State of California
Department of Motor Vehicles

THE RELATIONSHIP BETWEEN DRUG ARRESTS AND DRIVING RISK

JANUARY 1994

PETE WILSON
Governor

DEAN R. DUNPHY, Secretary
Business, Transportation and Housing Agency

FRANK S. ZOLIN
Director

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
January 1994

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
The Relationship Between Drug Arrests and Driving Risk

5. FUNDING NUMBERS

6. AUTHOR(S)
Leonard A. Marowitz

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
California Department of Motor Vehicles
Research and Development Section
P.O. Box 932382
Sacramento, CA 94232-3820

8. PERFORMING ORGANIZATION REPORT NUMBER
CAL-DMV-RSS-94-142

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This study compared the driving records of 106,214 persons arrested for drug offenses in 1989 with 41,493 comparison drivers drawn from the general driving population. The drug arrestees were grouped according to the six summary offense categories used by the Department of Justice (DOJ), which were felony narcotics, marijuana, dangerous drugs, and other drugs, and misdemeanor marijuana and other drugs. Time periods examined were 1 year pre-arrest, 1 year post-arrest and 2 years post-arrest. Each drug arrestee group had significantly more traffic violations and total accidents than the control group, except for 2 year post-arrest accidents for the felony narcotics group. Measures of accident culpability showed drug arrestees to be more responsible for the accidents in which they were involved than was the general driving population. Individuals arrested for drug offenses clearly pose an elevated traffic safety risk. These findings provide a public safety justification for state and federal initiatives designed to institute driver licensing actions against drug offenders, and support for the implementation of Public Law 101-516 in California.

14. SUBJECT TERMS
drug usage, problem drivers, crime, traffic law violations, accidents, accident causality

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT
Unclassified

20. LIMITATION OF ABSTRACT

ACKNOWLEDGMENTS

The author wishes to acknowledge and extend appreciation to the individuals who contributed to this study. Dr. Mary Janke, Research Manager II, described the problem to be addressed, some questions that needed answering, and some limitations inherent in the study. Clifford J. Helander, Research Manager I, provided ongoing direction and helped to assure that the study had a coherent and unified focus. Raymond C. Peck, Research Manager III, provided general direction and guidance, particularly with the statistical analyses. The above individuals reviewed report drafts and offered valuable input on both content and style.

Helen Tashima, Research Analyst II, provided valuable help in describing the structure, nuances, and idiosyncrasies of the data files. David J. DeYoung, Research Analyst II, offered helpful assistance with the statistical analysis. Quint Hegner and Charlotte Rhea of the Department of Justice, Law Enforcement Information Center, provided drug arrest data and documentation in a timely and cooperative manner. Debbie McKenzie, Staff Services Analyst, compiled the final document and assured that its format was consistent and clear.

<u>Report Author</u>:
Leonard A. Marowitz, Research Analyst II

EXECUTIVE SUMMARY

Introduction

- The Appropriations Act for Fiscal Year 1991 (Public Law 101-516) mandates the withholding of federal highway funds from states which do not enact and enforce a law which suspends for at least six months the driver's license of any individual convicted of a violation of the Controlled Substance Act, or any drug offense. For unlicensed or currently suspended drivers, a delay of at least six months would be required prior to issuance or reinstatement of a driver's license. Alternatively, the law provides that in order to avoid the federal monetary sanction, the Governor and Legislature of a state must certify in writing that they are opposed to the enactment or enforcement of such a law in their state.

- In the most recent session of the California Legislature, two bills (Assembly Bill 879-McDonald, and Assembly Bill 1302-Frazee) proposed suspending the driver's license of drug convictees in accordance with the federal mandate. In the absence of sufficient support for either of these bills, however, assembly Joint Resolution 37 (McDonald) was proposed which stated that California was opposed to taking action against the driving privilege of drug convictees, with the provision that the Legislature would reconsider its position during the 1994 legislative session. This resolution also did not get out of committee, and Federal Highway Administration funds amounting to $47 million in highway spending are currently being held in escrow.

- Legislative proposals to take licensing actions against persons convicted of specified drug offenses would be more supportable if there were a demonstrated connection between drug offenses and driving risk. If drug convictees, as a group, were shown to be high risk drivers, then the traffic safety rationale for such sanctions would be more convincing. The purpose of this study is to provide governmental decision makers with an objective, analytical evaluation of the relationship between drug offenses and traffic safety for use when formulating public policy.

- Studies performed in laboratories and on closed driving courses have shown that drugs generally diminish driving-related skills. However, while the literature shows evidence of the common involvement of drugs in traffic accidents, studies have not conclusively answered the question of whether the driving records of drug users and their involvement in accidents is any different than that of the general driving population. This study addresses that question. This study does not address the potential effects of license suspension on the subsequent drug use and driving risk of drug offenders. If such a law were passed, research should be undertaken to answer these questions.

Methods

- Drug offender subjects (N = 106,214) were drawn from the California Department of Justice (DOJ) Monthly Arrest and Citation Register (MACR) adult and juvenile arrest reports for drug offenses in 1989. All California law enforcement agencies report each arrest that they make to the MACR. A control sample of drivers from the general driving population (N = 41,493) was drawn from the DMV master file.

- Drug arrestees were grouped according to the six summary offense categories used by the DOJ, which are:
  1. Felony narcotics arrestees.
  2. Felony marijuana arrestees.
  3. Felony dangerous drugs arrestees.
  4. Felony other drug violations arrestees.
  5. Misdemeanor marijuana arrestees.
  6. Misdemeanor other drug arrestees.

- Groups were compared for the year prior to arrest, and the one- and two-year periods after arrest, on traffic convictions and total accident involvement. They were compared only for the year prior to arrest on accident culpability measures, which included measures of single-vehicle accidents, fatal and injury accidents, and investigating officer's assessment of accident fault. Drug arrestees, in separate groups for some analyses and combined into one group for others, were compared to controls on each measure.

Results

- Each drug arrestee group had significantly more traffic violations than the control group for all time periods examined.

- Each drug arrestee group was involved in significantly more total accidents than the control group during the year prior to and the year after arrest. During the two years after arrest, each drug arrestee group except the felony narcotics group was involved in significantly more total accidents than the control group.

- The combined drug arrestee groups were significantly more involved in single-vehicle accidents than was the control group.

- The combined drug arrestee groups were significantly more involved in fatal and injury accidents than was the control group.

- Each drug arrestee group was judged by investigating officers to have significantly greater fault for the accidents in which they were involved than the control group.

Discussion and Conclusions

- Drug arrestees committed 3.04 times as many traffic violations as the general driving population during the year prior to arrest, 2.22 times as many during the year after arrest, 2.02 times as many during the two years after arrest and 2.38 times as many over the entire three year period as did the general driving population.

- Drug arrestees were involved in 1.66 times as many traffic accidents as the general driving population during the year prior to arrest, 1.45 times as many during the year after arrest, 1.34 times as many during the two years after arrest, and 1.45 times as many traffic accidents over the entire three year period as was the general driving population.

- The consequences of arrest, most probably incarceration and resultant reduced driving exposure, decreased the rate of traffic violations and accident involvement by the drug arrestees during the years after arrest, but the commission of traffic violations by drug arrestees was still significantly greater than for the general driving population (except for felony narcotics group accidents during the two years after arrest).

- The weighted mean number of single-vehicle accidents for all drug arrestees was 2.47 times as great as the control group mean. The disproportionately large involvement of drug arrestees in accidents involving only one vehicle provides evidence that drug arrestees are more responsible for their accidents than is the general driving population and that drug impairment may have played a causal role in some of the increased accident risk.

- Drug arrestees tended to be involved in more serious accidents than the control group, as evidenced by a significantly disproportionate number of casualty (injury and fatality) accidents. This finding provides further support for the conclusion that drug offenders pose a driving-related public safety risk.

- Based on the investigating officer's assessment of accident fault, each drug arrestee group had significantly greater accident culpability than did the control group. The weighted mean accident culpability index value for all drug arrestees was 3.596, which was significantly different than the control group value of 3.891 (where 3 = most at fault, 4 = contributed and 5 = not at fault, so a lower score means higher culpability).

- Drug arrestee groups varied among measures of risk. No single drug arrestee group posed the greatest or least traffic safety risk on all measures, and the hierarchy of drug arrestee groups varied among measures. For pre-arrest measures, the felony dangerous drugs group tended to have the worst record and the felony marijuana group tended to have the best record. No such tendencies were readily discernible for the post-arrest time periods.

- The highly significant results obtained in this study should be interpreted as definitely indicating a substantial correlational relationship between drug arrests and traffic safety risk, and probably indicating at least some degree of causal relationship.

- The DOJ arrest categories do not map very well with drug use or impairment categories, which creates a limitation in making inferences about how the pharmacological properties of the drugs affect impairment and driving related tasks. For example, felony narcotics arrestees could have been involved with heroin (a depressant) or cocaine (a stimulant), so measures of this group do not reflect the impairment caused by a single class of drugs. No statement about the traffic safety risk associated with a specific drug, except marijuana, can be made from this study.

- This study clearly shows that individuals arrested for drug violations represent an elevated traffic safety risk, and that there is a nexus between drugs and traffic safety. Despite the incarceration and subsequent reduced driving exposure of about 90% of felony drug convictees (about 60% of felony arrestees are convicted) and a smaller, but unknown, percentage of misdemeanor drug convictees, these individuals demonstrated an elevated traffic safety risk level up to two years after arrest.

- These findings provide a public safety justification for state and federal initiatives designed to institute driver licensing actions against drug offenders, and support for the implementation of Public Law 101-516 in California.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

TABLE OF CONTENTS (Continued)

TABLES (Continued)

LIST OF FIGURES

TABLE OF CONTENTS (Continued)

FIGURES (Continued)

INTRODUCTION

Statement of Problem

Motor and perceptual skills, such as those involved in the driving task, are altered in individuals under the influence of drugs, both illegal (such as opiates, cocaine, amphetamines, phencyclidine-PCP, marijuana, and hallucinogens) and legal (such as prescribed medications, including barbiturates and other sedative/hypnotics, and over-the-counter medications, including antihistamines). While motorists driving under the influence of such drugs would be expected to represent an increased traffic safety risk due to the physiological effects of the drugs, the epidemiological evidence is not conclusive. In addition, although federal law calls for suspending the driver licenses of drug offenders (see below), no definite connection has been established between arrest for drug offenses and increased driving risk.

Legislative proposals to take licensing actions against persons convicted of specified drug offenses would be more supportable if there were a demonstrated connection between drug offenses and driving risk. While license suspension upon conviction for a drug offense may have an added deterrent effect on drug involvement, particularly among younger drivers for whom the driving privilege is highly valued, such driving sanctions would serve a more direct pragmatic purpose if they were known to remove high-risk drivers from the highways. If drug convictees, as a group, could be shown to be high risk drivers, then the traffic safety rationale for such sanctions would be more convincing.

The problem which this study addresses is that of the relationship between drug offenses and traffic safety. It answers the question of whether drug offenders represent a different driving risk than the general driving population, and whether the imposition of driver license sanctions upon drug convictees, in addition to any other punishment, might serve the interests of traffic safety.

Purpose of Study

Section 333 of the Federal Department of Transportation and Related Agencies Appropriations Act for Fiscal Year 1991 (Public Law 101-516) mandates the withholding of federal highway funds from states which do not enact and enforce a law which suspends for at least six months the driver's license of any individual convicted of a violation of the Controlled Substance Act, or any drug offense. For unlicensed or currently suspended drivers, a delay of at least six months would be required prior to issuance or reinstatement of a driver's license. Alternatively, the law provides that in order to avoid the federal monetary sanction the Governor and Legislature of a state must certify in writing that they are opposed to the enactment or enforcement of such a law in their state.

In the most recent session of the California Legislature, two bills (Assembly Bill 879-McDonald, and Assembly Bill 1302-Frazee) proposed suspending the driver's license of drug offenders in accordance with the federal mandate. In the absence of sufficient support for either of these bills, Assembly Joint Resolution 37 (McDonald) was proposed, which stated that California was opposed to taking action against the driving privilege of drug convictees, but that the Legislature would reconsider its position during the 1994 legislative session. None of these legislative proposals got out of committee.

As a result, Federal Highway Administration funds amounting to $47 million are currently being held in escrow. If California enacts legislation taking either of the alternative positions allowed by the federal mandate prior to August 1, 1994, the $47 million will be restored to California's funding authorization for fiscal year 1993/94. If no relevant legislation is enacted prior to August 1, 1994, these funds will be lost to California. If legislation is not enacted by California during the next fiscal year, additional federal highway funds amounting to $54 million will be lost.

The purpose of this study is to provide governmental decision makers with an objective, analytically derived evaluation of the relationship between drug offenses and traffic safety for use when reconsidering their position.

In considering the above purpose, it is important to also note what the study does not address. The primary objective of the federal license suspension mandate is to create an additional deterrent to drug use. This study does not attempt to evaluate or render an opinion on whether or not license suspension is effective in deterring drug use or decreasing driving risk. Such an evaluation, requiring a different research design and set of considerations beyond those presented here, should be undertaken to answer these questions.

<u>Study Questions</u>

Questions addressed in this study stem both from a theoretical interest in better understanding the relationship between drug offenses and driving risk, and from a public policy interest in measures directed at reducing risk to the general population.

These two interests are compatible, since understanding the relationship between drug offenses and driving should facilitate the formulation of appropriate public policy.

The first question addressed in this study is, "How does the traffic safety risk of drug arrestees compare with the overall driving population, as measured by the total number of traffic accidents and convictions for each group?" For drug arrestees, the driving record is examined for the year prior to arrest, the year after arrest, and the two years after arrest, and compared to that of the general driving population in each period. The second question is, "Is the arrest associated with a change in the total number of accidents and convictions for drug arrestees?" This pre-arrest/post-arrest evaluation examines change that might be related to the arrest. The third question is, "Given driving records prior to arrest, how do the total number of post-arrest accidents and convictions for drug arrestees compare with those of the overall driving population?" This is similar to the first question for the one- and two-year periods after arrest, with additional adjustment for the pre-arrest driving record.

The fourth question addressed in this study is, "How does the number of single-vehicle accidents for drug arrestees compare with that number for the overall driving population?" Single-vehicle accidents (vehicle ran off road or hit a fixed object) more clearly indicate driver responsibility because no other vehicle(s) contribute to the accident. In addition, some of the effects of drugs, such as sleepiness and loss of consciousness, increase the likelihood of single-vehicles accidents. This question, as well as the next two, attempts to assess the role of drug impairment and drug offender driving characteristics in accident causation, and is evaluated by comparisons of accident indices for the year prior to arrest. The fifth question is, "How does the involvement of drug arrestees in single-vehicle accidents compare with their involvement in multiple-vehicle accidents, relative to the general driving population?" The sixth question is, "How does the involvement of drug arrestees in fatal and injury accidents, relative to their involvement in property-damage-only accidents, compare to the general driving population?" The seventh question is, "How does the accident fault of drug arrestees compare with that of the general driving population?"

