APPENDIX D3
ALCOHOL AND DRUG EFFECTS ON PERFORMANCE

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BACKGROUND AND RATIONALE

A number of difficult questions underlie the topic of performance impairment by alcohol and drugs. This paper can address only some of the questions and will do so with a relatively broad brush. Laboratory research typically is an activity of refining, controlling, and reducing measurement. Engaged with that focus, we may lose, or risk losing, sight of the context within which the data from experiments have meaning and consequence. The task before us as conference attendees, however, is to identify and define as precisely as possible appropriate research objectives concerning alcohol and other drugs in transportation. By definition, the task requires a real-world view of the problem.

What do we presently know about the effects of alcohol and other drugs on performance? That first question calls for an evaluation of the sum of information which has been obtained over the years from laboratory study, epidemiology, accident investigations, and case reports. The evaluation can be expected to reveal the major gaps in the body of information.

The primary question can be answered only in light of the evaluation. That is, in the interest of transportation safety, what additional information is needed? There are at least two corollaries to this inquiry, one of which concerns the why of research objectives. [In a time of multiple societal problem and ever-shrinking budgets, the "why" associated with research need is essential to an inevitable prioritizing process.] "What" and "why" are, of course, inextricably bound together and will be the focus of conference discussion.

A second corollary concerns who needs additional information about alcohol and drug effects on performance. Because this issue to some extent sets the stage for conference discussions, it merits discussion at this point in time.

RESEARCH DIRECTIONS: WHO NEEDS IT?

Law Enforcement

Police officers, from patrolman to watch commander to chief, need information about the effects of alcohol and other drugs. The relevance to traffic enforcement is foremost and obvious, but the needs extend beyond traffic. Alcohol and drug problems currently impact virtually all areas of law enforcement and although some declines in drug use are evident, there is as yet no strong evidence that the contribution of drugs to crime will abate significantly within the decade.

Drug-related crimes cost American society about $20 billion dollars in 1983 (NIDA 1991). In 1988 approximately 75 percent of arrestees in a 14-city study tested positive for drugs (Wish et al. 1989). More than one-in-three women jailed in 1989 were accused or convicted of drug offenses (BJS 1992). The probability is high that individuals who are arrested for robberies, burglaries, assaults, vehicle thefts, forgeries, counterfeiting, and prostitution, as well as for traffic violations and crashes, and those whose business is the sale of drugs, will test positive for drugs. In other words, police officers frequently confront and arrest drug-impaired suspects.

They need to know how drugs influence suspects. If they are to remove impaired drivers from the roadway and if they are to protect arrestee and bystanders, as well as themselves, they need to know which substances impair and which lead to violent and unpredictable behavior. They need to be able to recognize the signs and symptoms that signal drug presence. Street lore abounds within law enforcement and often is on-the-mark, valuable information, but it also can be misleading and it is almost always incomplete. Currently, however, it may be the primary source of information for an officer who is outside the ranks of Narcotics or Drug Recognition.

The Criminal Justice System

The drug-influenced arrestee eventually makes his/her way through the criminal justice system where the relationship of drug impairment to crime might be expected to be a key element in disposition of the charges. Often it is not. The principal players in the system (defendant, prosecutors, defense counsel, judges, juries) frequently do not understand the nature of drug impairment, the relationship of drug influence to crime, or the degree of risk created by a specific substance. An observer can only wonder how often the lack of drug research results in miscarriage of justice.

The court may rely on the testimony of expert witnesses, among whom the level of expertise varies widely. In the best of circumstances, an expert will draw from scientific data to accurately enlighten the court. Obviously, however, testimony can be only as accurate and complete as available data.

Given the socioeconomic milieu of drug use, what sanctions are appropriate and effective for drug-related crimes? In California 25 percent of first-time DUI offenders re-offend with 5 years (Peck 1991). The prevention of recidivism is one of the most important goals of the criminal justice system (Ross 1991). Realistically, courts which lack drug-specific information on which to base sanctions are unlikely to achieve that goal.

The Workplace

During recent years, problems associated with impairment by drugs in the workplace have gained attention. The focus is appropriate and timely. Drug use is most prevalent among young adults ages 18-34 years, and that age group is a large segment of the working population. In 1988 nearly 17 percent of employed 18-to-25-year-olds had used marijuana within the last month, and 11 percent of 26-34 year olds had used it within the last year (NIDA 1991).

