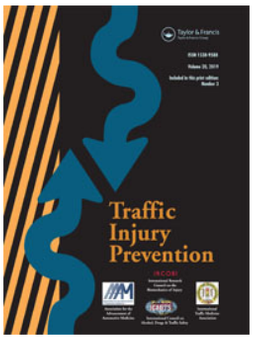

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# Predicting categories of drugs used by suspected drug-impaired drivers using the Drug Evaluation and Classification Program tests

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**ABSTRACT**

**Objective:** The purpose of this study was to statistically determine which combination(s) of drug-related signs and symptoms from the Drug Evaluation and Classification (DEC) protocol best predict the drug category used by the suspected drug-impaired driver.

**Methods:** Data from 1,512 completed DEC evaluations of suspected impaired drivers subsequently found to have ingested central nervous system (CNS) depressants, CNS stimulants, narcotic analgesics, and cannabis were analyzed using a multinomial logistic regression procedure. A set of evaluations completed on drug-free subjects was also included. The relative importance of clinical, behavioral, and observational measures in predicting drug categories responsible for impairment was also examined.

**Results:** Thirteen drug-related indicators were found to significantly contribute to the prediction of drug category, including being under the care of a doctor or dentist, condition of the eyes, condition of the eyelids, mean pulse rate, assessment of horizontal gaze nystagmus (HGN), convergence, performance on the One Leg Stand (OLS) Test, eyelid tremors, pupil size in darkness, reaction to light, presence of visible injection sites, systolic blood pressure, and muscle tone. Indicators related to the appearance and physiological response of the eye contributed the most to the prediction of drug category, followed closely by clinical indicators and performance on the psychophysical tests.

**Conclusions:** The findings from this study suggest that drug recognition experts (DREs) should be careful to review a set of key signs and symptoms when determining the category of drug used by suspected drug-impaired drivers. Drug use indicators related to the appearance and physiological response of the eye were found to contribute the most to the prediction of the drug category responsible for the impairment. These results could help form the basis of a core set of indicators that DREs could *initially* consult to form their opinion of drug influence. This in turn may enhance the validity, effectiveness, and efficiency of drug detection and identification by DREs and lead to a more effective and efficient DEC program, improved enforcement of drug-impaired driving, and greater acceptance of the DEC program by the courts.

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Drugged driving; drug-impaired driving; Drug Evaluation and Classification (DEC) Program; drug recognition expert (DRE); impairment testing; drugs

## Introduction

Alcohol has generally dominated the field of impaired driving, with drug-impaired driving recently emerging as a priority public health and safety issue. Recent changes to cannabis policy have heightened concerns about cannabis and driving. Currently, 9 states in the United States, Washington, D.C., and Uruguay have legalized nonmedical cannabis use; such use became legal in Canada on October 17, 2018. Several countries have also legalized the medical use of cannabis. The prevalence of cannabis use is expected to increase as a result of these policy changes and the introduction of a legal cannabis industry (Compton et al. 2017).

The use of psychoactive drugs by drivers poses a risk to road safety, and there is a growing body of literature documenting the impairing effects and elevated risk of traffic crash involvement following drug use (Beirness 2017; Beirness and Porath 2017; European Monitoring Centre for Drugs and Drug Addiction and Canadian Centre on Substance Use and Addiction 2018; World Health Organization 2016). Recent data from the NHTSA's Fatality Analysis Reporting System (FARS) reported that in 2015 drugs were present in 43% of fatally injured drivers with a known test result and alcohol was present in 37% of fatally injured drivers (NHTSA 2016). Drugs are less commonly detected among the general population of drivers on the road. Results from NHTSA's 2013–2014 National Roadside Survey detected drugs in 22% of all drivers both on weekend nights and on weekday days (Berning et al. 2015).

Drug-impaired driving also presents a significant challenge to law enforcement and, unfortunately, the research

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literature on the risks of driving after using drugs has lagged considerably behind that focusing on alcohol. In many respects, drug-impaired driving is a more complex issue than alcohol-impaired driving. For instance, there are numerous types of drugs, many of which have effects that differ dramatically from those of alcohol. In addition, unlike alcohol, it is currently not feasible to reliably detect or measure drug use among drivers in breath, although the technology to support this (and other measures, such as sweat) is advancing rapidly. Instead, a toxicological analysis of bodily fluids such as blood, urine, or oral fluid is required. The lack of tools and procedures to adequately assess drivers for impairment due to drugs other than alcohol presents an immediate complication for law enforcement and adjudication. Though a great deal can be learned from the successes in the area of alcohol and driving, drugs and driving is a more challenging issue that requires novel approaches to enforcement and adjudication. The Drug Evaluation and Classification (DEC) program provides the necessary evidence to demonstrate impairment due to drugs and support the charge.