The answers to these seven questions, which address conviction and accident involvement as well as accident culpability, have not been fully resolved by earlier research, although others have addressed them.

Background of DMV Interest

Janke (1990), at the request of a former DMV Director, wrote a paper entitled, "Drugs and Traffic Safety: Is There a Nexus?" In this paper, she pointed out that a nexus can be either a causal or non-causal connection, and stated that it is more defensible to take licensing actions against drug users on the basis of evidence for a causal relationship. She then presented existing evidence for or against a direct causal connection between drug use and accidents. Her lengthy review presented both epidemiological findings and experimental evidence from research conducted in laboratory or restricted driving settings.

She concluded by stating that if the focus of concern is broader than or different from traffic safety, such as using licensing actions as a tool for deterring illicit drug use, then the possible existence of a nexus may be irrelevant. However, she strongly recommended that any licensure measure be justified on traffic safety grounds based on sound scientific evidence that shows at least an associational nexus between drugs and accidents.

Janke recommended, and the Director approved, that a study be conducted comparing the average accident and traffic conviction records of people with recent drug convictions to those of the general driving population. No information would be generally available, of course, as to whether the incidents occurred while the driver was actually under the influence of drugs. Since only a few types of drug arrests are reported to DMV, she suggested using Department of Justice (DOJ) arrest data to identify drug offenders.

The present study, which attempts to show the associational nexus mentioned above, was originally initiated in the summer of 1991. The federal mandate for license actions for drug convictees and California's response provided additional impetus for its completion.

Literature Review

Two studies from the 1960s arrived at different conclusions about the relationship between drugs and driving; differences which have not been fully resolved to date. Waller (1965) compared the driving records of 352 California drivers convicted of illegal drug use with those of 922 randomly selected California drivers. The drug convictees had a significantly greater number of violations (1.8 times as many), but no more accidents, than the matched controls. Driving exposure apparently did not affect the findings, as both groups reported driving a similar number of miles. The author speculated that the difference in number of violations was not due to the effects of drugs, but to social rebellion. The lack of difference in accident rates was said to reflect both the development of drug tolerance and the belief that "most people addicted to drugs probably do not feel like driving during the fairly brief euphoric state after taking the drug."

Crancer and Quiring (1968) examined records of drivers in King County, Washington, an urban area centered around Seattle. The driving records of 302 licensed drivers with arrests, but not necessarily convictions, for illegal drug use were compared to the records of 687,228 drivers living in the same driving environment. The three types of illegal drug users studied were: (1) narcotics users, exclusive of marijuana; (2) "dangerous" drug users, including amphetamines, barbiturates, and hallucinogens, and (3) marijuana users. Compared to the control group, the violation rate was found to be 149% greater for narcotics users, 168% greater for dangerous drug users, and 180% greater for marijuana users. These differences were all statistically significant. The accident rate was shown to be 29% greater for narcotics users, 57% greater for dangerous drug users, and 39% greater for marijuana users. Only the differences for the dangerous drug users and the combination of all groups (39%) were statistically significant. Driving exposure was not estimated, so differences could not be attributed to, or adjusted for, miles driven.

The authors stated that it was not possible from this study to determine if the poorer driving records found among drug users were the result of physiological impairment due to drug use, or from "character disorder." As in the study by Waller, the results could only be generalized to users of illegal drugs who had been arrested for use, and this group of arrestees might not be representative of all (arrested and nonarrested) drug users.

Dott (1972) studied the effect of marijuana on risk acceptance in a simulated passing task. He found that subjects under the influence of marijuana completed fewer passes and took more time to decide to pass than did control subjects, except during an emergency situation. Subjects under the influence of marijuana did not have more accidents. The author concluded that marijuana appears to make individuals less willing to accept risk and it delays elective decision-reaction time, except in emergency situations. He stated that subjects appeared more cautious or more passive when confronted with a potentially hazardous passing situation than either normal subjects or subjects under the influence of alcohol.

Among more recent studies, Terhune (1982) used a scale which rated the relative contribution of drivers toward causing accidents in which they were involved. His goal was to determine whether a substance, such as alcohol or marijuana, increases the culpability of drivers in accidents. He stated that in order to show the causal role of a substance in accidents, "it is necessary (but not sufficient) to show that significantly more of the drivers in the substance group were judged culpable than were drivers in the drug free group." He found that motorists with marijuana, alone, in their systems had significantly elevated culpability rates when he evaluated the two highest (out of five) levels of culpability.

Sutton (1983) measured driving performance in a controlled obstacle course of subjects who had consumed alcohol (0.06% BAC), marijuana (2% D-9-THC), both, or neither. At the measured levels, he found no impairment for either alcohol or marijuana alone, but a significant impairment for the combination. The patrol officer who participated in the study by following vehicles driven by subjects stopped every driver under the combination condition, indicating that he could detect signs of their impaired driving.

Moskowitz (1985) reviewed the literature on marijuana and driving, and concluded that marijuana seriously impairs psychomotor performance related to driving, including coordination, tracking, perception, and vigilance. He pointed out that the threat to society of any drug which causes such impairment depends on who uses it, when they use it, and under what conditions they use it. Thus, he implied that the establishment of a connection between marijuana, or any other drug, and driving is necessary for classifying the drug as a threat to traffic safety.

Williams, Peat, Crouch, Wells, and Finkle (1985) reported on drugs which were detected in fatally injured young male drivers in the California counties of Los Angeles, Orange, Sacramento, and San Diego during parts of 1982 and 1983. Blood samples were obtained by coroners in these four counties from fatally injured drivers (except those driving large trucks) between the ages of 15 and 34. Of these, 37% had marijuana in their blood, 11% had cocaine, 4% had PCP, 3% had methamphetamine, and less than 1% had narcotic analgesics (opiates and their synthetic analogues), compared to 70% having alcohol.

Biasotti, Boland, Mallory, Peck, and Reeve (1986) had experienced users of both alcohol and marijuana drive a closed course under the influence of alcohol, marijuana, both drugs, or neither drug. They concluded that marijuana "impairs psychomotor abilities that are functionally related to driving and...driving skill itself may be impaired, particularly at high dose levels or among naive subjects." They also concluded that drivers under the influence of both alcohol and marijuana represented a greater risk than either drug alone, but that marijuana alone tended to cause less impairment than alcohol alone. Patrol officers in cars following the subjects would have stopped them about 60% of the time when they had consumed both drugs, compared to 50% for alcohol only, 32% for marijuana only, and 15% for the placebo subjects, so impaired driving was relatively apparent to the patrol officers.

Hurst (1987) looked at amphetamines and driving, and stated that spree users of amphetamines are a menace since they have been shown to have two to four times the rate of accidents as expected. Yet, he observed that amphetamine involvement in accidents is so low that either the spree use of amphetamines is rare in the driving population, or the user population usually separates such use from driving.

McLinden (1987) evaluated 164 cases occurring between 1983 and 1985 in which persons suspected of being under the influence of drugs, following a "nil" (defined as a BAC less than 0.02%) or "low" (liberally defined as a BAC up to 0.15%) BAC reading, were tested for drugs. Sixty-seven tested positive for a single drug, 37 for a single drug and alcohol, 49 for more than one drug, and 11 for more than one drug and alcohol. There were 92 instances of marijuana, 22 of opiates, 2 of cocaine, and 1 of methaqualone. The arresting officers' descriptions of cases testing positive only for marijuana included such comments as speech slurred, speech slow, unsteady, uneasy on feet, slow movements, confused, violent, aggressive, car weaved over double lines several times, driving erratic, and swerving in lane. The author concluded that marijuana can seriously impair driving ability; however, the inclusion of persons with a "low" BAC reading in the sample confounds these findings.

Siegel (1982) found that 18% of cocaine users admitted to driving while impaired. In a later paper, Siegel (1987) stated that the five patterns of nonmedical cocaine use, in increasing order of addiction, include experimental use, social use, circumstantial use, intensified use and compulsive use. He described widely available paraphernalia which have been adapted for intranasal and smoking use while driving. He examined cocaine use and driving behavior, and noted that the effects of the drug relative to behavior include visual impairment, euphoria and feelings of increased mental and physical abilities, suspiciousness or even paranoia. The author noted, however, that despite the concern with cocaine-caused accidents, there is no detailed study of cocaine use and driving behavior.

Moskowitz and Burns (1989) examined the effects of "an acute, moderate cocaine dose" (96 mg), alone and with alcohol, on laboratory tests of tracking ability, divided attention, and vigilance; skills which are important for driving. The subjects were experienced cocaine users. Composite scores of testing performed soon after drug dosing revealed that relative to the placebo condition, alcohol impaired performance, cocaine improved performance, and cocaine and alcohol together improved performance. Composite scores of testing performed two hours after drug treatment showed alcohol effects and alcohol plus cocaine effects to be nonsignificant, while cocaine effects continued to enhance performance. The authors concluded that cocaine enhanced the behaviors examined and that cocaine almost completely counteracted the decrements induced by a relatively low level (0.04-0.05%) of alcohol.

Chester (1989) reviewed studies on opiates and their effects on skills performance, including driving. He concluded that the evidence suggests that opiates affect skills performance much less than do other receptor-specific drugs, such as the legal benzodiazepines (e.g., Valium). Habitual opiate users develop a high degree of tolerance to the effects of the drugs, and the acute effects of opiates on the psychomotor performance of addicts and ex-addicts is slight.

Johnston, O'Malley, and Bachman (1989) reported drug use among high school, college, and young adult populations in 1988. For high school seniors, over 47% had used marijuana (18% in the last month), 12% cocaine (3.4% in the last month), 10% opiates (2% in the last month), and 9% hallucinogens (2% in the last month). For college students, the percentages were slightly greater for both use in general and use in the last month. For young adults aged 19 to 30, use of drugs generally rose with age, resulting in a lifetime prevalence of 75% for the use of any illicit drug. Use in the last month, however, remained the same or decreased slightly with age. These findings indicate that a history of drug use is common among people aged 17 to 30, and that in any given month a substantial percentage use at least one drug.

A survey of safety research by the Transportation Research Board (1990) referenced several surveys indicating that a high percentage of motorists have driven after consuming illicit drugs. Musty and Perrine (1989), for example, reported that 16% of male Vermont drivers who responded indicated that they had driven after using both alcohol and cocaine. Root (1989) found that 21% of driving fatalities in San Bernardino County had illicit drugs in their blood. Caplan, Levine, and Goldberger (1989) found a similar percentage of illicit drugs in a sample of driving fatalities in Maryland. Compton (1988) reviewed the literature and concluded that 10 to 20% of drivers involved in crashes have a drug other than alcohol in their system, usually in combination with alcohol. These findings were said to indicate the need for research in several areas, including the incidence of drug-impaired driving, the effects of drugs on driver behavior, and attitudes toward driving and drug use.

The National Transportation Safety Board (1990) stated that virtually all reports of fatal-to-the-driver heavy truck crashes reviewed found a high incidence of the same drugs and combinations of drugs, including marijuana, amphetamines, cocaine, and PCP, and that similar percentages (10-22%) of nonfatally and fatally injured drivers had drugs in their blood. In a sample of about 165 fatally injured truck drivers whose blood was analyzed for drugs, 12.8% showed marijuana, 8.5% cocaine, 7.3% amphetamines, and 0.6% PCP (12.5% showed alcohol). Forty-one percent were multiple drug users.

Tornros (1990) reviewed the literature for studies on the use of drugs by drivers. He cited studies which showed that 10% of college students in Illinois in 1975 used marijuana and drove at least once a week, 17% of high school students used marijuana and drove in Boston in 1982, and 20% of young adults used marijuana and drove, nationally, in 1983. Among a sample of motorists arrested for drugged driving (no presence of alcohol) in St. Louis from 1983 to 1986, PCP was found in 47%, marijuana in 47%, opiates in 11%, and cocaine in 9%.

Multiple drug use appears to be common. Block, Farnham, Braverman, Noyes, and Ghoneim (1990) surveyed 102 marijuana users to determine their use of other drugs. For heavy marijuana users (seven or more times a week), 83% had used cocaine, 80% psychedelics other than LSD, 79% LSD, 78% amphetamines, 55% narcotics other than heroin, 36% methaqualone, 14% heroin, and 12% PCP. For light marijuana users (one to four times a week), the percentages were slightly lower. All subjects in both groups had used alcohol.

The National Household Survey on Drug Abuse (1991) for 1990 found that 37% of the household population aged 12 and older reported "ever" having used an illicit drug, 13.3% having used one in the past year, and 6.4% having used one in the past month. The most commonly used illicit drug was marijuana, with 33.1% having used it at some time, 10.2% within the past year, and 5.1% within the past month. These findings support the perception of widespread, ongoing illegal drug use in the United States.

Soderstrom (1991) looked at drugs of abuse found in vehicular crash victims treated at the Maryland Institute for Emergency Medical Services Systems Shock Trauma Center during 1988 and 1989. Among car or truck drivers, 7.1% had cocaine, 3.5% had opiates, 3.0% had PCP, and 0.4% had amphetamines in their blood, compared to 33.9% with alcohol in their blood. In a subsequent retrospective study, marijuana was found in 34.0% of patients admitted to the Shock Trauma Center.

Sweedler (1992) investigated 182 fatal accidents involving 185 drivers from October 1987 to September 1988, which represents about 25% of the heavy-truck accidents that occurred in the United States during that period. Biological specimens for toxicological testing were obtained from 168 of the 185 fatally injured drivers. Of these, 112 (67%) tested positive for one or more drugs, with 56 (33%) testing positive for drugs of abuse. Alcohol was measured in 21 (13%) of the drivers, stimulants were found in 19 (11%) and marijuana was identified in 21 (13%). Evidence of polydrug use was found in 23 drivers (14%). Regional differences in drug use showed that fatal accidents occurring in California and Maryland had most of the cocaine cases, and fatal accidents occurring in California had virtually all the amphetamine cases. A prior record of alcohol and drug abuse was strongly related to a positive drug test, with 82% of drivers who had drug histories testing positive. Of the 56 cases in which drivers tested drug positive, 49 (88%) showed drug impairment was a factor in causing the accident.