To date, the most common response by industry to the problem of drugs in the workplace has been a program of urine drug screening, which at best is a partial and controversial solution. Although a positive urine can reveal recent drug use and may serve a company's objectives at the pre-employment stage, it provides essentially no information about an individual's current performance and safety status. Managers, supervisors, and policymakers have considerably less need for information about an employee's drug-use history than for indicators of current impairment. They need data, methods, and programs to facilitate rapid, non-invasive evaluation in cases of suspected on-the-job impairment.

The transportation industry is particularly vulnerable to drug-use consequences which create risks that extend beyond the commercial vehicle operators. For example, in 1985 4500 people died in crashes involving tractor-trailers; only 17 percent of those fatalities were the drivers themselves (NHTSA 1985). Truck drivers are, of course, motivated by the economics of the industry to drive long, monotonous hours. The resulting fatigue and boredom may, in turn, motivate drug use. The drivers believe that at least 20 percent of their ranks drive under the influence, with marijuana, methamphetamine, or cocaine being the drugs-of-choice (Beilock 1989).

Truck drivers are a high risk group and their drug-related performance errors make headline news, as do those of airline cockpit crew, tanker captains, and railroad engineers. Because of those work environments, alcohol and drug use can have tragic consequences, but it is important to keep in mind the many less visible jobs which are also incompatible with drug use. Moreover, the impairment issue extends to drugs other than alcohol, marijuana, and stimulants. Prescription and OTC medications almost certainly play a role, albeit ill-defined, in workplace risks.

At any one time, half the adult population takes medications, which range from vitamins and hormones to maintenance therapeutic agents and acute-care preparations (Faich 1986). Although true workplace prevalence rates are unknown, these numbers strongly suggest that substantial numbers of employees go about their jobs under the therapeutic effects of medication. Whether and to what degree safety is compromised because the medications impair performance is also largely unknown.

Calling attention to a workplace drug problem that may be overlooked by non-medical personnel, deHart (1990) noted that environment and work demands can potentiate the adverse effects of a medication. He illustrates the potential with two examples: heavy physical work can generate hypoglycemic reaction in an otherwise well-controlled diabetic. A patient who is taking a beta blocker to control hypertension may experience heat exhaustion in conditions of relatively mild thermal loading.

Because of the high costs of drug development, new medications reach the marketplace when there is virtually no information about associated risks for performance. The development process, from discovery to market, typically extends over more than 10 years at average total costs of $100 million dollars (Tilson 1990). Although the process generates a great deal of data, little-to-none of it pertains to workplace safety. The kind of information, which the prescribing physician, patient, and responsible workplace parties need in order to make safety-consistent decisions, is typically not available until post-market experiences begin to accumulate.

Questions of workplace safety are complicated. There are potential but often unspecified, perhaps unrecognized, drug-disorder interactions. Decisions about the risks of a particular drug require that they be weighed against performance deficits associated with the disorder itself. For example, psychiatric distress can be impairing and as Potter (1990) points out, only the most severely affected men seek treatment (women are treated more often). Thus, employed men who are experiencing depression or manic-depressive illness are likely not to be treated. Potter believe the lack of treatment is a much greater problem for performance that the effects of drugs.

The individual who does seek treatment for psychiatric disorder may be prescribed an anxiolytic, antidepressant, antimanic, or antipanic drug, all of which

carry the potential for performance impairment, at least during the acute treatment phase. In a study with schizophrenic patients, Gerhard and Hobi (1987) found that performance impairment, which was measurable early in the course of treatment, abated as the patients reached a pharmacological steady state. Since there have been few studies over an extended period of treatment, however, the clinician typically prescribes treatment for his patient without data concerning chronic dose performance effects.

Evaluation of these issues of disorder and drug effects needs to take note of what may be an increase in the numbers of people for whom treatment with psychotropic drugs is indicated. Lifetime incidence of major psychiatric illness in the United States for individuals older than 60 years is lower than the incidence for ages 44-55 years (Robins et al. 1984). Although it is possible that the difference occurs because older people forget or deny such illness, it is also possible that the finding reflects a true cohort effect, demonstrating an increase in the prevalence of major psychiatric illness. Data from Canada showing higher suicide rates in younger populations appears to support the latter explanation (Gershon 1988).

Workplace issues are not limited to acute drug effects on performance but extend to drug seeking, chronic effects, and hangover/withdrawal effects. The problems are particularly acute in transportation-intensive industries but apply to other environments as well. The issues are enormously complex, and solutions which are both acceptable and effective remain elusive. Policies have undergone scrutiny and change in recent years, but significant progress in minimizing the adverse effects of drugs in the workplace awaits additional research.