The DEC program was developed to assist law enforcement officers in gathering objective information on the clinical and behavioral effects of drug use to facilitate the detection, identification, and prosecution of drug-impaired drivers. Based on scientific and medical knowledge about the known signs and symptoms associated with various drugs, the DEC program is a systematic and standardized 12-step procedure used by trained law enforcement officers, known as drug recognition experts (DREs), to recognize and evaluate behaviors and physiological indicators associated with 7 different drug categories: Central nervous system (CNS) depressants, inhalants, dissociative anesthetics, cannabis, CNS stimulants, hallucinogens, and narcotic analgesics. The results of the 12-step protocol, when corroborated by toxicological evidence of drug use, provide sufficient evidence to proceed with drug-impaired driving charges (Beirness and Porath 2017; Porath-Waller et al. 2009).

Evidence of the validity and accuracy of the DEC program is accumulating. A review of existing laboratory and field evaluation studies on the DEC program reported the overall accuracy of DEC evaluations made by trained DREs on impaired drivers to be more than 80% (Beirness et al. 2007). A study of 1,349 DEC evaluations completed by DREs in Canada reported an overall accuracy rate of 95% (Beirness et al. 2009), with some drug classes being more difficult to detect than others. Taken together, these research findings (Beirness et al. 2007, 2009) provide confidence in the use of the DEC procedure to detect persons impaired by substances other than alcohol. However, as encouraging as the results are, they also indicate that the DEC program is not perfect. Beirness and colleagues (2007, 2009) have noted that some drug classes are more difficult to detect accurately than others. For example, the sensitivity of the DEC procedure in detecting CNS depressants was lower than that for other drugs. In addition, drugs used in combination with alcohol or other drugs are more difficult to detect accurately. Most errors fell under the category of false negatives (i.e., cases where the DRE failed to identify the subject as impaired by a particular drug class but the toxicology analysis revealed the drug to be present). False positives (i.e., cases where the DRE believed that a subject was impaired by a drug but the toxicology revealed that no drugs were present) were rare. The variable accuracy rates among the different classes of drugs require further investigation and suggest that further work may be necessary to identify and specify the most reliable signs and symptoms of particular drug classes.

Smith et al. (2002) investigated the importance of face-to-face interactions with the subject, physical evidence (e.g., presence of drugs or paraphernalia), and confessions/statements made by the suspect in DREs' determinations of whether a suspect is under the influence of a drug(s) and, if so, which category of drug(s) is involved. Records from 70 DEC cases from 4 drug categories (cannabis, narcotic analgesics, CNS stimulants, and CNS depressants) and no-drug cases were provided to 18 DREs from Oregon with the statements made by suspects or arresting officers, toxicology results, and descriptions of drugs or paraphernalia found on the suspect omitted from the evaluation reports. Using a limited set of information from the DEC evaluations (including the written reports of direct observations and physiological and psychophysical test results), the DREs were asked to determine whether each of the 70 suspects was under the influence of a drug(s) and, if so, what category of drug(s) was involved. Overall, the DREs correctly identified positive drug influence in nearly 95% of cases. The findings also revealed that when officers determined that a suspect was under the influence of a drug, their accuracy in specifying the drug category was 80.7% for cannabis, 94% for narcotic analgesics, 78.4% for CNS stimulants, 68.6% for CNS depressants, and 65.6% for cases not involving drugs. The investigators concluded that the majority of drug category decisions could be made solely on the basis of recorded observations of the suspect and the DEC evaluation results, with face-to-face interactions, physical evidence, and suspect statements contributing to the totality of the situation and serving as useful adjuncts to DRE decision making.

In a re-analysis of data from a previous study that involved having volunteers consume specified quantities and types of drugs, Shinar and Schechtman (2005) evaluated the ability of DREs to detect drug impairment and the impairing drug category solely on the basis of the results from the 4 psychophysical tests (Modfied Rhomberg Balance [MRB] test, Walk and Turn [WAT] test, One Leg Stand [OLS] test, and Finger to Nose [FTN] test; for a review of these tests, see Porath-Waller and Beirness 2014) and limited clinical indicators of drug use (e.g., nystagmus, pupil diameter under different light conditions, pulse rate, blood pressure, temperature). Four drugs—corresponding to 4 different drug categories—were evaluated in this study: cannabis, CNS depressants (e.g., alprazolam), narcotic analgesics (e.g., codeine), and CNS stimulants (e.g., amphetamine). The results suggested that DREs were forming their opinion

about the category of drug consumed based on only 1 or 2 pivotal signs or symptoms while ignoring others, even if contradictory to their judgment.