Lucke (1992) reported on the results of a pilot study which was a component of a study on alcohol and drug involvement in traffic crashes. Preliminary results of samples collected over a one-year period from about 200 injured drivers at one hospital showed that 54% had drugs, alcohol, or both in their systems, 32% had impairing drugs other than alcohol, and 79% of drivers 25-34 years old had alcohol, drugs, or both. With regard to the time of the accident, none of the drivers in crashes between 8 a.m. and noon had any impairing drugs in their systems, while 67% of drivers involved in crashes between midnight and 8 a.m. showed evidence of drugs. Finally, 72% of drivers in single vehicle crashes had impairing substances in their systems.

Burns (1993) reviewed epidemiological findings on several drugs found in fatally injured drivers. Among these findings were marijuana having been found in 7-10% of fatally injured drivers, in 15% of tractor-trailer drivers who participated voluntarily in a survey, and in 6% of traffic crash victims in Maryland. Cocaine was found in 11% of fatally injured young male drivers in California. Alcohol was often present among crash victims who were found to have other drugs in their blood.

Overall, the literature shows evidence of the common involvement of drugs in traffic accidents. However, the lack of epidemiological evidence regarding the presence of illegal drugs in otherwise equivalent samples of drivers not involved in accidents makes it difficult to conclude whether drug offenders have a higher or lower rate of accidents than the general driving population. This lack of definitive epidemiological data prevents a similar evaluation of traffic violations. Additionally, the copresence of alcohol in many epidemiological studies makes it difficult to unravel the separate effects of drugs and alcohol on both traffic accidents and violations. Finally, for some drugs, particularly marijuana, their presence in tissue and body fluids does not correlate well with time of ingestion and impairment.

Studies to date have not conclusively answered the question of whether the driving records of drug users and their involvement in accidents is any different than that of the general driving population. The current study looks at a subgroup of drug users who have been identified as such by their arrest for a drug violation, while recognizing that this subgroup may not be totally representative of all drug users due to ethnic, socioeconomic, or other differences.

METHODS

Subjects

Selection of drug offender subjects. Drug offender subjects included in this study were drawn from the California Department of Justice (DOJ) Monthly Arrest and Citation Register (MACR) adult and juvenile arrest reports for drug offenses in 1989. All California law enforcement agencies report each arrest that they make to the MACR, which retains only the highest category of offense reported. While most arrests involving drug violations would be reported, any drug arrests also involving more serious crimes, such as armed robbery, would not be included in the MACR as a drug offense. During 1989, a total of 306,112 drug arrests, involving 287,068 adults and 19,044 juveniles, were reported to the MACR.

Grouping of drug offenders. Drug arrestees were grouped according to the six summary offense categories used by the DOJ, which are:

1) Felony narcotics arrestees.
   "Narcotics," as defined by the California Health and Safety Code, include opiates and cocaine, and chemically related substances, whether of natural or synthetic origin.

2) Felony marijuana arrestees.
   Includes marijuana and hashish; generally involves distribution or sale to anyone, growing or cultivating, or giving to a minor, as well as possession of concentrated cannabis (the separated resin obtained from marijuana).

3) Felony dangerous drugs arrestees.
   Includes sale to minors, transporting, possession for sale or sale of controlled substances, and possession of tranquilizers, amphetamines, nonamphetamine stimulants, phencyclidine, and a wide range of Schedule III, IV, and V drugs.[1]

[1]Schedule III drugs include limited quantities of certain opioid drugs, some depressants, paregoric, and certain barbiturates. Schedule IV drugs include phenobarbital, chloral hydrate, benzodiazepines, and Darvon. Schedule V drugs include Lomotil and small amounts of codeine in cough preparations and analgesics.

4) Felony other drug violations arrestees.
Includes offering a controlled substance but giving another substance in lieu, possessing peyote, psilocybin or psilocyn, providing room for manufacture, storage, or distribution of a controlled substance, selling equipment to be used to manufacture a controlled substance, possessing chemicals which are used to manufacture methamphetamine, forging prescriptions, and representing oneself as a physician.

5) Misdemeanor marijuana arrestees.
Includes possession of any amount and giving less than 1 oz. to an adult.

6) Misdemeanor other drug arrestees.
Includes possession or being under the influence of a controlled substance, other than marijuana, disorderly conduct while under the influence of a drug or a drug and alcohol, possessing imitation controlled substances, visiting where a controlled substance is being used, hypodermic needle and syringe offenses, possessing or delivering paraphernalia, not registering as a controlled substance offender, prescription misrepresentations or alterations, and failing to maintain dangerous drug records.

Data files used in study. Four data files were made. Each file contained drug offenders grouped according to the DOJ summary drug offense categories identified above. A control group was identified for each file by adding one digit to the driver's license number of each subject in the drug offense categories. Because the assignment of driver's license numbers is essentially a random process, this systematic sampling of control group members forms an unbiased control group. Within each file, the groups were compared on total traffic violations and total accidents.

Briefly, two of these files (combined files) included the total number of traffic violations and accidents on all driver records matching each MACR record. (In addition to the "regular" driver record, an indefinite number of "X-records"[2] may have matched a given MACR record. These were included in the combined files.) In one of the two combined files (combined separate file), individuals with multiple arrests were entered into each

[2]X-records are created when conviction abstracts or accident reports do not match the existing record of any California licensed driver. Reasons for nonmatches include drivers falsifying their identification, not having a driver's license, and being an out-of-state licensed motorist who commits a major traffic violation. These drivers are given fictitious driver license numbers beginning with the letter X.

summary offense group for which an arrest occurred. In this data file a subject could potentially appear in each summary drug group; however, appearing in more than one group was not very common. For the other combined file (combined grouped file), all individuals who had incurred arrests in more than one summary offense group were put into a separate group, called the multiple different offense arrestee group. Arrestees could only appear once in this file, no matter how many different summary arrest categories they originally were in.

The other two of the four data files (no-X files) were made by using only the regular driver record for each match. These two files are similar to the two combined files described above in that one (no-X separate file) contains multiple arrests for individuals categorized separately by offense group, while the other (no-X grouped file) segregates arrestees with multiple different offenses into a separate group.

For both the combined and no-X files, only the first arrest of 1989 for each individual appears in each summary offense group, including the multiple different offense arrestee group. Therefore, an individual could appear only once in each drug arrestee group. Finally, each control group was reduced to 46% of its original size, using a random number generator, to approximate the size of the largest drug offender group.

Of the four files, results for only the no-X separate file are presented in this report, for reasons stated in the Results section. All data which follow are based on analyses of the no-X separate file.

Analytical sample: Final group sizes. After combining the summary drug offense groups and control groups to make each of the four files to be analyzed and adding covariates (to be discussed later) to each record, it became apparent that an important statistical software test could not be run on files as large as had been made. Therefore, each group in each file was reduced by 50% using a random number generator, except for the felony other drug violations arrestee group. This was not reduced in size as it already was much smaller than the other groups.

The final group sizes for the analytical sample from the no-X separate file are as follows:

Group	Number
Felony narcotics	40,526
Felony marijuana	5,817
Felony dangerous drugs	14,088
Felony other drugs	1,796
Misdemeanor marijuana	9,957
Misdemeanor other drugs	34,030
Multiple different drugs	Not applicable
Drug groups subtotal	**106,214**
Control	41,493
File total	**147,707**

<u>Demographics.</u> All four drug offender files had essentially the same subject composition. The percentages of males and females in the no-X separate file, as representative of all the files, was as follows:

Group	Male	Female
Felony narcotics	79%	21%
Felony marijuana	82%	18%
Felony dangerous drugs	75%	25%
Felony other drugs	67%	33%
Misdemeanor marijuana	87%	13%
Misdemeanor other drugs	76%	24%
Drug groups subtotal	**79%**	**21%**
Control	57%	43%
File total	**72%**	**28%**

The race/ethnicity of subjects in the drug arrestee groups was contained in the MACR data, but since DMV records do not contain race/ethnicity this demographic variable was not available for the controls. The race/ethnicity of the drug arrestee groups in the no-X separate file was as follows:

Group	White	Hispanic	Black	Other*
Felony narcotics	23%	31%	44%	1%
Felony marijuana	40%	42%	16%	1%
Felony dangerous drugs	72%	20%	6%	1%
Felony other drugs	55%	12%	31%	1%
Misdemeanor marijuana	54%	24%	17%	4%
Misdemeanor other drugs	39%	38%	21%	2%

*American Indian, Chinese, Japanese, Filipino, and Pacific Islander subjects each comprise less than 1% of total drug arrestees.

The mean ages of each of the groups in the no-X separate file were as follows:

Group	Mean age
Felony narcotics	28.3
Felony marijuana	26.2
Felony dangerous drugs	28.1
Felony other drugs	31.8
Misdemeanor marijuana	24.4
Misdemeanor other drugs	28.6
Drug groups mean	**27.9**
Control	31.6
File mean	**29.0**

Design

Since the drug offender subjects in this study were self-selected into groups based on arrests for their drug activities, random assignment to groups was not possible. The study therefore has a quasi-experimental design in which pre-existing independent variables other than those of interest (covariates; e.g., sex and age) were used to adjust group mean differences to make the samples more equivalent on these variables. Covariates, to be useful, should be highly related to the dependent variable of interest. Issues germane to quasi-experimental designs, including validity, design, and making inferences of causality have been discussed in detail elsewhere (see Cook & Campbell, 1979).

For each file, total traffic violations and accidents were compared among all groups. All drug arrests occurred in 1989, and the date of each arrest served as a reference point for all the time periods examined. Each subject in the control group was also given a "reference date" to act as a time period boundary. This reference date was the same as the arrest date of the drug arrestee whose driver's license number led to the control subject's being chosen.

Total traffic violations and accidents were obtained for each subject for the one-year period prior to arrest (or reference date for controls), and for the one- and two-year periods following the date of arrest. Within each file, groups were compared in three ways. First, they were compared for each of the three time periods. Then they were compared for the one- and two-year post-arrest periods, using the pre-arrest driving record violations (for post-arrest violation comparisons) and accidents (for post-arrest accident comparisons) as a covariate in addition to the other covariates used. Finally, they were compared for pre-arrest to post-arrest changes.

In order to assess the extent to which arrestees in each drug offense group caused the accidents in which they were involved, relative to the general driving population, three analyses were performed. First, single-vehicle accident involvement by each group was compared within each file for the one-year pre-arrest period. Second, the presence of linear relationships between accident type (single- or multiple-vehicle) and group (drug arrestee or control) and between accident outcome (fatal/injury or property-damage-only) and group (drug arrestee or control) were evaluated. Third, accident fault, as assessed by the investigating officer and rated using the DMV accident responsibility code, was calculated for each subject for the one-year pre-arrest period. The mean assessment of accident fault (accident culpability index) for all groups were then compared.

<u>Statistical Analyses</u>

<u>Covariates</u>. Adjustments for preexisting group differences were made statistically through the use of covariates which addressed differences either inherent in the subjects or in the area where they lived, as related to traffic safety. These covariates included:

1) Age
2) Gender
3) Zip code injury accident average, 1987 to 1992

4) Zip code accident average, 1987 to 1992
5) Zip code major conviction average, 1987 to 1992
6) Zip code moving violation average, 1987 to 1992

The zip code indices provide measures of the accident and traffic law enforcement rate in the offender's area of residence. For further information on the calculation of these measures, see Peck & Kuan (1982).

Analyses of covariance and other analyses. Each analysis of covariance (ANCOVA) was performed using the SAS statistical software GLM procedure, Version 6.07 (SAS Institute Inc., 1990). The ANCOVA procedure is presented in detail in Keppel (1982). All tests of homogeneity of regression (slopes) performed to determine whether to use common or separate slope adjustments for each covariate were performed using the BMDP statistical software 1V procedure (BMDP Statistical Software, Inc., 1990).

Analyses were performed with some covariates treated as having common slopes and others as having separate slopes, according to the outcomes of the homogeneity of regression tests. Subsequent analyses were performed with all covariates treated as having common slopes. These subsequent analyses, which did not remove sums of squares for interactions between treatment variables and covariates, evaluated treatment main effects without regard to treatment-group interactions[3].

Although the use of a common slopes model in the presence of group by covariate interaction (slope heterogeneity) produces some bias and ambiguity in the estimated main effects, the adjusted means still usually provide interpretable differences in marginal means--that is, adjusted differences between groups across all levels of the covariates. This interpretation of significant main effects under conditions of slope heterogeneity should also consider the relative size of the main effects and interactions. When the mean squares for main effects are much larger than the interaction mean square (slope heterogeneity), it is clear that there is a real difference in adjusted group means.

As noted above, slope differences imply interactions, which in the context of this study are indications that the relationship between drug use and safety risk vary as a function of offender characteristics (e.g., age, gender, etc.). The existence of such interactions can

[3]Values of the adjusted means for the separate slopes and common slopes models can be obtained by writing the author.

be of theoretical and practical interest in their own right. The use of a separate slopes model also alters the interpretation of main effects since the main effects are adjusted for correlation with the interactions, which ignores the conventional conception of main effects as having hierarchical precedence to interactions.

Although a detailed consideration of the slope differences was beyond the scope of this analysis, the slope differences were inspected and models employing separate slopes were fit to the data. These results are only briefly described in this report but are described in more detail in unpublished working papers. Slope differences were examined for the gender and age covariates among the seven groups (six drug arrestee groups plus control) for the total and single-vehicle accident analyses.

ANCOVA summary tables show the effect of all covariates, calculated by the BMDP 1V procedure. Subsequent analyses removed all covariates with zero slopes, which are reflected in the treatment and error terms of the ANCOVA summary tables.

The dependent variables of total violations and total accidents were each evaluated with one-way, between-groups ANCOVAs using the six covariates shown above. These analyses of the dependent variables (total-violations and total accidents) were performed for each of the three time periods (1 year prior to arrest, 1 year after arrest, and 2 years after arrest). The tests compared group means for each time period.

These same two dependent variables were also analyzed using ANCOVAs for each of the two post-arrest time periods (1-year and 2-years) using the 1-year pre-arrest conviction or accident rate, depending on dependent variable, as a covariate in addition to the six covariates shown above. These tests compared groups for each post-arrest time period, adjusting for pre-arrest driving record.

Finally, total violations and accidents were also analyzed for pre-arrest to post-arrest driving record changes using single-factor within-subjects ANCOVAs. These repeated measures tests were performed for each of the two pre-arrest to post-arrest combinations (1 year pre- to 1 year post-arrest and 1 year pre- to 2 years post-arrest), using the six covariates shown above. These tests compared changes in driving record as affected by the arrest (time) and the interaction of group and arrest (time).

