drivers. However, much more research is needed using alternative study designs and with a larger sample size that better reflects the driving population, with respect to age.

RECOMMENDATIONS

There are several recommendations for what a future study of similar scope should entail.

1. A key addition would be a second method of impairment assessment such as a DRE evaluation to be used in conjunction with the blood sample analysis.
2. Use of driving simulators should be included as an additional measurement of impairment.
3. A green lab studies could be conducted with the proper approvals and protocols in place which has been presented as an administrative and legal hurdle.
4. Recruitment of participants will be important to ensure they reflect the driving population in terms of demographics, drug use and drug tolerance. A known barrier with the green lab approach is obtaining approval to dose participants at a high enough level to mimic real-world impairment.
5. Several devices that claim to measure impairment should be evaluated.
6. An appropriate timeline to execute a research study with the recommendations above shall be as follows:
    a. 6 months for procurement request for proposal, vendor selection and contract execution.
    b. 18 - 24 months for the vendor to plan, execute and deliver the research study.
    c. Flexibility to renew or extend the contract if there are recommendations to continue the study.
    d. Involvement of the HSO and other state partners in the creation of legislative bills that will address this issue.

CONTRACTOR INFORMATION

Traffic Injury Research Foundation, USA, Inc. (TIRF USA)

The Traffic Injury Research Foundation, USA, Inc. is an independent road safety research institute focused on road users and behaviors that result in driver error and account for a majority of road crashes. Established as a registered 501(c)(3) non-profit in the US in 2013, TIRF USA is governed by a Board of Directors, and funded by grants, contracts and donations. Grant and contract funding is earmarked for specific projects and sustaining donations help provide charitable services to public and private sectors. TIRF USA, Inc. has worked closely with TIRF in Canada through a relationship established with an exchange of services agreement. Both TIRF USA, Inc. and TIRF Canada are widely recognized in North America and have worked extensively with all levels of government.

TIRF USA and TIRF have improved road safety by generating and providing knowledge on current and emerging issues and trends. Our work includes conducting research and sharing evidence to inform decisions and action by government, business and industry, traffic safety agencies, and non-profit organizations around the world. Our work is relevant to legislation, program and policy development, enforcement, education, and training. TIRF provides four core services:

1. Research on road crashes
2. Evaluation
3. Program & policy development
4. Knowledge transfer & exchange

The TIRF USA, Inc. team includes leading research scientists, engineers, support staff, and administrative personnel. TIRF also has strategic partnerships with international research agencies that greatly expand its scientific and technical expertise.

Principal team members for this project consisted of the following members and roles:

Ms. Robyn Robertson, Secretary of the Board of TIRF USA and President & CEO with TIRF, served as Principal Investigator. She has extensive experience in organizational and project management, and in scientific research. Ms. Robertson has a Master of Criminology degree (Applied). Her professional training also diverse courses in psychology, business administration, marketing, accounting, and executive development courses. As a principal investigator and project manager, she was involved in all aspects of project work. She is well-versed in contemporary road safety issues including drugged driving, risk assessment, impaired driving and technologies, cognitive impairment, elderly drivers, and fitness to drive, rural road safety and young drivers. Most recently, Ms. Robertson led the development of a

series of fact sheets on drug impaired driving as co-chair of a Drugged Driving Working Group of the International Council on Alcohol, Drugs and Traffic Safety (ICADTS; https://www.icadtsinternational.com/Fact-Sheets). Robyn also supervised the development of a TIRF web-based tool, the Drug-Impaired Driving Learning Centre (https://druggeddriving.tirf.ca/); a one-stop, comprehensive, web-based tool designed to inform decision-making by synthesizing research related to drug-impaired driving, and the identification of gaps in research. Robyn was the lead author on a Transportation Research Board (TRB) Circular titled Drug-Impaired Driving. Research Needs (Robertson, R.D., Woods-Fry, H., Vanlaar, W.G.M., Brown, T.G., Moore, C. (2019). Drug-Impaired Driving. Research Needs. Transportation Research Circular E-C250. Washington, DC: Transportation Research Board.). Robyn has published more than 250 major reports and articles in traffic safety, criminal justice, and professional journals. She has undertaken several critical reviews of the literature and has considerable experience collecting quantitative and qualitative data. Most notably, Ms. Robertson is the author of TIRF's multi-disciplinary knowledge translation model based upon her 23 years of experience working directly with practitioners representing criminal justice, transportation, and health systems. She is very proficient in communicating technical information to non-technical audiences and has negotiated strong working relationships to engage practitioners in research. Ms. Robertson is a member of the Editorial Board of the Journal of Safety Research, a member of the Transportation Research Board Committee on Impairment in Transportation, and a member of the International Scientific Advisory Board, Belgian Road Safety Institute (ISBR).