A DEC evaluation is a comprehensive assessment that requires about 45–60 min to complete. In the course of conducting the 12 steps of the evaluation, the officer records more than 100 different pieces of information in numerical, narrative, and pictorial form. The officer then assesses these data to determine whether the subject is impaired and which drug category or categories are most likely responsible for the impairment. The amount of information is extensive and some have questioned whether the number of pieces of information collected is too large to reasonably consider in rendering an opinion about the class of drug involved (Schechtman and Shinar 2005; Shinar and Schechtman 2005) and that it may be possible to initially focus on a core set of measures from the evaluation without significantly compromising accuracy (Porath-Waller and Beirness 2010; Porath-Waller et al. 2009). Because the DEC evaluation provides evidence of impairment and drug influence, it is important that the opinion of the evaluating officer in terms of drug category is accurate. Therefore, it may prove beneficial and enhance the accuracy of DEC evaluations if, when forming their opinion, DREs first consider elements of the evaluation that are most predictive of various drug categories and use the other elements to capture the totality from all indicators.

Research suggests that it may be possible to identify a core set of measures from DEC evaluations that can be used to guide opinions about drug category/categories without significantly compromising accuracy (Porath-Waller and Beirness 2010; Porath-Waller et al. 2009). Using data from 742 completed evaluations from Canada, Porath-Waller and colleagues (2009) reported that DREs can focus on a limited set of key signs and symptoms when determining the category of drug used by a suspected drug-impaired driver without significantly compromising the accuracy of their evaluations. These investigators identified a set of 9 signs and symptoms—pulse rate, condition of the eyes, condition of the eyelids, lack of convergence, hippus, rebound dilation, reaction to light, injection sites, and systolic blood pressure—from single-drug category cases that best predicted 3 classes of drugs used by suspected drug-impaired drivers (CNS stimulants, narcotic analgesics, and cannabis). Based on this set of 9 clinical indicators, an overall classification rate of 81% was obtained across the 3 drug categories. As other indicators are considered by the DRE, the totality of the evaluation would be expected to improve the classification rate.

In a follow-up study to this work, Porath-Waller and Beirness (2010) analyzed the signs and symptoms that were most predictive of common drug combinations (CNS stimulants with cannabis, CNS stimulants with narcotic analgesics, and cannabis with alcohol) from a sample of 819 completed evaluations from Canada. Results showed that 10 clinical indicators significantly enhanced the prediction of drugs used by subjected drug-impaired drivers: The condition of the eyes, lack of convergence, rebound dilation, reaction to light, presence of visible injection sites, assessment of horizontal gaze nystagmus (HGN), pupil size in darkness, performance on the OLS test, muscle tone, and performance on the WAT test. The immediate implication from this research is that it may not be necessary for DREs to collect all of the information that the evaluation currently demands: it may be possible to limit the evaluation to a core set of measures. Due to the limited cases available, however, it was not possible to evaluate the full set of data in the DEC cases.

The objective of the current study was to determine which signs and symptoms from the DEC protocol significantly predict the category of drug used by suspected drug-impaired drivers. This work extends the current literature by also assessing the relative importance of clinical, behavioral, and observational measures from the drug evaluation in predicting the drug category responsible for impairment. Because the breadth of information collected during a DEC evaluation is sizeable, this research aims to provide guidance to DREs regarding a possible set of drug-related signs and symptoms that they could initially focus on to inform their opinion of drug influence. This initial set of indicators would then be viewed alongside the other indicators and observations from the evaluation to assess the totality of drug symptomatology. This approach could help to further improve the effectiveness and efficiency of drug detection and identification by DREs and lead to a more effective and efficient DEC program. This study does not, however, assess the validity of the DEC procedure.

## Methods

A sample of 1,512 DEC evaluations conducted on suspected drug-impaired drivers between April 22, 2000, and December 24, 2012, in which the evaluating officer's opinion was confirmed by toxicological analysis of blood samples was obtained from the DEC coordinators in 11 states that were geographically distributed across the United States. To be included in the current study, each case had to include the Drug Influence Evaluation (DIE) face sheet, narrative report, and toxicology report. Based on the International Association of Chiefs of Police (IACP) criteria for correct opinion, the opinion of the DRE concerning the drug category responsible for the impairment was deemed confirmed if the toxicological analysis disclosed the presence of at least one drug category named by the DRE. Included cases also had to involve specific drug categories that are commonly encountered by DREs: CNS depressants, CNS stimulants, narcotic analgesics, and cannabis. All of the information from the DIE face sheets, narrative reports, and toxicology reports was coded to create a database of measures for statistical analysis. All personal identifying information was removed from the DEC evaluations by the DEC coordinators. Four drug categories were represented in this set of evaluations, including CNS depressants ($n = 431$), CNS stimulants ($n = 166$), narcotic analgesics ($n = 194$), and cannabis ($n = 541$). Also included were 180 rule-out cases whereby the opinion of the evaluator was that the suspect was not under the influence of any drug and no drug was

Table 1. Prediction of drug category from signs and symptoms among DEC evaluations: CNS depressants vs. no-drug cases.