Legislators and Regulatory Agencies

Reasoned and effective laws concerning alcohol and drugs require scientifically valid data about the effects of the substances. Also, the risks and costs associated with alcohol and other drugs is key information for the agencies which regulate their production and distribution. Either over- or understatement of risks due to a lack of research and a lack of data is a costly disservice to the public.

Citizens

Finally, parents, teachers, counsellors, youth leaders, and various other members of the community who serve as role models, sanction behaviors, and communicate norms need accurate information about drug effects. The Los Angeles Times recently reported that two local teenagers died from the use of inhalants. They were not delinquents or chronic drug users. Apparently, they were "good" kids from an intact, middle-class family, who decided as a lark to get high. They turned to the most available source of an intoxicant, their homes. Their deaths illustrate the tragic consequences of parental ignorance that the propellants in common household products are sufficient for intoxication and death. In this connection, drug experts at all levels might ponder their responsibility to communicate their findings to a wider audience and to do so in language which the nondrug expert can readily comprehend.

RESEARCH DIRECTIONS: WHAT DO WE KNOW ALREADY?

The Literature

A rather large, rather fragmentary literature documents the body of knowledge about alcohol and drugs. In large measure, the study of effects on performance has proceeded agency by agency, investigator by investigator in a reactive manner. As safety problems associated with the use of a substance have been recognized, research (typically lagging by some years) has accumulated around the substance and related issues. Proactive, systematic, and thorough study of a potentially impairing illicit drug or new therapeutic agent has not been the rule. Research has not been notably theory drive with an overriding, sustaining focus.

The literature encompasses several decades, several disciplines, many investigators, more than a single raison d'etre, and many kinds of substances. It reflects medical, psychological, human factors, and traffic safety inquiry, economic issues, and health and safety concerns. If the questions posed here are to be productively addressed, part of the task at hand is to impose order which will permit evaluation of that body of knowledge. For these purposes, a traditional review, even if restricted to the most important books, papers, reports, and other documents, seems not the best way to proceed. A review would not necessarily reflect a consensus concerning importance, but it certainly would exhaust both the writer's and the readers' pre-conference time. The unwieldy base of information must be wrestled into a format which will facilitate organized discussion of broad issues.

Data appear to have accumulated largely as a function of perceived severity of safety, economic and social problems surrounding the various substances. Problem-severity has also served loosely as a criterion variable in the organization of the following sections. The discussion is restricted to those substances perceived

to be the cause of the most severe problems as a result either of extent of use and/or degree of performance impairment.

To some extent, the criterion fails where severe drug problems are specific to a time and place. Methamphetamine, which in 1988 contributed to less than 2 percent of emergency room cases nationwide, accounted for 27 percent of emergency room cases in San Diego (DAWN 1989). The large number of "meth" labs in San Diego County create a major problem, but it is restricted in area and therefore does not generate significant study. The magnitude of the Hawaiian "ice" (smokable methamphetamine) problem in Hawaii has not been duplicated elsewhere. Phencyclidine (PCP), the drug found most frequently in impaired drivers in Los Angeles in 1985 (Compton 1986), now is relatively rare in L.A. but remains a drug-of-choice in Washington, D.C. Despite differences by locale, however, there appears to be sufficient continuity and commonality for severity to serve as an organizing variable.

The Substances

Alcohol

Alcohol ranks at the top of the list of impairing substances in terms of extent of use, problem severity, accomplished research, and what is known about effects on performance. Because of the relationship of blood alcohol concentration (BAC) to impairment and the technology of breath sampling, the issues are less difficult than for some other substances.

Alcohol-and-driving is perceived as a problem of sufficient magnitude to generate research. Traffic safety problems directly and indirectly have given rise to a large proportion of the accomplished research. Further, the traffic safety literature is a primary source of data about the broader topic of alcohol effects on performance.

In 1989 there were 45,555 traffic fatalities in 40,718 fatal crashes. Even though more than 22,000 of the 1989 drivers, bicyclists, and pedestrians had been drinking, the statistics reflect a decrease over time in the role of alcohol. The proportion of fatalities in which the BAC of at least one driver or nonoccupant was 0.10 percent or higher decreased by 15.3 percent from 1982 to 1989 (FARS 1989).

Data obtained in many controlled laboratory studies of alcohol with human subjects demonstrate and define impairment of skills important to safe performance. The deficits are both statistically significant and practically relevant. Note, however, that much of the laboratory research was conducted as single-dose studies with subjects dosed to mean blood alcohol concentrations (BACs) of 0.10 percent or higher.