Single-vehicle accidents were compared for the one-year pre-arrest period using one-way between-groups ANCOVAs. These tests used the six covariates shown above to evaluate accidents in which the vehicle that the subject was driving either ran off the road or hit a fixed object, implying that the subject was responsible for the accident without the contributory effect of another driver.

The presence of linear relationships between group (drug arrestee or control) and accident type[4] (single- or multiple-vehicle), and between group and accident outcome[5] (fatal/injury or property-damage-only) were evaluated using chi square tests (SAS, Version 6.08, FREQ procedure). For the former, single- and multiple-vehicle accidents were each summed for all drug arrestee groups and then compared to the number of control group single- and multiple-vehicle accidents. For the latter, fatal/injury and property-damage-only accidents were each summed for all drug arrestee groups and then compared to the number of control group fatal/injury and property-damage-only accidents.

A culpability index was developed using DMV accident responsibility codes. Accident responsibility in California is determined by the investigating officer, noted on the accident report sent to DMV, and included on the record of each driver. For accidents occurring in the one-year pre-arrest period, the time period used in this analysis, the codes that subjects in this study had on their records were as follows:

Code #	Code description
2	Fault not determined
3	Party found most at fault
4	Contributed to the cause of the accident
5	Not at fault, other party at fault
8	Emergency vehicle
9	Emergency vehicle -- other party found at fault

Mean culpability scores were calculated for each group based on all the accidents that subjects in the group had during the one-year prior to arrest (or reference date). Since an accident report code of 2 does not clarify relative fault in an accident and codes of 8

[4]Based on CHP reported accidents only. Single-vehicle accidents are those in which the vehicle runs off the road or hits a fixed object. Multiple-vehicle accidents involve multiple motor vehicles or multiple vehicles and pedestrians.
[5]Based on all reported accidents, including those reported under the California financial responsibility law.

and 9 pertain to unusual and rare occurrences, the mean culpability scores for each group were calculated using only accidents with codes 3, 4, and 5. As a result, the lower the mean score that was obtained for a group, the higher the accident culpability of that group.

The culpability indices of groups were compared using one-way between-groups ANCOVAs with the six covariates shown above. These tests compared the fault or blame for accidents of each group in each file.

<u>Newman-Keuls post hoc tests</u>. Newman-Keuls post hoc tests were performed for all ANCOVAs in which the omnibus *F* tests were significant. The Newman-Keuls test for unbalanced designs is described in Winer (1971). Once the *F* test rejects the null hypothesis of group equality, multiple post hoc comparisons are performed to determine which of the group means differ from the others. There are several of these tests, the Newman-Keuls being one which has moderate criteria for assessing significant differences among group means. It is widely used in social and behavioral research. Although it usually does not maintain the experiment wise Type I error rate at the nominal alpha level, the requirement of a significant omnibus *F* provides additional protection against Type I error rate inflation.

<u>Statistical power</u>. The power of a statistical test of a null hypothesis is the probability that it will lead to the rejection of the null hypothesis when the null hypothesis is false. Statistical power was estimated using power nomograms (Marowitz, 1991) which were constructed for ANCOVAs using the techniques described in Cohen (1988). Power estimates made prior to performing the analyses and based on expected effect sizes were approximately 0.9. However, it was decided to use the empirical findings of the analyses, specifically R^2, to estimate power.

Briefly, the above procedure requires the determination of four variables. One of these variables, alpha level, was chosen to be 0.05 for all tests. For the example of the one-year pre-arrest total conviction ANCOVA, the other three variables and their calculation were as follows:

1) Degrees of freedom for main effects (u) = No. of levels - 1 = 6.
2) The harmonic mean of the group sizes (N) = 7155.

3) The standardized or normalized effect size (f) is calculated from the following equation:

$$f = \frac{\eta^2}{1 - \eta^2} = \frac{0.089593}{1 - 0.089593} = .313703$$

where, η^2 is the proportion of variance accounted for by population membership and is equal to multiple R^2.

The power nomogram for ANCOVA, with alpha = 0.05 and $u = 6$ was used. A straight edge was placed on N = 7155 on the left axis, and on $f = .313703$ on the right axis. The center axis, which showed power, was crossed by the straight edge above the power = 0.99 point.

Overall type I error. There were 62 ANCOVAs performed in this study. Sixteen of these tests were performed on the no X separate file, as follows:

Design	# of ANCOVAs
Total convictions and accidents, each time period	6
Total convictions and accidents, post-arrest with pre-arrest as an added covariate	4
Total convictions and accidents, pre- and post-arrest	4
Single-vehicle accidents, pre-arrest	1
Culpability, pre-arrest	1
Total	16

The performance of a large number of F tests increases the probability that the null hypothesis will be rejected in one or more cases when it should be accepted. The true probability ($alpha_{overall}$) that the null hypothesis will be rejected on any test, when its rejection level is specified on each individual test ($alpha_{individual}$), for any number of tests (n), can be calculated by the following equation:

$$alpha_{overall} = 1 - (1 - alpha_{individual})^n$$

For the purpose of making significance claims in this study, an $alpha_{overall}$ of 0.05 was chosen. The adjusted per comparison alpha levels ($alpha_{individual}$) required to maintain $alpha_{overall}$ at 0.05 were 0.0016 for the 16 statistical tests performed on the no X separate file and presented in this report, and 0.0062 for the 62 statistical tests performed on all four files.

Thus, even though a large number of ANCOVA's were performed in this study, the level of significance obtained on each test was so high that the overall alpha level for statistical significance was met. The above procedure gives a valid estimate of the overall adjusted alpha level used for all ANCOVAs considered simultaneously, and prevents the overstating of statistical significance (or misstating of actual significance criterion) when multiple tests are performed.

RESULTS

File Similarity and Choice of No-X Separate File for Analysis

Four files, each containing six or seven categories of drug arrestees plus a control group, were analyzed. While the files differed in the inclusion or deletion of multiple matching DMV records, and in the placing of drug arrestees in all drug categories in which they were arrested or in grouping these multiple arrestees separately, the results of the analyses were similar. This finding reflects the highly significant effects found in all the analyses performed in this study.

In order to most clearly present the findings of the study, the results of only one of the files, the no-X separate file, will be presented. As stated previously, this file contains the "regular" (official) driving record of each subject, and drug arrest subjects appear once in each category of drug offense for which they were arrested in 1989.

The inclusion of subjects in more than one group is known to violate the ANCOVA requirement for independence of groups. However, since the results for the combined and separate files were similar, and the combined files do not violate the independence requirement, the results obtained for the separate files are considered to be representative of those obtained for all the files. The no-X separate file was chosen, additionally, because it was constructed like files used in previous studies, all of which contained only matching regular driving records.

Between-Groups ANCOVAs for Each Time Period

One-year pre-arrest total violations. Zip code accident average did not vary significantly with total number of violations, so it was not used as a covariate. However, the other five covariates were used. The model summary table showing highly significant differences among the group means is as follows:

Table 1

ANCOVA Summary Table for Total Violations
During the Year Prior to Arrest (Common Slopes Model)

Source of variation	Sum of squares	Degrees of freedom	Mean square	*F*	Significance level
Group	13583.30	6	2236.88	1352.22	$p<0.001$
Covariates	5398.13	6	899.69	538.41	$p<0.001$
Error	247270.11	147695	1.67		
Homogeneity of slope*	983.13	36	27.31	16.40	$p<0.001$

*Error: SS = 245816; *df* = 147658; MS = 1.66

A comparison of group means is shown in the following graph:

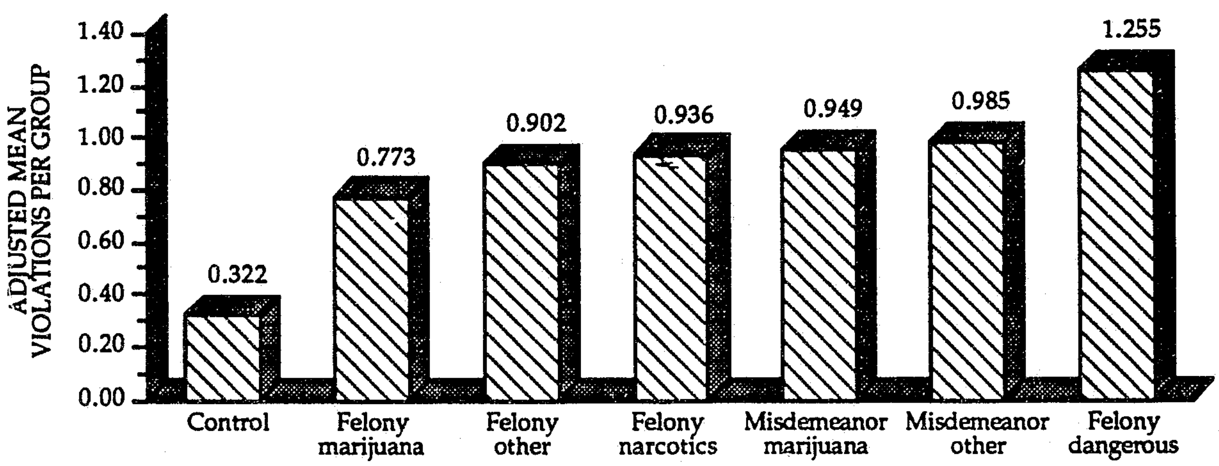

Figure 1. Adjusted group means, 1-year pre-arrest total violations.

Newman-Keuls post hoc multiple comparisons showed the control group to have significantly fewer total violations than each of the drug arrestee groups ($p<0.05$ for each comparison). This finding and the results of comparisons among the drug arrestee groups are as follows:

Group	Direction	Relative to ($p<0.05$)
Control	Less than	All drug arrestee groups
Felony marijuana	Less than	All other drug arrestee groups
Felony other drugs	Less than	Misdemeanor other & felony dangerous
Felony narcotics	Less than	Felony dangerous
Misdemeanor marijuana	Less than	Felony dangerous
Misdemeanor other drugs	Less than	Felony dangerous

The felony dangerous drugs group had significantly more violations than all other groups—a rate 3.9 times that of the controls.

One-year post-arrest total violations. The model summary table showing highly significant differences among the group means is as follows:

Table 2

ANCOVA Summary Table for Total Violations
During the Year After Arrest (Common Slopes Model)

Source of variation	Sum of squares	Degrees of freedom	Mean square	*F*	Significance level
Group	4744.00	6	790.67	655.48	$p<0.001$
Covariates	3922.88	6	653.81	542.73	$p<0.001$
Error	177661.52	147658	1.20		
Homogeneity of slope*	494.25	36	13.73	11.43	$p<0.001$

*Error: SS = 177429; df = 147658; MS = 1.20

A comparison of group means is shown in the following graph:

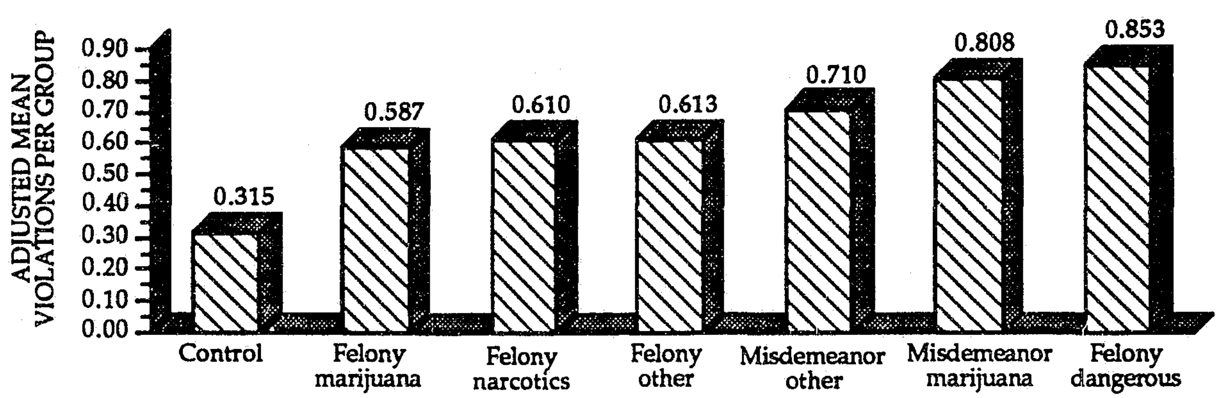

Figure 2. Adjusted group means, 1-year post-arrest total violations.

Newman-Keuls post hoc multiple comparisons showed the control group to have significantly fewer total violations than each of the drug arrestee groups ($p<0.05$ for each comparison). This finding and the results of comparisons among the drug arrestee groups are as follows:

Group	Direction	Relative to ($p<0.05$)
Control	Less than	All drug arrestee groups
Felony marijuana	Less than	Misdemeanor other, misdemeanor marijuana & felony dangerous
Felony narcotics	Less than	Misdemeanor other, misdemeanor marijuana & felony dangerous
Felony other drugs	Less than	Misdemeanor other, misdemeanor marijuana & felony dangerous
Misdemeanor other drugs	Less than	Misdemeanor marijuana & felony dangerous
Misdemeanor marijuana	Less than	Felony dangerous

Again, the felony dangerous drug group has the poorest records—a rate 2.7 times that of the controls.

<u>Two-year post-arrest total violations</u>. The model summary table showing highly significant differences among the group means is as follows:

Table 3

ANCOVA Summary Table for Total Violations
During the Two Years After Arrest (Common Slopes Model)

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance level
Group	12239.14	6	2039.86	768.71	$p<0.001$
Covariates	14109.31	6	2351.55	888.60	$p<0.001$
Error	390250.08	147658	2.64		
Homogeneity of slope*	1676.13	36	46.56	17.67	$p<0.001$

*Error: SS = 389177; df = 147658; MS = 2.64

A comparison of group means is shown in the following graph:

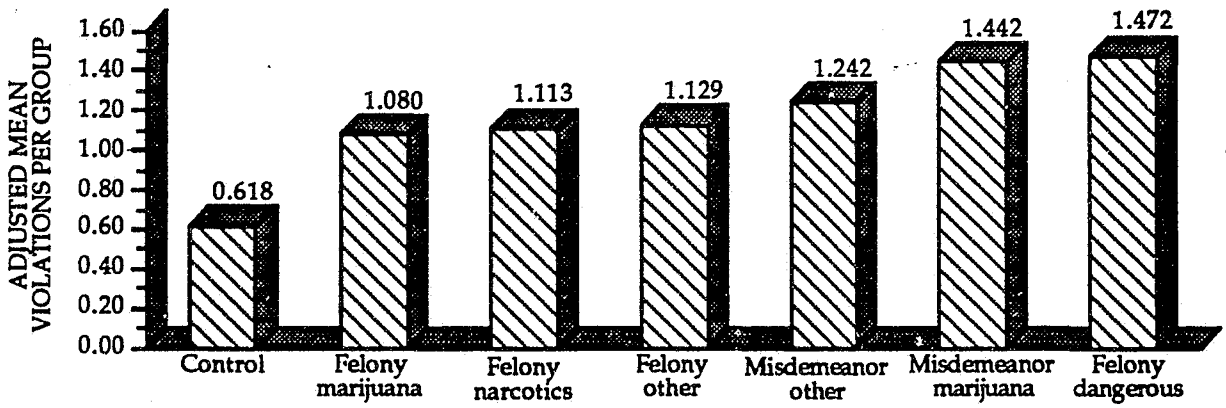

Figure 3. Adjusted group means, 2-year post-arrest total violations.