| Signs and symptoms | *B* | SE | Wald's $\chi^2$ test | OR | 95% CI for OR |
|---|---|---|---|---|---|
| Being under the care of a doctor or dentist | −1.76 | 0.53 | 11.14* | 0.17 | 0.06, 0.48 |
| Not impaired vs. impaired assessment of HGN | −2.84 | 0.56 | 26.01* | 0.06 | 0.02, 0.17 |
| Not impaired vs. impaired performance on OLS test | −2.23 | 0.59 | 14.23* | 0.11 | 0.04, 0.34 |
| Not impaired vs. impaired performance on WAT test | −2.20 | 0.67 | 10.97* | 0.11 | 0.03, 0.41 |
| Slow vs. normal reaction to light | 2.79 | 0.60 | 21.49* | 16.20 | 5.00, 52.58 |

*$P < .0022$.

found as a result of toxicological analysis of the bodily fluid sample provided (referent group).

### Data analysis

All statistical analyses were performed using IBM SPSS Statistics Ver. 22. The data were screened and cleaned for accuracy and all relevant statistical assumptions were assessed (Tabachnick and Fidell 2007). Bivariate relationships between the signs and symptoms collected during the DEC evaluation and the drug categories were examined using chi-square analyses and Cramer's *V* correlation (Kent 2001; Tabachnick and Fidell 2007).

To assess the prediction of drug category from the various signs and symptoms measured during the DEC evaluation, multinomial logistic regression analyses were performed. This multivariate analysis allows the prediction of an outcome variable that has more than 2 categories from a set of predictor variables that may be continuous, discrete, dichotomous, or a combination of variable types (Tabachnick and Fidell 2007). This procedure selects the best set of predictors after accounting for the variance of other factors. Logistic regression also permits the calculation of classification rates for the outcome categories in order to provide an estimate of the relative success or effectiveness of the model in correctly predicting the category of drug used. For all analyses, regression coefficients, chi-square tests, odds ratios (ORs), and 95% confidence intervals (CIs) are reported.

Finally, the drug-related signs and symptoms from the DEC evaluations were then conceptually grouped based on whether they were clinical indicators (e.g., pulse rate, blood pressure, body temperature, muscle tone), performance on psychophysical tests, appearance and physiological response of the eyes, or observations or self-reported statements from the subject. These groups of variables were then entered as blocks into a sequential multinomial logistic regression procedure to determine the relative importance of the 4 groups of indicators in predicting drug category.

## Results

### Bivariate results

As a preliminary analysis to inform the multinomial logistic regression analyses predicting drug category from the drug-related signs and symptoms assessed during the DEC evaluations, the bivariate associations between the various DEC indicators and drug categories were examined (see Table 1 in the Appendix, online supplement). The categorization of the drug-related signs and symptoms were based on DEC standards; the exception was the total sway and estimation of 30 s on the MRB Test. For the categorization of total sway, we examined the frequency distributions for the amount of sway (in inches) noted front-to-back and side-to-side, observing a cutoff in the distributions at 2 inches. We then summed the 2 measures to produce a total measure of sway on the MRB test (<2 in., 2+ in.). For the estimation of 30 s, we adopted the general practice used by DREs (Richman 2010) that an accurate estimate falls within the range of 25 to 35 s. Any estimates below 25 s were considered fast, whereas any estimates above 35 s were considered slow.

As indicated by the values of the chi-square statistics, most of the signs and symptoms assessed during the DEC evaluation were significantly correlated with drug category. Inspection of the Cramer's *V* measures for these significant chi-square statistics provides an indication of the strength of the association between the signs and symptoms and the drug category. The signs and symptoms most strongly associated with drug category were being under the care of a doctor or dentist, condition of the eyes, assessment of HGN, rebound dilation, reaction to light, muscle tone, and pupil size in room light and darkness.

### Multivariate results

A multinomial logistic analysis was performed on the set of DEC cases to determine the prediction of drug category (CNS depressants, CNS stimulants, narcotic analgesics, and cannabis) from the drug-related signs and symptoms assessed during an evaluation. Signs and symptoms that were included in the final model included subject was sick or injured (yes, no); subject was under the care of a doctor or dentist (yes, no); subject was taking any medication (yes, no); condition of the eyes (normal, bloodshot, watery, reddening of the conjunctiva, combination of these); ability to follow a stimulus (yes, no); condition of eyelids (normal, droopy); mean pulse rate (low, normal, high); assessment of HGN (not impaired, impaired); convergence (present, absent); performance on the OLS test (not impaired, impaired); leg tremors (yes, no); eyelid tremors (yes, no); performance on the WAT test (not impaired, impaired); pupil size in room light (constricted, normal, dilated); pupil size in darkness (constricted, normal, dilated); pupil size in direct light (constricted, normal, dilated); reaction to light (little to none, slow, normal/quick); visible injection sites (none, old/fresh); systolic blood pressure (low, normal, high); body temperature (low, normal, high); muscle tone