Mr. Craig Lyon served as Project Manager. Craig is the Director of Road Safety Engineering at the Traffic Injury Research Foundation. He has a Master of Applied Science degree from the University of Toronto and a Bachelors of Engineering degree from Toronto Metropolitan University (previously Ryerson). Craig's research interests are in the application of advanced statistical analysis methods to analyze data related to the effects of roadway infrastructure, drivers, and administrative policies on safety. Craig is recognized as an expert in the statistical analysis of safety data and has been a member of the Transportation Research Board Committees on Safety Data, Analysis and Evaluation and Highway Safety Performance. Craig has over 25 years of experience in transportation engineering with a focus on the quantitative analysis of road safety, including the development and evaluation of road safety improvement programs; investigating the safety effects of planning and design decisions; before-after crash investigation studies; the investigation of vehicle-pedestrian crashes; the effects of driver sanction programs and driver education on driver safety; and, the evaluation of commercial driver testing procedures.

Dr. Ward Vanlaar is the Chief Operating Officer with TIRF and served as a senior advisor in this project. Dr. Vanlaar has M.A. degrees in statistics and criminology and a Ph.D. in transportation science. Dr. Vanlaar has extensive experience in the field of drug impaired driving, as cognitive impairment, and evaluation research. He co-authored the aforementioned TRB circular on drug impaired driving. Also, TIRF has maintained since the

1970s Canada's National Fatality Database, a database like the NHTSA FARS data. This database is used extensively to investigate a variety of research topics such as alcohol- and drug-impaired driving. Dr. Vanlaar is the Principal Investigator (PI) on many research projects using these data. In addition to his work on alcohol and drug impaired driving, Dr. Vanlaar has also devoted much of his time to cognitive impairment in road safety. He was the PI in a study to develop a cognitive road test to distinguish between cognitive impaired and non-impaired drivers (Vanlaar, W.G.M., Mainegra Hing, M., Meister, S., Charles, J.M., Ireland, L., Mayhew, D., Carr, D., Barco, P., Robertson, R.D. (2019). Pilot study of a new road test to assess cognitive fitness to drive. Transportation Research Part F 65, pp. 258–267.). Dr. Vanlaar has published more on this topic in the academic literature; a full list of references is available upon request. Ward has published over 200 reports and peer-reviewed articles in leading journals such as Accident Analysis and Prevention, the Journal of Safety Research, Traffic Injury Prevention, the International Journal of Injury Control and Safety Promotion and the Stata Journal. He taught statistics as a part-time professor at the University of Ottawa, served as a board member of the Canadian Association of Road Safety Professionals (CARSP) and is a past board member of the Association of Transportation Safety Information Professionals (ATSIP). Dr. Vanlaar is an associate editor of Accident Analysis and Prevention and serves on the editorial board of the Journal of Safety Research, on the Committee on Safety Data, Analysis and Evaluation and the Committee on Impairment in Transportation Research Board (TRB) of the National Academies.

Center for Forensic Science Research and Education (CFSRE) and NMS Labs

The Center for Forensic Science Research and Education (CFSRE) is a non-profit 501(c)3 research and academic institution with a close working relationship with NMS Labs. CFSRE is a globally recognized industry leader in innovative forensic science research, development, and new technology assessments, and in the delivery of unmatched educational and training services for the forensic science community and beyond.

As drug-impaired driving continues to increase, the CFSRE has been actively involved in monitoring epidemiological aspects of drugs in DUID cases to assist with the development of evidence-based public policy. The CFSRE operates in conjunction with recognized leaders from drug-testing laboratories and law enforcement agencies with extensive backgrounds in drug-impaired driving. This initiative began in 2007 and ha/s evolved over the years to meet the needs of the human performance forensic toxicology community. DUID investigations involving alcohol and other drugs remain a large area of work for forensic toxicologists who are often called upon to deliver and interpret analytical findings in a court of law. However, a toxicologist's interpretation is often based on the results and conclusions from peer-reviewed literature and publications. Understanding the impact of drug-impaired driving in the United States requires 1) advanced analytical research to confirm the substance(s) present in an individual's system, 2) comparative data from case review in collaboration with drug

recognition expert (DRE) evaluations, and 3) surveying of the drug landscape as drug trends and combinations change or evolve.