Newman-Keuls post hoc multiple comparisons showed the control group to have significantly fewer total violations than each of the drug arrestee groups ($p<0.05$ for each comparison). This finding and the results of comparisons among the drug arrestee groups are as follows:

Group	Direction	Relative to ($p<0.05$)
Control	Less than	All drug arrestee groups
Felony marijuana	Less than	Misdemeanor other, misdemeanor marijuana & felony dangerous
Felony narcotics	Less than	Misdemeanor other, misdemeanor marijuana & felony dangerous
Felony other drugs	Less than	Misdemeanor other, misdemeanor marijuana & felony dangerous
Misdemeanor other drugs	Less than	Misdemeanor marijuana & felony dangerous
Misdemeanor marijuana	Same as	Felony dangerous

Consistent with the preceding results, we again find that the felony dangerous drugs group accumulated the largest number of violations—almost 2.4 times that of the controls.

One-year pre-arrest total accidents. Zip code moving violation average did not vary significantly with one-year pre-arrest accidents, so it was not used as a covariate in this analysis. However, the other five covariates were used. The model summary table showing highly significant differences among the group means is as follows:

Table 4

ANCOVA Summary Table for Total Accidents During the Year Prior to Arrest (Common Slopes Model)

Source of variation	Sum of squares	Degrees of freedom	Mean square	*F*	Significance level
Group	33.73	6	5.62	71.82	$p<0.001$
Covariates	32.29	6	5.38	68.83	$p<0.001$
Error	11555.57	147665	0.08		
Homogeneity of slope*	6.91	36	0.19	2.46	$p<0.001$

*Error: SS = 11540; *df* = 147658; MS = 0.08

A comparison of group means is shown in the following graph:

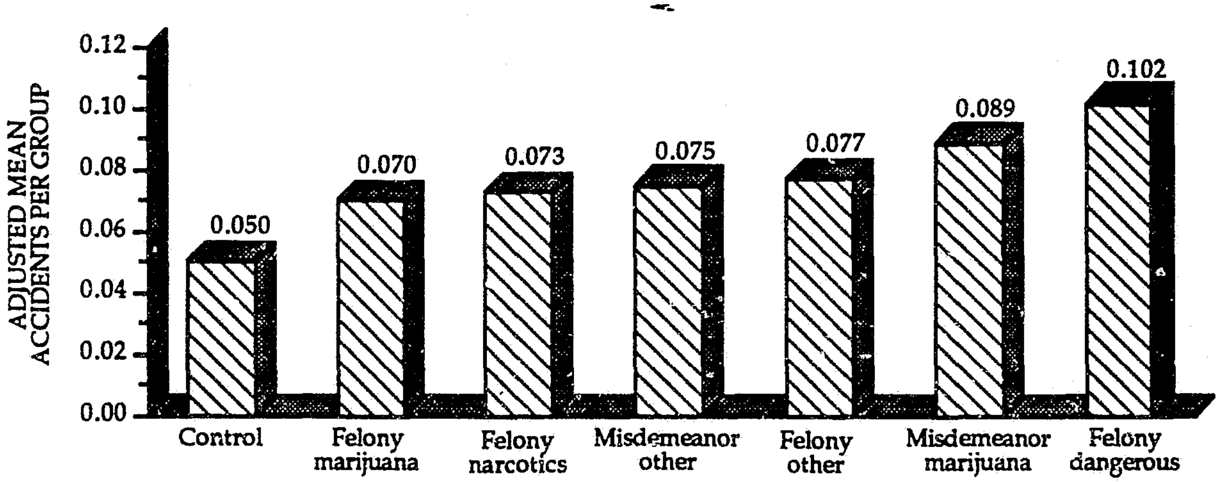

Figure 4. Adjusted group means, 1-year pre-arrest total accidents.

Newman-Keuls post hoc multiple comparisons showed the control group to have significantly fewer total accidents than each of the drug arrestee groups ($p<0.05$ for each comparison). This finding and the results of comparisons among the drug arrestee groups are as follows:

Group	Direction	Relative to ($p<0.05$)
Control	Less than	All drug arrestee groups
Felony marijuana	Less than	Misdemeanor marijuana & felony dangerous
Felony narcotics	Less than	Misdemeanor marijuana & felony dangerous
Misdemeanor other drugs	Less than	Misdemeanor marijuana & felony dangerous
Felony other drugs	Less than	Misdemeanor marijuana & felony dangerous
Misdemeanor marijuana	Less than	Felony dangerous

Again, we find that the felony dangerous drug group accumulated the worst record, with an accident rate over two times that of the controls.

Slope differences among groups for gender were significant ($p<0.001$). While males had higher accident rates than females in all groups, the differences varied, being greatest in the misdemeanor marijuana group and least in the felony other drug group.

Slope differences among groups for age were also significant ($p<0.001$). Younger drivers had a higher accident rate than older drivers in all groups, except the felony other drugs group in which older drivers had a higher accident rate.

<u>One-year post-arrest total accidents</u>. Zip code moving violation average did not vary significantly with one-year post-arrest accidents, so it was not used as a covariate for this analysis. However, the other five covariates were used. The model summary table showing highly significant differences among the group means is as follows:

Table 5

ANCOVA Summary Table for Total Accidents
During the Year After Arrest (Common Slopes Model)

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance level
Group	18.17	6	3.03	45.29	$p<0.001$
Covariates	33.07	6	5.51	82.55	$p<0.001$
Error	9870.60	147665	0.07		
Homogeneity of slope*	5.63	36	0.16	2.34	$p<0.001$

*Error: SS = 9856; df = 147658; MS = 0.07

A comparison of group means is shown in the following graph:

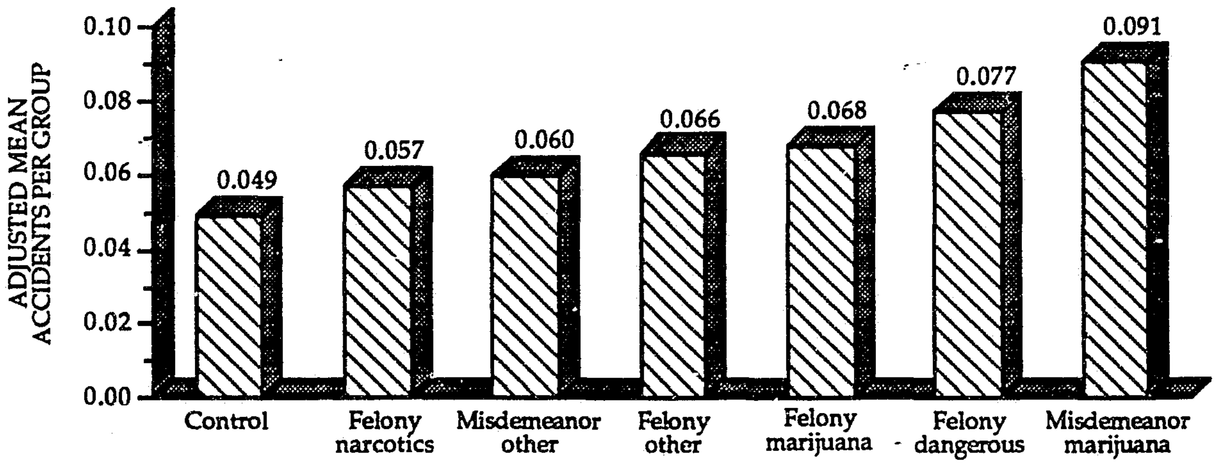

Figure 5. Adjusted group means, 1-year post-arrest total accidents.

Newman-Keuls post hoc multiple comparisons showed the control group to have significantly fewer total accidents than each of the drug arrestee groups ($p<0.05$ for each comparison). This finding and the results of comparisons among the drug arrestee groups are as follows:

Group	Direction	Relative to ($p<0.05$)
Control	Less than	All drug arrestee groups
Felony narcotics	Less than	Felony marijuana, felony dangerous & misdemeanor marijuana
Misdemeanor other drugs	Less than	Felony dangerous & misdemeanor marijuana
Felony other drugs	Less than	Felony dangerous & misdemeanor marijuana
Felony marijuana	Less than	Felony dangerous & misdemeanor marijuana
Felony dangerous drugs	Less than	Misdemeanor marijuana

In contrast to the previous comparisons, the felony dangerous drugs group is no longer the most extreme group. Instead, the misdemeanor marijuana group has significantly more entries (1-year post-arrest accidents) than all of the other groups, and a rate over twice that of the controls.

Again, slope differences among groups for gender were significant ($p<0.001$). While males had higher accident rates than females in all groups, the differences varied, again being greatest in the misdemeanor marijuana group and least in the felony other drug group.

Slope differences among groups for age were also significant ($p<0.001$). Again, younger drivers had a higher accident rate than older drivers in all groups, except the felony other drugs group in which older drivers had a higher accident rate.

Two-year post-arrest total accidents. Zip code moving violation average did not vary significantly with two-year post-arrest accidents, so it was not used as a covariate for this analysis. However, the other five covariates were used. The model summary table showing highly significant differences among the group means is as follows:

Table 6

ANCOVA Summary Table for Total Accidents
During the Two Years After Arrest (Common Slopes Model)

Source of variation	Sum of squares	Degrees of freedom	Mean square	*F*	Significance level
Group	44.85	6	7.47	58.35	$p<0.001$
Covariates	112.22	6	18.70	146.35	$p<0.001$
Error	18907.49	147665	0.13		
Homogeneity of slope*	13.98	36	0.39	3.04	$p<0.001$

*Error: SS = 18861; df = 147658; MS = 0.13

A comparison of group means is shown in the following graph:

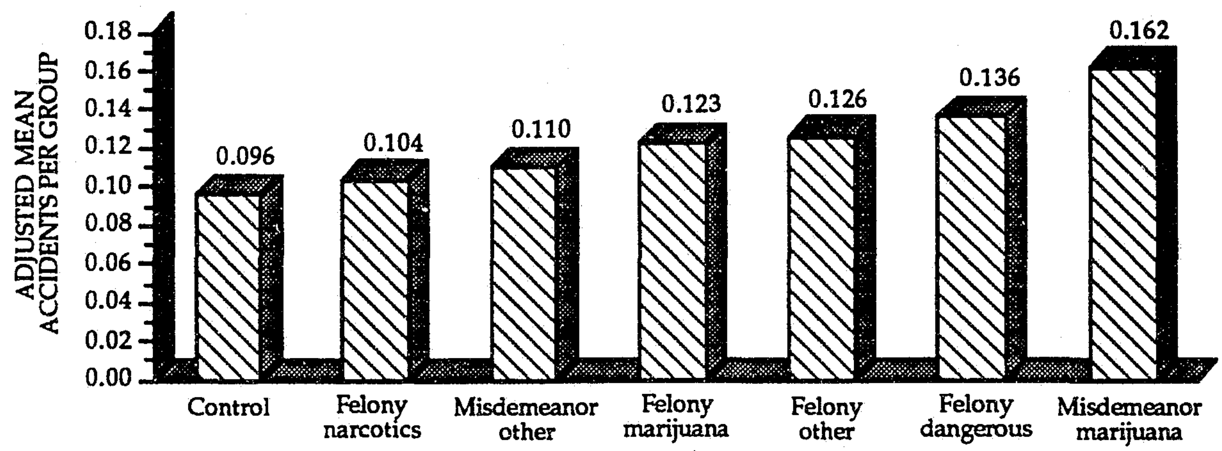

Figure 6. Adjusted group means, 2-year post-arrest total accidents.

Newman-Keuls post hoc multiple comparisons showed the control group to have significantly fewer total accidents than five of the drug arrestee groups ($p<0.05$ for each comparison). However, the control group total accident rate was not significantly different from the felony narcotics arrestee group. This finding and the results of comparisons among the drug arrestee groups are as follows:

Group	Direction	Relative to ($p<0.05$)
Control	Less than	Misdemeanor other, felony marijuana, felony other, felony dangerous & misdemeanor marijuana
Felony narcotics	Less than	Felony marijuana, felony other, felony dangerous & misdemeanor marijuana
Misdemeanor other drugs	Less than	Felony marijuana, felony other, felony dangerous & misdemeanor marijuana
Felony marijuana	Less than	Misdemeanor marijuana
Felony other drugs	Less than	Misdemeanor marijuana
Felony dangerous drugs	Less than	Misdemeanor marijuana

As with the preceding analysis of one-year post-arrest accidents, the misdemeanor marijuana group had significantly more accidents than all other groups—almost 1.7 times more than the controls.

Again, slope differences among groups for gender were significant ($p<0.001$). While males had higher accident rates than females in all groups, the differences varied, again being greatest in the misdemeanor marijuana group and least in the felony other drug group.

Slope differences among groups for age were also significant ($p<0.001$). For this time period, younger drivers had a higher accident rate than older drivers in all groups, with the difference being greatest for the misdemeanor marijuana group and the lowest for the felony other drugs group.

Between-Groups ANCOVAs for Each Post-Arrest Time Period, Adjusted for Pre-Arrest Differences in Addition to the Other Covariates

The preceding analyses did not adjust for prior driving record, using as covariates age, gender, and four zip code variables as shown earlier. Additional between-groups ANCOVAs for each post-arrest time period were run using the same covariates as above plus adjusting for pre-arrest differences between groups in the outcome measure (i.e., violations or accidents). These results were virtually identical to those reported above, indicating that adjusting for pre-arrest differences in outcome measures had little effect on the post-arrest values of the outcome measures beyond that accounted for by the other covariates.