**Table 2.** Prediction of drug category from signs and symptoms among DEC evaluations: CNS stimulants vs. no-drug cases.

| Signs and symptoms | *B* | SE | Wald's $\chi^2$ test | OR | 95% CI for OR |
|---|---|---|---|---|---|
| High vs. normal mean pulse rate | 2.39 | 0.51 | 22.08* | 10.93 | 4.03, 29.63 |
| Not impaired vs. impaired performance on OLS test | −2.76 | 0.58 | 22.35* | 0.06 | 0.02, 0.20 |
| Slow vs. normal reaction to light | 3.13 | 0.60 | 26.97* | 22.79 | 7.00, 74.18 |
| Rigid vs. normal muscle tone | 1.95 | 0.60 | 10.54* | 7.04 | 2.17, 22.87 |

*$P < .0022$.

(near normal, flaccid, rigid); and total sway during the MRB test (<2 in., 2+ in.).

Signs and symptoms that were not statistically significant at the bivariate level were excluded from the final model (i.e., tracking, pupil size, use of finger pad during FTN test). A number of drug-related signs and symptoms were also excluded from the final model because their initial inclusion violated the statistical assumption of adequacy of expected frequencies (i.e., being diabetic or epileptic, having a disability or defect, rebound dilation, vertical gaze nystagmus, body tremors, completion of the MRB test and estimate of 30 s on the MRB test). That is, more than 20% of cells had an expected frequency of less than 5. When this assumption is violated, statistical power is attenuated and it restricts the goodness-of-fit criteria used to evaluate the model (Tabachnick and Fidell 2007). Finally, the number of hits on the FTN test, a continuous variable, was found to violate the statistical assumption of linearity in the logit model. When this assumption is violated, the analysis is not appropriate and may mislead the results (Tabachnick and Fidell 2007). In an attempt to establish a linear relationship between the logit model and this continuous variable, a logarithmic transformation was performed; unfortunately, this transformation did not make that relationship linear. As a result, this variable was excluded from the final model.

Results from the overall multinomial logistic regression test indicated that the set of 22 signs and symptoms obtained from the DEC evaluation significantly distinguished the 4 drug categories (CNS depressants, CNS stimulants, narcotic analgesics, and cannabis) from the no-drug cases, $\chi^2$ (132, $N = 1{,}512$) = 2,078.08, $P < .0001$. Overall, the correct classification rate for the 4 drug categories and no-drug cases was 86.5%—that is, more than four-fifths of all cases were correctly classified based on the inclusion of the set of 22 drug-related indicators in the overall multinomial logistic regression model. Based on the set of 22 signs and symptoms from the overall model, the classification rate was 89.7% for CNS depressants, 74.0% for CNS stimulants, 89.2% for narcotic analgesics, 91.8% for cannabis, and 64.9% for the no-drug cases.

Table 2 in the Appendix (see online supplement) shows the unique contribution of the individual predictors (from the set of 22 drug-related signs and symptoms) to the overall multinomial logistic regression model by comparing models with and without each predictor. Using a Bonferroni correction ($P < .0022$) to control for Type I error, 13 signs and symptoms significantly contributed to the prediction of drug category, including being under the care of a doctor or dentist, the condition of the eyes and eyelids, mean pulse rate, assessment of HGN, convergence, performance on the OLS test, eyelid tremors, pupil size in darkness, reaction to light, presence of visible injection sites, systolic blood pressure, and muscle tone.

As a follow-up to the overall multinomial logistic regression analysis, a binary logistic regression analysis was conducted to determine the specific signs and symptoms that distinguished the CNS depressant drug category from the no-drug category (i.e., the reference group). Table 1 presents the regression coefficients, chi-square tests, ORs, and 95% CIs for the signs and symptoms for the CNS depressant drug category compared to no-drug cases. Using a Bonferroni correction ($P < .0022$) to control for type I error, the signs and symptoms that reliably distinguished the CNS depressants cases from the no-drug cases were being under the care of a doctor or dentist, assessment of HGN, performance on the OLS and WAT tests, and reaction to light.

The ORs indicate whether there is an increased or decreased likelihood of the signs and symptoms being associated with the CNS depressant drug category compared to the no-drug category; ORs greater than 1 reflect an increased likelihood, whereas ORs less than 1 reflect a decreased likelihood (in some instances, the ORs have been flipped to avoid stating double negatives and ease interpretation for the reader). Results indicated that subjects who used CNS depressants were more likely to be under the care of a doctor or dentist, exhibit impaired assessment of HGN, demonstrate impaired performance on the OLS and WAT tests, and have a slow reaction to light compared to those who had not used drugs.