A staple in the CFSRE drug-impaired drug research program is the DUID laboratory survey titled "Recommendations for Drug Testing in DUID & Traffic Fatality Investigations." The survey began in 2007 and is now followed by triennial updates from the CFSRE, the most recent occurring in 2020. The structure of the survey is designed to gain insights on policies for testing, most commonly encountered analyses, and technology used for screening and confirmation testing. Additional areas of the survey include responding laboratory statistics, differences between matrix (e.g., blood, urine and oral), compliance with the recommendations, and laboratory resources. The survey results are now used as an effort to provide minimum guidelines for DUID testing in the United States. In 2019, the CFSRE was awarded a project by the National Institute of Justice in the United States to perform comprehensive drug testing on over 2,500 authentic DUID discarded specimens. Samples were analyzed for emerging novel psychoactive substances (NPS), such as novel synthetic opioids and synthetic cannabinoids, in addition to other impairing substances such as CNS stimulants, CNS depressants, narcotic analgesics and dissociative anesthetics.

The CFSRE/NMS Labs team consists of Dr. Barry Logan and Ms. Amanda Mohr.

Dr. Barry Logan is Executive Director at the non-profit Center for Forensic Science Research and Education (CFSRE) at the Fredric Rieders Family Foundation in Willow Grove, Pennsylvania. He is also Chief Scientist at NMS Labs in Horsham PA, where he leads a team of forensic toxicologists and certifying scientists. He holds academic appointments at Arcadia, Thomas Jefferson and Indiana Universities in the United States. Dr. Logan is a Fellow of the American Board of Forensic Toxicologists (ABFT). He has over 200 publications and has made over 700 presentations in forensic toxicology and analytical chemistry, including work on the effects of illicit and prescription drugs on drivers, and drug caused and related death. His current research priorities are focused on new drug trends, the opioid crisis, rapid reporting of drug mortality data, and the analytical and interpretive toxicology and chemistry of novel psychoactive substances, founding www.NPSDiscovery.org in 2018. Dr Logan's contributions to the field of toxicology were recognized in 2021 by the International Association of Forensic Toxicologists (TIAFT) presentation of the Alan Curry Lifetime Career Achievement Award.

Ms. Amanda (Mandi) LA Mohr serves as an Associate Director at the CFSRE working in the area of forensic toxicology. Ms. Mohr is a graduate of The University of Montana graduating in 2010 with honors with dual degrees in Human Biological Sciences and Sociology with an emphasis in Criminology. She then obtained a Master of Science in Forensic Science from Arcadia University in 2012. In 2018, Ms. Mohr became a diplomat in Forensic Toxicology of the American Board of Forensic Toxicology (D-ABFT). Ms. Mohr has authored or co-authored over 30 peer-reviewed publications and has presented her work nationally and internationally. Ms. Mohr's current research interests include oral fluid drug testing, drug-

impaired driving, and novel psychoactive substances (NPS). In recognition of advancements, she has made to the field of forensic toxicology, Ms. Mohr was awarded the Forensic Sciences Foundation Student Scholarship Award by the American Academy of Forensic Sciences in 2013, UCT's Excellence in SPE Award in 2016 and most recently the 2019 Irving Sunshine Award for Outstanding Research by a Young Investigator by the Toxicology Section of the American Academy of Forensic Sciences. Ms. Mohr is an active member within the forensic science community and member of several professional organizations including the Society of Forensic Toxicologists (SOFT), the American Academy of Forensic Sciences (AAFS – Toxicology Section), the International Society for the Study of Emerging Drugs (ISSED), and the National Safety Council's Alcohol, Drugs and Impairment Division (NSC-ADID). She currently serves as the Chair of Toxicology section of the AAFS and was recently appointed to serve on the NSC-ADID's executive committee. Ms. Mohr also serves on the Oral Fluid committee of SOFT and AAFS.

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Commander Barry Hartkopp from the Boulder Police Department for providing two law enforcement officers each day of the field study to serve as security to ensure the researchers' and participants' safety.

Cognivue, Inc. for loaning 4 Thrive devices to TIRF to be used for the purpose of this field study. This saved the State of Colorado a considerable expense in acquiring necessary equipment.

SME Experts

Vanessa Beall - Lab Director at Colorado Bureau of Investigation

Lt. Colonel Barry Bratt, Region One Commander for the Colorado State Patrol

Heather Krug, State Cannabis Sciences Program Manager, Colorado State Public Health Laboratory

Allison Rosenthal, Division of Criminal Justice, Department of Public Safety

Ean Seeb, Senior Policy Advisor on Cannabis to the Governor of Colorado

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