Pre-Arrest/Post-Arrest Within Groups ANCOVAs

Total violations one year pre-arrest compared to one year post-arrest. All six covariates were used in this analysis. The main effects of group and time, and their interaction were all highly significant ($p<0.001$). The summary table is as follows:

Table 7

Within-Groups ANCOVA Summary Table for Total Violations for 1-Year Pre-Arrest Compared to 1-Year Post-Arrest (Common Slopes Model)

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance level
Group	16917.78	6	2819.63	1539.43	$p<0.001$
Time	3374.65	1	3374.65	3217.58	$p<0.001$
Group x time	1404.63	6	234.10	223.21	$p<0.001$
Covariates	17398.56	7	2485.51	2232.28	$p<0.001$
Error	309480.92	147658	2.10		
Homogeneity of slope*	462.31	42	11.01	9.91	$p<0.001$

*Error: SS = 163985; df = 147651; MS = 1.11

It will be recalled that the effect of primary interest is the group x time interaction since it represents the effect of the drug arrest convictions, including any incarceration, on subsequent driving record. The highly significant interaction which was found resulted largely from the drug arrestee groups having decreased conviction means, relative to their prior means, during the one-year post-arrest period, while the control group prior mean remained almost unchanged.

Total violations one year pre-arrest compared to two years post-arrest. Zip code moving violation average did not vary significantly with violations, so it was not used as a covariate. However, the five other covariates were used. The main effects of group and time were highly significant. Since the post-arrest time period was twice as long as the pre-arrest time period for this analysis, however, the significant effect of time is not surprising. The interaction between group and time was also highly significant. The summary table is as follows:

Table 8

Within-Groups ANCOVA Summary Table for Total Violations for 1-Year Pre-Arrest Compared to 2-Years Post-Arrest (Common Slopes Model)

Source of variation	Sum of squares	Degrees of freedom	Mean square	*F*	Significance level
Group	25574.15	6	4262.36	1535.39	$p<0.001$
Time	4962.43	1	4962.43	3182.90	$p<0.001$
Group x time	448.59	6	74.76	47.95	$p<0.001$
Covariates	46372.31	7	6624.61	2728.49	$p<0.001$
Error	459781.69	147658	3.11		
Homogeneity of slope*	1595.31	42	37.98	15.71	$p<0.001$

*Error: SS = 356994; *df* = 147651; MS = 2.42

The highly significant interaction occurred because the misdemeanor marijuana group had much more of an increase in total violations from the year prior to arrest to the two years after arrest than did the other drug arrestees groups, while the felony dangerous and felony narcotics groups had the lowest increases.

Total accidents one year pre-arrest compared to one year post-arrest. Zip code moving violation average did not vary significantly with accidents, so it was not used as a covariate. However, the other five covariates were used. The main effects of group and time, and their interaction, were all highly significant ($p<0.001$). The summary table is as follows:

Table 9

Within-Groups ANCOVA Summary Table for Total Accidents for 1-Year Pre-Arrest Compared to 1-Year Post-Arrest (Common Slopes Model)

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Significance level
Group	46.89	6	7.81	101.43	$p<0.001$
Time	7.75	1	7.75	113.78	$p<0.001$
Group x time	5.02	6	0.84	12.28	$p<0.001$
Covariates	70.74	7	10.11	151.93	$p<0.001$
Error	20114.45	147665	0.14		
Homogeneity of slope*	5.54	42	0.13	1.98	$p<0.001$

*Error: S S = 9818; df = 147651; MS = 0.07

Again, the effect of primary interest is the highly significant interaction between group and time. This was due to substantial accident decreases in the year after arrest for the felony dangerous drugs, felony other, felony narcotics and misdemeanor other groups, while the misdemeanor marijuana, felony marijuana and control groups showed little change.

Total accidents one year pre-arrest compared to two years post-arrest. Zip code moving violation average did not vary significantly with accidents, so it was not used as a covariate. However, the five other covariates were used. The main effects of group and time were highly significant, but, again, since the post-arrest time period was twice as long as the pre-arrest time period for this analysis, the significant effect of time is not surprising. The interaction between group and time was also highly significant. The summary table is as follows:

Table 10

Within-Groups ANCOVA Summary Table for Total Accidents for 1-Year Pre-Arrest Compared to 2-Years Post-Arrest (Common Slopes Model)

Source of variation	Sum of squares	Degrees of freedom	Mean square	*F*	Significance level
Group	69.53	6	11.59	105.68	$p<0.001$
Time	120.57	1	120.57	1246.44	$p<0.001$
Group x time	9.05	6	1.51	15.60	$p<0.001$
Covariates	190.86	7	27.26	214.24	$p<0.001$
Error	28566.98	147665	0.19		
Homogeneity of slope*	14.34	42	0.34	2.68	$p<0.001$

*Error: SS = 18782; *df* = 147651; MS = 0.13

The highly significant interaction occurred because the misdemeanor marijuana group had much more of an increase in total accidents from the year prior to arrest to the two years after arrest than the other groups, and the felony dangerous, felony narcotics and misdemeanor other groups had the lowest increases.

Between-Groups ANCOVAs for One-Year Pre-Arrest Single-Vehicle Accidents

Zip code moving violation and injury accident averages did not vary significantly with single-vehicle accidents, so they were not used as covariates. However, the four other covariates were used. The model summary table showing highly significant differences among the groups is as follows:

Table 11

ANCOVA Summary Table for Single-Vehicle Accidents During the Year Prior to Arrest (Common Slopes Model)

Source of variation	Sum of squares	Degrees of freedom	Mean square	*F*	Significance level
Group	1.75	6	0.29	36.44	$p<0.001$
Covariates	0.61	6	0.10	12.68	$p<0.001$
Error	1181.97	147696	0.008		
Homogeneity of slope*	0.47	36	0.01	1.62	$p<0.01$

*Error: SS = 1180; *df* = 147658; MS = 0.008

A comparison of group means is shown in the following graph:

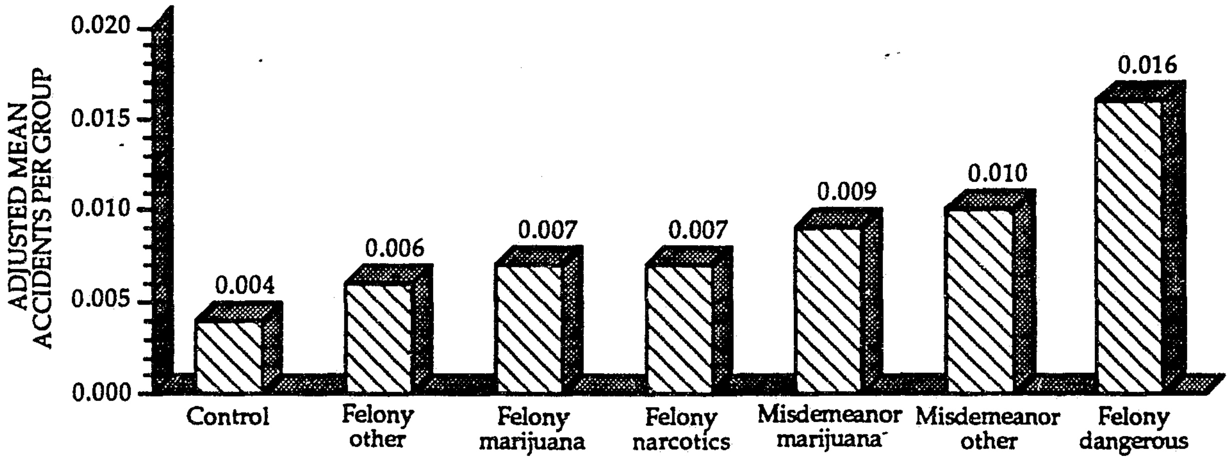

Figure 7. Adjusted group means, 1-year pre-arrest single-vehicle accidents.

Newman-Keuls post hoc multiple comparisons showed the control group to have significantly fewer single-vehicle accidents than the misdemeanor marijuana and other, and the felony dangerous drug arrestee groups ($p<0.05$ for each comparison). The difference between the control and both the felony marijuana and narcotics groups approached significance ($p<.10$ for each comparison)[6]. This finding and the results of comparisons among the drug arrestee groups are as follows:

Group	Direction	Relative to ($p<0.05$)
Control	Less than	Misdemeanor marijuana, misdemeanor other, & felony dangerous
Felony other	Less than	Misdemeanor other, & felony dangerous
Felony marijuana	Less than	Felony dangerous
Felony narcotics	Less than	Felony dangerous
Misdemeanor marijuana	Less than	Felony dangerous
Misdemeanor other	Less than	Felony dangerous

Like pre-arrest total accidents, the felony dangerous drugs group had the worst single-vehicle accident record. This group had single-vehicle accidents at a rate of 60% greater

[6]The non-significant difference between the control and felony other drug arrestee groups may reflect insufficient power to identify significance for this comparison as a consequence of the relatively small size of the felony other drug arrestee group (n = 1,769).

than the second worst drug arrestee group, and about four times as great as the controls.

As with total accidents for all time periods, slope differences among groups for gender were significant ($p<0.001$). Males had higher accident rates than females in all groups, except the felony other drug arrestee group.

Unlike total accidents, slope differences among groups for age were not significant. For single-vehicle accidents during the year prior to arrest, younger drivers had a slightly higher accident rate than older drivers in the felony other drugs, misdemeanor marijuana, misdemeanor other, and control groups. The other groups showed no age-related accident rate difference.

One-Year Pre-Arrest Accident Type and Outcome

The chi square tests which evaluated the presence of relationships between group and accident type and between group and accident outcome were based on the number of single-vehicle and multiple-vehicle accidents reported by law enforcement that involved subjects from all drug arrest groups and those involving controls. The data upon which the analysis of group and accident type was based are shown in the following matrix:

	Single-vehicle accidents	Multiple-vehicle accidents	All accidents total
Control group	159	1,150	1,309
Drug groups	1,007	5,001	6,008
All groups total	1,166	6,151	7,317

The chi square test showed that there was a significant relationship (chi sq = 17.18, df = 1, $p<0.001$) between group membership (drug arrestee vs. control) and type of accident (single-vehicle vs. multiple-vehicle). Drug arrestees who were involved in accidents had significantly more single-vehicle accidents than did controls who were involved in accidents.

The data upon which the analysis of group and accident outcome was based are shown in the following data matrix:

	Property-damage-only accidents	Fatal/injury accidents	Total accidents
Control group	1,289	594	1,883
Drug groups	5,307	3,234	8,541
All groups total	6,596	3,828	10,424

The chi square test indicated that there also was a significant relationship (chi sq = 26.51, *df* = 1, *p*<0.001) between group membership and accident severity (fatal/injury vs. property-damage-only). This finding showed that drug arrestees were involved in disproportionately more fatal and injury accidents, and in disproportionately fewer property-damage-only accidents, than were controls.

Investigating Officer's Determination of Accident Fault

The analysis of the investigating officer's determination of accident fault was based on a total of 7,230 accidents prior to arrest date (see Table 12) involving drug arrestees and controls in which fault for the accidents was determined by law enforcement personnel. Fault determinations for each group are as follows:

Group	Most At fault	Contributed	Not at fault	Total
Felony narcotics	1,374	55	642	2,071
Felony marijuana	195	8	97	300
Felony dangerous drugs	792	40	263	1,095
Felony other drugs	67	4	31	102
Misdemeanor marijuana	435	15	190	640
Misdemeanor other drugs	1,380	53	441	1,874
Control	613	33	502	1,148
Total	4,856	208	2,166	7,230

Zip code moving violation average did not vary significantly with pre-arrest accidents, so it was not used as a covariate in the ANCOVA. However, the five other covariates were used. The model summary table showing highly significant differences in accident fault, as reflected in the accident culpability index of each group, is as follows:

Table 12

ANCOVA Summary Table for Accident Fault During the Year Prior to Arrest (Common Slopes Model)

Source of variation	Sum of squares	Degrees of freedom	Mean square	*F*	Significance level
Group	122.79	6	20.46	25.15	$p<0.001$
Covariates	15.63	6	2.60	3.20	$p = 0.004$
Error	5833.59	7188	0.81		
Homogeneity of slope*	39.17	36	1.09	1.34	$p = 0.08$

*Error: SS = 5832; df = 7181; MS = 0.81

Accident fault determinations were each assigned a numerical score equal to the standard code number used for each by DMV (most at fault = 3, contributed = 4, and not at fault = 5). Thus, the higher the mean score (accident culpability index) for a group, the lower the culpability of that group in causing accidents. A comparison of group means is shown in the following graph:

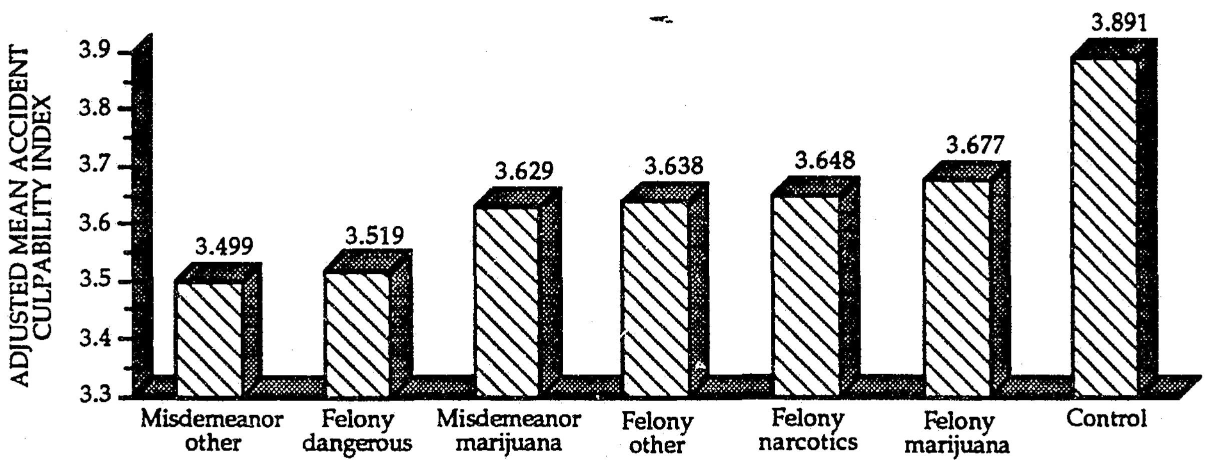

Figure 8. Adjusted group means, 1-year pre-arrest culpability index.

Newman-Keuls post hoc multiple comparisons showed the control group to have significantly less accident fault, as reflected in group accident culpability indices, than each of the drug arrestee groups ($p<0.05$ for each comparison). This finding and the results of comparisons among the drug arrestee groups are as follows:

Group	Direction	Relative to ($p<0.05$)
Control	Less than	All drug categories
Felony dangerous drugs	Same as	All other drug groups

All drug arrestee groups had accident culpability indexes that were statistically the same, and all were statistically different from the controls.