A binary logistic regression analysis was also conducted to determine which signs and symptoms from the overall model distinguished the CNS stimulant drug category from the no-drug category (i.e., the reference group). Table 2 presents the regression coefficients, chi-square tests, ORs, and 95% CIs for the signs and symptoms for the CNS stimulant drug category compared to the no-drug category. Findings revealed that suspected drug-impaired drivers who consumed CNS stimulants were more likely than those who did not consume any drugs to have a higher-than-normal mean pulse rate, demonstrate impaired performance on the OLS test, have a slow reaction to light, and have rigid muscle tone.

The signs and symptoms from the overall model that distinguished the narcotic analgesics drug category from the no-drug category were also investigated in a follow-up binary logistic regression analysis. The regression coefficients, chi-square tests, ORs, and 95% CIs for the signs and symptoms for the narcotic analgesic category compared to the no-drug category are displayed in Table 3. Findings revealed

**Table 3.** Prediction of drug category from signs and symptoms among DEC evaluations: Narcotic analgesics vs. no-drug cases.

| Signs and symptoms | *B* | SE | Wald's $\chi^2$ test | OR | 95% CI for OR |
|---|---|---|---|---|---|
| Being under the care of a doctor or dentist | −2.68 | 0.78 | 11.75* | 0.07 | 0.02, 0.32 |
| Droopy vs. normal eyelids | 2.67 | 0.78 | 11.60* | 14.38 | 3.10, 66.66 |
| Constricted vs. normal pupil size in darkness | 3.92 | 1.07 | 13.58* | 50.60 | 6.28, 407.78 |
| Slow vs. normal reaction to light | 2.58 | 0.80 | 10.47* | 13.21 | 2.78, 63.09 |

*$P < .0022$.

**Table 4.** Prediction of drug category from signs and symptoms among DEC evaluations: Cannabis vs. no-drug cases.

| Signs and symptoms | *B* | SE | Wald's $\chi^2$ test | OR | 95% CI for OR |
|---|---|---|---|---|---|
| Condition of the eyes: Reddening of the conjunctiva vs. normal | 2.92 | 0.71 | 16.74* | 18.49 | 4.57, 74.79 |
| Bloodshot vs. normal | 2.74 | 0.59 | 21.34* | 15.55 | 4.85, 49.79 |
| Combination vs. normal | 3.13 | 0.58 | 28.78* | 22.97 | 7.31, 72.16 |
| Low vs. normal mean pulse rate | 2.69 | 2.38 | 1.29* | 14.77 | 0.14, 155.96 |
| High vs. normal mean pulse rate | 1.55 | 0.39 | 15.45* | 4.70 | 2.17, 10.16 |
| Lack of convergence vs. convergence | 1.27 | 0.40 | 10.35* | 3.57 | 1.64, 7.77 |
| Not impaired vs. impaired performance on OLS test | −1.21 | 0.40 | 9.35* | 0.30 | 0.14, 0.65 |
| Absence vs. presence of eyelid tremors | −1.34 | 0.37 | 13.10* | 0.26 | 0.13, 0.54 |

*$P < .0022$.

that subjects who consumed narcotic analgesics were more likely than those who did not consume any drugs to be under the care of a doctor or dentist and have droopy eyelids, constricted pupils in darkness, and a slow reaction to light.

To investigate those signs and symptoms from the overall model that distinguished cannabis from the no-drug category (i.e., the reference group), a final binary logistic regression analysis was conducted. The regression coefficients, chi-square tests, ORs, and 95% CIs for the signs and symptoms for the cannabis drug category compared to the no-drug category are displayed in Table 4. Findings revealed that compared to subjects who had not used drugs, those who consumed cannabis were more likely to have one or more eye conditions (i.e., reddening of the conjunctiva, bloodshot eyes, watery eyes), a higher than normal mean pulse rate, a lack of convergence, impaired performance on the OLS test, and eyelid tremors.

### *Prediction of drug category from groupings of drug-related signs and symptoms among DEC evaluations*

The set of 22 signs and symptoms from the overall multivariate logistic regression that significantly distinguished the 4 drug categories (CNS depressants, CNS stimulants, narcotic analgesics, and cannabis) from the no-drug cases was grouped into 4 conceptual blocks:

1. Clinical indicators (i.e., systolic blood pressure, body temperature, mean pulse rate, muscle tone).
2. Performance on the psychophysical tests (i.e., performance on the WAT test and OLS test, total sway during the MRB test).
3. Appearance and physiological response of the eyes (i.e., assessment of HGN; convergence; reaction to light; ability to follow stimulus; eyelid tremors; condition of the eyes and eyelids; and pupil size in room light, darkness, and direct light).
4. Observations and self-reported statements from the subject (i.e., under care of doctor/dentist, being sick or injured, use of medication, visible injection sites, and leg tremors).

A sequential multinomial logistic regression analysis was then performed to assess the prediction of drug category from each of these 4 blocks and determine their unique contribution to the model. The order in which the blocks were entered into the regression model was based on the objectivity of the signs and symptoms measurement (i.e., clinical indicators, psychophysical tests, condition of the eyes, and observations and statements by the subject) because, to the best of our knowledge, there is no previous work or theory to guide such a decision.

Findings revealed that all 4 blocks of drug-related signs and symptoms significantly distinguished the 4 drug categories from the no-drug cases, and Table 5 presents their unique contribution to the model. As indicated by the chi-square statistics, the block of drug-related signs and symptoms related to the appearance and physiological response of the eyes was found to contribute the most to the model, followed closely by the set of clinical indicators. The set of observations and statements made by the subject was found to contribute the least to the prediction of drug category yet was still statistically significant.

## Discussion

The objective of this study was to determine which combination(s) of elements of the DEC protocol offer the best predictive validity of the category of drug responsible for impairment in the most efficient and effective manner. To accomplish this, we collected a large sample of DEC cases conducted on suspected drug-impaired drivers and confirmed by toxicological analysis of blood samples. Through a series of multivariate statistical models, we statistically identified the set of drug-related measures from the DEC evaluation that best predicted the most prevalent drug categories (CNS depressants, CNS stimulants, narcotic analgesics, and cannabis) used by suspected drug-impaired drivers. We also

**Table 5.** Contribution of groupings of signs and symptoms in predicting drug category among DEC evaluations.

| Groups of signs and symptoms | $\chi^2$ | Df |
|---|---|---|
| Clinical indicators | 887.15* | 32 |
| Performance on psychophysical tests | 251.09* | 12 |
| Appearance and physiological response of the eyes | 998.80* | 68 |
| Observations and statements by the subject | 58.96* | 20 |
| Full model | 2,078.08* | 132 |

*$P < .0001$.

determined the relative importance of clinical, behavioral, and observational measures in predicting the drug category responsible for impairment.

Findings revealed that a statistical model that includes 13 drug-related indicators was found to significantly contribute to the prediction of drug category (being under the care of a doctor or dentist, condition of the eyes, condition of the eyelids, mean pulse rate, assessment of HGN, convergence, performance on the OLS test, eyelid tremors, pupil size in darkness, reaction to light, presence of visible injection sites, systolic blood pressure, and muscle tone). Based on this set of 22 indicators, an overall correct classification rate of 86.5% was obtained across the 4 drug categories and no-drug cases, reflecting the success of the model in correctly predicting the drug categories and attesting to the validity of these indicators of drug use. Classification was found to be better for some categories (e.g., cannabis) than others (e.g., CNS stimulants). The results also showed that drug use indicators related to the appearance and physiological response of the eye were found to contribute the most to the prediction of drug category responsible for the impairment. Taken together, the findings from this work suggest that DREs can *initially* focus on a limited set of key signs and symptoms when determining the categories of drugs used by suspected drug-impaired drivers.

These results are consistent with those previously obtained by Porath-Waller and colleagues (2009). In their study, 9 drug-related signs and symptoms were found to significantly predict 3 classes of drugs (CNS stimulants, narcotic analgesics, and cannabis) with an overall classification rate of 81%. Considerable overlap can be observed with respect to the particular signs and symptoms that significantly predicted drug category in that study and the current work. Specifically, 7 indicators were common to the models used in both studies, including the condition of the eyes, condition of the eyelids, mean pulse rate, convergence, reaction to light, presence of visible injection sites, and systolic blood pressure. In contrast to the study conducted by Porath-Waller and colleagues (2009), however, the present investigation obtained a relatively higher rate of correct classification of cases, which is likely the result of the greater number of drug-related indicators that were included in the prediction model.

The present work also investigated the unique contribution of specific groupings of drug-related signs and symptoms from the DEC evaluation and found that indicators related to the appearance and physiological response of the eyes contributed the most to the prediction of drug category, followed closely by clinical indicators and performance on the psychophysical tests. Interestingly, observations and statements made by the subject contributed the least to the prediction of drug category and were not found to be a statistically significant predictor of drug combination. To the best of our knowledge, this is the first analysis that has assessed the relative contribution of groupings of signs and symptoms from the DEC evaluation.

The results from this study could help form the basis of a core set of indicators that DREs could *initially* consult to form their opinion of drug influence, an approach previously suggested by others (Bigelow et al. 1985; Heishman et al. 1998). However, prediction of drug category based on the limited set of key signs and symptoms identified in this study was not found to be perfect, pointing to the need to consider the other indicators from the evaluation and the observational skills of the DRE to assess the totality of drug symptomatology. Nevertheless, focusing initial attention on the key signs and symptoms identified in this research may enhance the validity, effectiveness, and efficiency of drug detection and identification by DREs and may lead to a more effective and efficient DEC program, improved enforcement of drug-impaired driving, and greater acceptance of the DEC program by the courts. The findings from the present study add to the accumulating evidence of the validity and accuracy of the DEC program (Beirness et al. 2007, 2009; Smith et al. 2002) and will help to further support the program and the work of its DREs.