DISCUSSION AND CONCLUSIONS

Traffic Violations

Between groups. Total traffic violations were greater for all drug arrestee groups than for the control group for all time periods examined. Thus, individuals arrested for drug offenses of all kinds had, on average, more violations for driving offenses than did the general driving population. This was found for the year prior to arrest in 1989, and for the one- and two-year periods after arrest.

For each time period, the overall mean number of traffic violations for all drug arrestees, weighted by group size, was compared with the mean number of violations for the control group. The magnitude of these highly significant differences were as follows:

Time period	Arrestee groups mean violations	Control group mean violations
1 year prior to arrest	0.979	0.322
1 year after arrest	0.700	0.315
2 years after arrest	1.251	0.618

Drug arrestees committed 3.04 times as many traffic violations as the general driving population during the year prior to arrest, 2.22 times as many during the year after arrest, and 2.02 times as many during the two years after arrest. Since a substantial proportion of these drug arrestees were incarcerated (served time in jail, prison, and/or a residential rehabilitation center) during the one and two year periods following arrest (discussed in detail later), the statistically significant (group x period studied) decrease in the relative number of traffic violations committed during these time periods may reflect decreased driving exposure rather than a change in driving behavior. Conversely, even though a substantial proportion of drug arrestees were incarcerated during the post-arrest time periods, they still had significantly more traffic violations during these periods than did the general driving population.

When the mean number of violations for all drug arrestee groups for the entire three year period (1 year pre-arrest plus 2 years post-arrest) are combined, the drug arrestees averaged 2.240 violations compared to 0.940 for the controls. Thus, the drug arrestees committed 2.38 times as many traffic violations over this three year period as did the general driving population.

<u>Between groups, adjusted for pre-arrest differences.</u> After adjusting for pre-arrest total convictions, in addition to the six other covariate adjustments, all drug arrestee groups still had significantly more traffic violations than did the control group for both the one- and two-year periods after arrest. This additional adjustment decreased the omnibus *F* values for the main effect of group as well as the amount of the differences between drug arrestees and controls, as can be seen from comparisons of the weighted mean of all drug arrestee groups with the control group for each time period:

Time period	Arrestee groups mean violations	Control group mean violations
1 year after arrest	0.661	0.426
2 years after arrest	1.197	0.790

Adjusting for pre-arrest driving record, drug arrestees committed 1.55 times as many traffic violations as the general driving population during the year after arrest, and 1.52 times as many during the two years after arrest. These findings show that the effect of incarceration did not result in drug arrestees having the same violation rate as controls, even after pre-arrest violation rate was used as an additional covariate adjustment.

<u>Prior to arrest compared to after arrest</u>. The arrest of these drug offenders was associated with a decrease in the mean number of traffic violations in the year after arrest and in the two years after arrest, when compared to the general driving population. As stated above, the decrease in violations was possibly due to incarceration which lessened driving exposure. The general driving population had very similar annual mean numbers of traffic violations during all three years included in the study, as one would expect, while the drug arrestees had decreasing annual mean numbers, as shown below:

Time period	Arrestee groups mean violations	Control group mean violations
1 Year Prior to Arrest	0.979	0.322
1st Year After Arrest	0.700	0.315
2nd Year After Arrest	0.551	0.303

The decrease in annual number of traffic violations by drug arrestees indicates that the assumed incarceration of a substantial proportion of this group may have had a beneficial effect on traffic safety by removing from the road many members of a group having a higher than average number of traffic violations. The annual number of traffic violations decreased by 30% in the first year after arrest, relative to the year prior to arrest, and by a further 14% in the second year after arrest. The total beneficial effect on traffic safety was a 44% reduction in traffic convictions by drug arrestees within two years after arrest. Effects beyond the second year after arrest, if any, are beyond the scope of this study.

While statistical regression (regression toward the mean) cannot be discounted as a factor causing some of the decrease in violation rate in succeeding years, its effect is considered to be minimal because relatively few of the drug arrests were triggered by traffic violations. Since only a small fraction of drug arrests were associated with traffic violations, drug arrestees were not selected because of extreme driving behavior which can regress toward the mean in subsequent time periods. They were selected because of drug arrests.

Conclusions about traffic violations. Drug arrestees committed significantly more traffic violations than did the general driving population during the year prior to arrest and up to two years after arrest ($p<0.01$). The consequences of arrest, most probably incarceration, decreased the annual number of traffic violations by 30% in the first year after arrest and 44% during the two years after arrest, but commission of traffic violations by drug arrestees was still significantly greater than for the general driving population.

Traffic Accidents

Between groups. Total traffic accidents were greater for all drug arrestee groups than for the control group for both the year prior to arrest and the year after arrest. Examination of the two-year period after arrest showed that all drug arrestee groups, except the felony narcotics group, had significantly more accidents than the control group. The lack of a significant difference between felony narcotics arrestees and the general driving population in two-year total accidents probably reflects a high percentage of felony narcotics arrestees receiving prison sentences, which lessened their driving exposure to a greater degree than other arrestees.

For each time period, the weighted mean number of accidents of all the drug arrestee groups were compared to the mean number of accidents for the control group. The magnitude of these differences were as follows:

Time period	Arrestee groups mean accidents	Control group mean accidents
1 year prior to arrest	0.083	0.050
1 year after arrest	0.071	0.049
2 years after arrest	0.129	0.096

Drug arrestees were involved in 1.66 times as many traffic accidents as the general driving population during the year prior to arrest, 1.45 times as many during the year after arrest, and 1.34 times as many during the two years after arrest. As with traffic violations, the decreased driving exposure due to incarceration probably explains the decreased involvement in accidents by drug arrestees after arrest, relative to the general driving population. Again, the effect of statistical regression on the decreased accident rate would be expected to be minimal for the same reasons as stated above for violations.

Even with reduced driving exposure, all drug groups were involved in significantly more accidents than the general driving population during the year after arrest, and all drug arrestee groups except felony narcotics arrestees, who may have received the longest sentences, had significantly more accidents than the general driving population over the two-year post-arrest period.

When the mean number of accidents for all drug arrestee groups for the entire three year period (1 year pre-arrest plus 2 years post-arrest) are combined, the drug arrestees averaged 0.212 accidents compared to 0.146 for the controls. Thus, the drug arrestees were involved in 1.45 times as many traffic accidents over this three year period as was the general driving population.

Between groups, adjusted for pre-arrest differences. After additional covariate adjustment for pre-arrest total accidents, all drug arrestee groups, except felony narcotics arrestees, were involved in significantly more traffic accidents in the year after arrest than the control group. In the two years after arrest, all drug arrestee groups, except felony narcotics and misdemeanor other arrestees, were involved in significantly more traffic accidents than the control group.

These findings show that the effect of incarceration did not result in the members of most drug arrestee groups having the same accident rate as controls, even after pre-arrest accident rate was used as an additional covariate adjustment. The covariate adjustment for pre-arrest driving record, combined with the high rate of incarceration of felony narcotics arrestees, probably accounted for the lack of a significant difference in accident involvement between felony narcotics arrestees and the general driving population during both the one and two-year periods after arrest. The covariate adjustment for pre-arrest driving record may have accounted for the lack of a significant difference between the misdemeanor other arrestees group and the general driving population during the two years after arrest.

The additional adjustment for pre-arrest total accidents decreased the omnibus *F* value for the main effect of group as well as the apparent difference between drug arrestees and controls, as can be seen from comparisons of the weighted mean of all drug arrestee groups with the control group for each time period:

Time period	Arrestee groups mean accidents	Control group mean accidents
1 year after arrest	0.071	0.050
2 years after arrest	0.128	0.098

When pre-arrest total accidents are used to make an additional covariate adjustment, drug arrestees were involved in 1.42 times as many traffic accidents as the general driving population during the year after arrest, and 1.31 times as many during the two years after arrest.

<u>Prior to arrest compared to after arrest</u>. The arrest of drug offenders was associated with a decrease in their involvement in traffic accidents in the one- and two-year periods after arrest. Again, incarceration would be expected to lower driving exposure during the post-arrest periods, so the decreased involvement should not necessarily be ascribed to a change in driving behavior. Accident rates for each year were as follows:

Time period	Arrestee groups mean accidents	Control group mean accidents
1 year prior to arrest	0.083	0.050
1st year after arrest	0.071	0.049
2nd year after arrest	0.058	0.047

When considering the traffic safety impact of incarcerating drug arrestees, the annual number of accident involvements decreased by 14% in the first year after arrest, relative to the year prior to arrest, and by a further 16% in the second year after arrest. A beneficial effect on traffic safety was, therefore, a 30% reduction in the number of accident involvements by drug arrestees during the two years after arrest. Effects beyond the second year after arrest, if any, were not analyzed in this study.

Conclusions about traffic accidents. Drug arrestees were involved in significantly more traffic accidents than the general driving population during the year prior to arrest and up to two years after arrest (except felony narcotics arrestees for the 2-year post-arrest period). Incarceration following arrest resulted in decreased driving exposure which probably accounted for much of the 14% decrease in accident involvement by drug arrestees seen during the first year after arrest, and the 30% decrease seen during the two years after arrest.

Accident Culpability

Single-vehicle accidents. Single-vehicle accidents provide a more direct measure of accident responsibility, or culpability, than do total accidents because the subject is generally the only driver involved, and therefore is generally responsible for the single-vehicle accident.

A substantial proportion of drug arrestees were convicted and subsequently incarcerated, resulting in their reduced driving exposure during the years after arrest. Therefore, the year prior to arrest provides the best comparison of drug arrestees and the general driving population for single-vehicle, as well as total, accidents.

The combined drug arrestee groups were involved in significantly more single-vehicle accidents than the control group in the year prior to arrest. The weighted mean number of single-vehicle accidents for all drug arrestees (0.00947) was 2.47 times as great as the control group mean (0.00384). This difference was greater than the 1.70 difference for pre-arrest multiple-vehicle accidents (0.04708 vs. 0.02772).

Drivers who demonstrate a tendency toward greater single-vehicle accident risk relative to the general driving population should be considered to pose an elevated traffic safety risk. Since all drug arrestee groups, as a whole, exhibited this tendency, they pose an elevated traffic safety risk.

Accident type and outcome. Another way of evaluating single-vehicle accidents for drug arrestees and controls is to calculate the percentage of single- and multiple-vehicle accidents that are single-vehicle accidents. Thus, for all drug arrestees, 16.5% of single- and multiple-vehicle accidents were single-vehicle accidents, while, for the general driving population, 12.1% were single-vehicle accidents. When each drug arrestee group was evaluated separately, the following percentages of single-vehicle accidents among single- and multiple-vehicle accidents were found:

Group	Percentage single-vehicle among single- and multiple-vehicle accidents
Control	12.1%
Felony narcotics	14.1%
Felony marijuana	15.1%
Felony other drugs	10.4%
Felony dangerous drugs	21.3%
Misdemeanor other drugs	18.4%
Misdemeanor marijuana	14.8%

Felony dangerous drug arrestees had the highest percentage, while felony other drug arrestees had the lowest percentage.

Drug arrestees had proportionately more single-vehicle, relative to multiple-vehicle, accidents than did controls. Accident involvement is a rare event containing a large random component. However, the disproportionately large involvement of drug arrestees in accidents involving only one vehicle (relative to multiple-vehicle accidents) provides evidence that drug arrestees are more responsible for their accidents than is the general driving population. Because drug arrestees are arguably more likely to drive under the influence of drugs than is an average driver, drug impairment may play a causal role in some of the increased accident rate.

The relative over-involvement of drug arrestees in fatal and injury accidents also underscores the heightened traffic safety risk that they pose. When drug arrestees are involved in accidents, a disproportionately large number of fatalities and injuries occur. When the general driving population is involved in accidents, disproportionately more property-damage-only accidents occur. While property-damage-only accidents are not to be taken lightly, the threat to public safety posed by fatal and injury accidents is so great that the relative over-involvement of drug arrestees in these accidents enhances the conclusion that drug arrestees pose a heightened traffic safety risk.

Investigating officer's determination of fault. Accident culpability can also be directly measured by examination of investigating law enforcement officer's determination of fault on accident reports. As contrasted to single-vehicle accident rates, accident culpability index scores are measures of fault which are based on only those subjects from each group who were actually involved in accidents which were investigated and in which fault was assessed.

As measured by the officer's designation of fault index, each drug arrestee group had significantly greater accident culpability than did the control group. The weighted mean accident culpability index value for all drug arrestees was 3.596, which was significantly different than the control group value of 3.891 (where 3 = most at fault, 4 = contributed and 5 = not at fault, so a lower score means higher culpability). This difference indicated greater accident culpability for drug arrestees than for the general driving population.

Conclusions about culpability. Drug arrestees not only were involved in more accidents than the general driving population, but they caused or contributed to accidents in which they were involved to a greater extent than the general driving population. Drug arrestees, as a whole, had more involvement in single-vehicle accidents, had increased risk for single-vehicle accidents and for fatal/injury accidents, and were more at fault for the accidents in which they were involved.

These findings indicate that drug arrestees, as a whole, cause disproportionately more accidents than does the general driving population and, as a group, pose an elevated traffic safety risk.

Differences Among Drug Arrestee Groups

Traffic violations. The felony dangerous drug arrestee group had significantly more mean traffic violations in all time periods than all other drug arrestee groups (except for the misdemeanor marijuana group during the 2-year post-arrest period). Felony marijuana drug arrestees had the fewest mean number of traffic violations of all drug arrestee groups in all time periods; significantly fewer than all drug arrestee groups in the year prior to arrest, and significantly fewer than all drug arrestee groups except felony narcotics and other drug arrestees in both the one- and two-year post-arrest time periods.

Misdemeanor marijuana arrestees, those cited largely for simple possession of marijuana, had the second highest mean number of traffic violations of all drug arrestee groups in all time periods (tied with felony narcotics and misdemeanor other drug arrestees during year prior to arrest). Since many of these arrestees (those who possessed less than one gram of marijuana) were cited for an infraction which did not require that any jail time be served, this group of drug arrestees did not have their overall driving exposure lowered by incarceration to the extent that other drug arrestee groups did, which may help account for their elevated traffic violation rate, especially during the post-arrest time periods.