The results also have important implications for the DEC program and DREs conducting drug influence evaluations on suspected drug-impaired drivers. The findings indicate that DREs can initially focus on a limited set of key signs and symptoms to help determine the categories of drugs used by suspected drug-impaired drivers to facilitate the interpretation of the evidence and enhance the effectiveness and efficiency of their evaluations. This does not suggest that these are the only indicators that should be assessed. However, it does indicate that the key indicators should be considered first and that all other signs, symptoms, and observations be brought into the process to capture the totality of the case.

The findings can also be integrated into DEC program training by emphasizing the utility of initially focusing on a set of critical indicators of drug use. Moreover, the results could be used to help develop an automated system that would assist DREs in determining, on a case-by-case basis, the category of drugs most likely to be responsible for the observations and symptoms recorded in the evaluation. The data from the DIE face sheet would be entered into a computer program and an algorithm would weight the various components of the evaluation according to their respective contribution and assess the probability of the case being representative of a particular class (or classes) of drugs. Schechtman and Shinar (2005) provided initial evidence of the value of this approach. The development of such a system would not replace the DEC program but would rather provide a tool to support DREs and contribute to the effectiveness and efficiency of the DEC program.

A number of potential limitations should be considered when interpreting the current investigation's findings.

Firstly, the sample of DEC cases used in the present study was not randomly selected and should not be considered representative of all cases conducted in the United States. The cases were selected for inclusion in the study based on several selection criteria, including confirmation by toxicological analysis of blood, cases that resulted from traffic stops (as opposed to training cases), cases involving particular drug categories, and states approved by IACP and NHTSA regional administrators to contact regarding their participation in the study. Secondly, the cases that were included in the final sample were subject to various forms of selection bias. In addition to asking particular states to contribute cases to the study, it is highly unlikely that the states randomly selected the cases that they contributed. Thirdly, although the data used in the current study were collected over a 12-year period, we do not have any reason to believe that variability in the DREs' reporting or laboratory protocols may have affected the current findings. The DEC program is a systematic and standardized protocol used throughout North America and there have been no significant changes to this protocol over the years.

This study is also limited by the fact that certain categories of drugs (e.g., hallucinogens, inhalants, dissociative anesthetics) were not investigated due to insufficient sample sizes. This result is not unexpected following a review of the epidemiological data for these classes of substances. Recent data from the 2012 National Survey on Drug Use and Health in the United States (Substance Abuse and Mental Health Administration [SAMHSA] 2013) revealed that the past-year prevalence of hallucinogens is low (1.7%). The prevalence of phencyclidine (or PCP, a dissociative anesthetic) is also quite low (0.0% past-year prevalence and 2.4% lifetime prevalence reported in 2011; SAMHSA 2012), and this substance is also rarely found among drivers. The use of ketamine—another dissociative anesthetic drug—by drivers is also rare (0.8%; Lacey et al. 2009), and most laboratories do not even test for this substance. Moreover, the experimental literature indicates that the effects of ketamine are so profound that most users would be unable to drive a motor vehicle following its consumption. In terms of inhalants, the results of the 2012 National Survey on Drug Use and Health also reported a low past-year prevalence rate (0.7%; SAMHSA 2013), with use generally more common among youth aged 12 to 17, many of whom are too young to drive (2.6%). The effects of inhalants are often short term but can be debilitating for drivers.

Another potential limitation of the present study relates to the scoring used to determine impairment due to drugs on the WAT and OLS tests and for the assessment of HGN. In the absence of any published scoring criteria for determining impairment due to drugs on these tests, we adopted the scoring used for determining impairment due to alcohol (Stuster and Burns 1998). This research has demonstrated that 88% of individuals who present 4 or more clues (between both eyes) on the HGN test will likely have a blood alcohol concentration (BAC) of 80 mg/dl or greater. On the OLS test, 83% of individuals who exhibit 2 or more indicators in the performance of this test have a BAC of 80 mg/dl or greater. Finally, Stuster and Burns (1998) showed that 79% of individuals who exhibit 2 or more indicators in the performance of the WAT test will have a BAC of 80 mg/dl or greater.

In conclusion, the findings from this study suggest that DREs should be careful to review a set of key signs and symptoms when determining the category of drug used by suspected drug-impaired drivers. Drug use indicators related to the appearance and physiological response of the eye were found to contribute the most to the prediction of the drug category responsible for the impairment. These results could help form the basis of a core set of indicators that DREs could *initially* consult to form their opinion of drug influence. This in turn may enhance the validity, effectiveness, and efficiency of drug detection and identification by DREs and lead to a more effective and efficient DEC program, improved enforcement of drug-impaired driving, and greater acceptance of the DEC program by the courts.

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