Total accidents. The felony dangerous drug arrestee group had a significantly higher accident rate than all other drug arrestee groups for the year prior to arrest, but only the second highest rate for both post-arrest periods. The misdemeanor marijuana arrestee group, which had the second highest accident rate for the year prior to arrest, had significantly higher accident rates than all other drug arrestee groups for both post-arrest periods. Again, these findings may be reflective of the varying frequency and duration of incarceration for these two groups.

The felony marijuana, felony narcotics, misdemeanor other drugs and felony other drugs groups had the lowest rate of traffic accident involvement in the year prior to arrest. In the year after arrest, the felony narcotics, misdemeanor other and felony other drug groups had the lowest rate of traffic accidents of all drug arrestee groups. During the two years after arrest, the felony narcotics and misdemeanor other groups had the lowest traffic accident rate.

Accident culpability. The greatest rate of single-vehicle accidents was found in the felony dangerous drugs, misdemeanor other drugs and misdemeanor marijuana groups, and the least in the felony other drugs group. For the investigating officer's determination of fault, all drug arrestee groups showed the same level of culpability.

These measures of culpability appear to be measuring similar and related, but not identical, phenomena. Given the randomness inherent in accident involvement, it is not surprising that measures of slightly different phenomena would give slightly different results. Overriding the different hierarchies obtained among drug arrestee categories by these measures is the finding that the control group had significantly fewer single-vehicle accidents than the combined drug arrestee groups, significantly lower single- to multiple-vehicle and fatal/injury to property-damage-only accidents, and significantly lower accident fault assessments by investigating officers than all drug arrestee groups.

Limited Driving Exposure Due to Incarceration

A substantial number of subjects in all drug arrestee groups were incarcerated during the post-arrest time periods analyzed in this study, and some of them were incarcerated during part of the pre-arrest year because their drug involvement did not necessarily begin with the event that resulted in the arrest used for this study. A very small and undetermined number of control subjects was likely incarcerated during all or parts of the pre-arrest and post-arrest time periods, as well.

The percentage of drug arrestees incarcerated during the pre-arrest period would be expected to have been somewhat higher than the percentage of the general driving population incarcerated during this period. During the post-arrest time periods, a high percentage of drug arrestees were incarcerated. Using DOJ Offender-Based Transactions Statistics for 1989 and 1990, the following incarceration rates were found for felony drug arrestees:

Felony drug arrest category	Percentage of arrestees incarcerated*
Narcotics	54.6%
Marijuana	52.9%
Dangerous drugs	54.3%
Other drug violations	50.5%
Weighted mean	54.3%

*Percentages are weighted means for dispositions received largely in 1989 and 1990, the years that almost all the 1989 arrestee cases would have been disposed. Data reported represent about 60% of the adult felony arrests reported by law enforcement.

It should be noted that the above data are for felony drug arrestees. Among the approximately 60% of these arrestees who were convicted, roughly 90% were incarcerated after conviction.

While no comparable data were available for misdemeanor drug arrestees, it does appear that the driving exposure of drug arrestees was probably slightly decreased from what it otherwise would have been during the year prior to arrest, and greatly decreased during the one- and two-year periods after arrest.

The decreased driving exposure, slight or great, for drug arrestees means that the number of traffic violations they committed, the total accidents they were involved in, and the single-vehicle accidents in which they were involved, were less than they otherwise would have been. This leads to the conclusion that the differences seen between drug arrestees and controls would have been even greater and more significant if driving exposure for the drug groups had not decreased following arrest.

Limitations Inherent in Quasi-Experimental Designs

Quasi-experimental studies, such as this one, generally allow considerable control over external threats to validity. Subjects select themselves into naturally formed groups, in this study as a result of their drug arrests, and are not, therefore, placed in groups that are, to them, artificial or forced in nature. In this study, subjects were accessible from the populations from which they were drawn. The dependent variables, such as traffic convictions, were well defined and well measured.

This study used drug arrestees as representative of all drug offenders. Drug offenders who were not arrested in 1989 were not included in this study. Since about 270,000 different individuals (unduplicated count) were arrested for drug offenses in California in 1989 (among an estimated 4.3 million individuals using drugs in California in 1989, Gfroerer & Brodsky, 1991), the drug arrestee total represents about 6.3% of all drug users in California in 1989. As stated previously, the subgroup of drug offenders who were arrested for drug violations may not be totally representative of all drug offenders due to ethnic, socioeconomic, or other differences. Thus, generalizing the results of this study to all drug offenders must be done cautiously, with the proviso that drug arrestees are useful, but not perfect, representatives of drug offenders in general.

Quasi-experimental studies are subject to threats to internal validity, especially the threat of inequality of groups. Self-selection of subjects could result in groups that differ on some factor(s) that is related to the dependent measure. Adjustments to the groups are made during analyses so that the effect of this factor(s) is statistically removed from the dependent measure and the effect of the factor of interest (drug or control group) can be analyzed. These adjustments were made by the covariates used in this study. A limitation is that the available covariates might not have provided enough adjustment to make the groups sufficiently similar for good analyses, and that there may have been other unknown covariates which could have provided better or greater adjustment.

The degree to which causality can be inferred in a quasi-experimental design depends on how well threats to internal validity were met. The relationship between the independent variable in this study, grouping subjects by drug arrest category and as controls, and the dependent variable, traffic violations or accidents, could be considered to have been a causal relationship only if other factors which influenced the dependent variable were largely or fully accounted for. Thus, in this study, causality could only be inferred to the extent that the covariates used in the study removed extraneous sources of variance and that there were no other factors which contributed significantly, or at least substantially, to the variance of the dependent variable.

Since data for a limited number of factors were available for the study, the relationship of many other independent variables (potential covariates) to the dependent variable could not be determined. While the covariates that were used in the study are known to contribute to the variance of the dependent variable, they do not completely obviate the threat to internal validity. Thus, it is not possible to state with certainty that there was a causal relationship between group membership and a dependent driving risk measure. There may have been one or more other factors (for example, either mental health or employment status) which affected both drug arrests and driving behavior.

The highly significant results obtained in this study should be interpreted as definitely indicating high positive correlational relationships between the independent and dependent variables, and probably indicating at least some degree of causal relationship, since the covariates used are known to have accounted for a substantial amount of the variance in the dependent variables. Findings on single-vehicle accidents, accident fault and other measures of accident culpability provide added evidence for the strength of these relationships.

None of the differences described were controlled for miles driven in the pre- or post-arrest periods, so we are not able to determine the extent to which different amounts of driving affect any of the measures. Further, the nature of arrest categories do not map very well with drug use or impairment categories, which creates a limitation in making inferences about how the pharmacological properties of the drugs affect impairment and driving related tasks. For example, felony narcotics arrestees could have been involved with heroin (a depressant) or cocaine (a stimulant), so measures of this group do not reflect the impairment caused by a single class of drugs. No statement about the traffic safety risk associated with a specific drug, except marijuana, can be made from this study.

Policy Implications

This study provides governmental decision makers with an objective, analytically derived evaluation of the relationship between drug offenses and traffic safety. Study findings clearly show that individuals arrested for drug violations represent an elevated traffic safety risk, and that there is a nexus between drugs and traffic safety. It should be noted, however, that this study used drug arrestees as subjects, while proposed legislation and the federal mandate stated in Public Law 101-516 deal with drug convictees (approximately 60% of felony drug arrestees and an unknown, but probably smaller, percentage of misdemeanor drug arrestees, are convicted). Yet, despite the incarceration of about 90% of felony drug convictees and a smaller, but unknown, percentage of misdemeanor drug convictees, these individuals demonstrated an elevated traffic safety risk level up to two years after arrest.

These findings provide a public safety justification for state and federal initiatives designed to institute driver licensing actions against drug offenders, and support for the implementation of Public Law 101-516 in California.

REFERENCES

Biasotti, A. A., Boland, P., Mallory, C. Peck, R., & Reeve, V. C. (1986). Marijauna and alcohol: A driver performance study. Sacramento, CA: California Department of Justice.

Bishop, Y. M. M., Fienberg, S. E., & Holland, P. W. (1975). Discrete multivariate analysis. Cambridge , MA: MIT Press.

Block, R. I., Farnham, S., Braverman, K., Noyes, R. Jr., & Ghoneim, M. M. (1990). Long-term marijuana use and subsequent effects on learning and cognitive functions related to school achievement: Preliminary study. In J. W. Spencer & J. J. Boren (Eds.), Residual effects of abused drugs on behavior (pp. 96-111). Rockville, MD: National Institute on Drug Abuse: Research Monograph 101.

BMDP Statistical Software, Inc. (1990). BMDP Statistical Software Manual, Volume 2. Berkeley, CA: BMDP.

Burns, M. (1993). Alcohol and drug effects on performance. In Alcohol and other drugs in transportation: Research needs for the next decade. Washington, DC: Transportation Research Board (Transportation Research Circular 408).

California Department of Justice. (1990). 1989 Offender-Based Transaction Statistics (OBTS): Data Information and Limitations. Sacramento, CA: Author.

California Department of Justice. (1991). 1990 Offender-Based Transaction Statistics (OBTS): Data Information and Limitations. Sacramento, CA: Author.

Caplan, Y., Levine, B., & Goldberger, R. (1989). Drugs in driver fatalities: A preliminary study in the state of Maryland. Presented at the 11th International Conference on Alcohol, Drugs, and Traffic Safety, Chicago, IL. (Cited in TRB. 1990. Special Report 229: Safety Research for a Changing Highway Environment. Washington, DC: National Research Council.)

Chester, G. B. (1989). Understanding the opioid analgesics and their effects on skills performance. Alcohol drugs and driving, 5, 111-138.

Compton, R. (1988). Use of controlled substances and highway safety: A report to congress (Report DOT-HS-807-261). Washington, DC: National Highway Traffic Safety Administration.

Cohen, J. (1988). Statistical power for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Cook, T. C. , & Campbell, D. T. (1979). Quasi-experimentation: Design & analysis issues for field settings. Boston, MA: Houghton Mifflin Company.

Crancer, A., Jr., & Quiring, D. L. (1968). Driving records of persons arrested for illegal drug use. Olympia, WA: Department of Motor Vehicles.

Department of Health and Human Services. (1991). National household survey on drug abuse: Main findings 1990. (DHHS Publication No. ADM 91-1788). Washington, DC: U. S. Government Printing Office.

Dott, A. B. (1972). Effect of marijuana on risk acceptance in a simulated passing task. Washington, DC: United States Department of Health, Education, and Welfare.

Gfroerer, J., & Brodsky, M (1991, March). Estimation of drug abuse prevalence in California using the national household survey on drug abuse. Paper presented at the annual meeting of the Sacramento Statistical Association, Sacramento, CA.

Hurst, P. M. (1987). Amphetamines and driving. Alcohol, Drugs, and Driving, 3(1), 13-17.

Janke, Mary K. (1990). Drugs and traffic safety: Is there a nexus? Sacramento, CA: California Department of Motor Vehicles.

Johnston, L. D., O'Malley, P. M., & Bachman, J. G. (1989). Drug use, drinking, and smoking: National survey results from high school, college and young adult populations (1975-1988). (DHHS Publication No. ADM 89-1638). Washington, DC: Superintendent of Documents., U.S. Government. Printing Office.

Keppel, G. (1982). Design & analysis: A researcher's handbook (2nd ed.). Englewood Cliffs, NJ: Prentice-Hall, Inc.

Lucke, R. E. (1992). Alcohol and other drug involvement in serious traffic crashes: Development of a research protocol. Transportation Research Circular, 397, 10-14. Washington, DC: Transportation Research Board.

Marowitz, L. (1991). Nomograms for power, sample size and effect size for statistical tests. Sacramento, CA: Department of Motor Vehicles.

McLinden, V. J. (1987). Experiences in relation to drugs/driving offences. Journal of Forensic Sciences Society, 27(2), 73-80.

Moskowitz, H. (1985). Marihuana and driving. Accident Analysis & Prevention, 17, 323-345.

Moskowitz, H., & Burns, M. (1989). Cocaine effects on performance. Unpublished manuscript.

Musty, R., & Perrine, M. W. (1989). Use of drugs and alcohol during driving in Vermont. Paper presented at the 11th International Conference on Alcohol, Drugs, and Traffic Safety, Chicago, IL. (Cited in TRB. 1990. Special Report 229: Safety Research for a Changing Highway Environment. National Research Council, Washington, DC.)

National Transportation Safety Board. (1990). Safety study: Fatigue, alcohol, other drugs, and medical factors in fatal-to-the-driver heavy truck crashes, Volume 1 (Report No. NTSB/SS-90/01). Washington, DC: Author.

Peck, R. C., & Kuan, J. (1982). A statistical model of individual accident risk prediction using driver record, territory and other biographical factors. Sacramento, CA: Department of Motor Vehicles.

Root, I. (1989). Illicit drugs of abuse in traffic fatalities. Paper presented at the 11th International Conference on Alcohol, Drugs, and Traffic Safety, Chicago, IL. (Cited in TRB. 1990. Special Report 229: Safety Research for a Changing Highway environment. National Research Council, Washington, DC.)

SAS Institute Inc. (1990). SAS/STAT User's Guide, Version 6, Volume 2 (4th ed.). Cary, NC: Author.

Siegel, R. K. (1982). Cocaine smoking. Journal of Psychoactive Drugs, 14, 307.

Siegel, R. K. (1987). Cocaine use and driving behavior. Alcohol, Drugs, and Driving, 3, 1-8.

Soderstrom, Carl A. (1991). Drug involvement among drivers admitted to a regional trauma center. Paper presented at the Transportation Research Board 70th Annual Meeting. Washington, DC.

Sutton, L. R. (1983). The effects of alcohol, marijuana and their combination on driving ability. J. Studies on Alcohol, 44, 438-445.

Sweedler, B. M. (1992). Drug presence in fatally injured truck drivers. Transportation research circular (No. 397). Washington, DC: Transportation Research Board, 6-9.

Terhune, K. W. (1982). The role of alcohol, marijuana, and other drugs in the accidents of injured drivers: Volume 1 -- Findings (Report No. DOT HS-806-199). Washington, DC: National Highway Traffic Safety Administration.

Tornos, J. (1990). The Presence of drugs in traffic. Linkoping, Sweden: Swedish Road and Traffic Institute.

Waller, J. A. (1965). Chronic medical conditions and traffic safety: Review of the California experience. New England J. Medicine, 273, 1413-1420.

Williams, A. F., Peat, M. A., Crouch, D. J., Wells, J. K., & Finkle, B. S. (1985). Drugs in fatally injured young male drivers. Public Health Reports, 100(1), 19-25.

Winer, B. J. (1971). Statistical principles in experimental design (2nd ed.). New York: McGraw-Hill Book Company.