It is evident from more recent experiments, which have examined lower alcohol levels, that impairment of important skills also occurs at low BACs (Moskowitz and Robinson 1988; Moskowitz, Burns, and Williams 1985). This conclusion, which stand at odds with studies from much earlier times and with statutory BAC limits in more recent times, can be credited in part to more precise measurements of safety-critical skills. It reflects both advances in technology and the measurement sophistication of a maturing area of study.

It now is clear that performance changes begin with departure from zero BAC. The exact point on an ascending BAC curve at which the changes become significantly impairing is, within broad limits, a function of task demands, individual skill, and individual tolerance to alcohol. As a central nervous system depressant, alcohol acts on the brain and essentially all performance is susceptible to impairment at some BAC. However, there are wide differences between drinkers and skills and the BACs at which significant impairment occurs.

Coordination, balance, simple sensory functions, and a variety of overlearned, highly practiced skills are relatively resistant to alcohol, and the BAC at which they are affected reflects the individual's tolerance to alcohol. An inexperienced drinker may sway, stumble, fall, slur speech, etc. at low to moderate BACs. On the other hand, a chronic and/or heavy drinker is likely to exhibit none of these signs of alcohol influence until very high BACs (> 0.20 percent). This failure by the tolerant drinker to display obvious signs of intoxication may mistakenly be interpreted as evidence that performance is unimpaired, a mistake which undoubtedly contributes to the intractability of problems with chronic drinkers.

Perceptual, information processing, and attention processes are highly sensitive to alcohol, and it is these which are particularly critical to safe performance. Furthermore, there is a kind of unfortunate double liability. The alcohol consumer can observe his/her own stumbling, falling, or difficulty carrying out everyday tasks. These deficits may or may not contribute to an accident, depending on the activity and the environment, but the drinker can recognize them and adjust his activities. In contrast, the most introspective of drinkers likely will be unaware of those alcohol-related failures which are most critical to safety (e.g., his/her own misperceptions, failures to attend, and slowed central processes).

These general conclusions are based on the findings of many studies. Citations have been omitted for the most part since a few arbitrarily chosen references would not adequately represent the breadth of the underlying research. Moskowitz and Robinson (1988) provide a recent, comprehensive reference list, with studies conveniently categorized by task/skill in the body of the document.

Marijuana

Although other substances are widely perceived as being more "dangerous," marijuana ranks just below alcohol on the basis of extent of use.

Marijuana remains the most commonly used illicit drug in the United States. A third of Americans—almost 66 million people—have tried it one or more times. Four million youth (12-17), 17 million young adults (18-25) and over 45 million adults age 26 and older have used marijuana.

In 1988, 5.9 percent (11.6 million) of the population age 12 and older were current marijuana users (that is, had used it in the past month). Of the 21.1 million people who had used marijuana in the previous year, almost one-third, or 6.6 million, used it once a week or more. (NIDA 1991)

A national survey of workers aged 19-27 years reported that rates of workplace marijuana use differ by occupation. The highest rate (17 percent) was reported for entertainment/recreation followed by 13 percent for construction, 11 percent for services, and 10 percent for manufacturing.

In a 1986 review of the epidemiology of road accidents involving marijuana, Simpson concluded that the "... literature relevant to marijuana and driving is fragmented and relatively sparse," (p. 28). He nonetheless states that the practice of driving after or during marijuana use is common among young adults. About one in six teenage drivers admits to driving after using marijuana. The difficulty of determining the contribution of marijuana to crashes is illustrated by his finding concerning the frequency of combining marijuana with alcohol. From a review of several major studies involving more than 2500 fatalities, he reports that when marijuana was present in the blood (7–10 percent of the fatally injured drivers), alcohol was also present about 80 percent of the time.

Lund et al. (1988) reported that cannabinoids were found in 15 percent of the blood or urine samples obtained from tractor-trailer drivers who participated voluntarily in a survey. However, what the relationship of their marijuana use and their driving skills might have been is not clear.

The issue of traffic risk is complicated by the fact that marijuana frequently is used with other drugs, and by the fact that it is not possible to relate the level of delta-9-tetrahydrocannabinol (THC) or its metabolite in body fluids to a degree of impairment. Although there is a correlation between plasma THC levels and effects when looking at group data, between-individual variation is great, and the predictive value of a single plasma level is very limited (Agurell and Hollister 1986).

The 1992 reports concerning marijuana are of the good news–bad news variety, which somewhat complicates the evaluation of what is known about its behavioral effects and risks to society. The downward trend in the number of users, as can be seen in the figure below, is a positive sign on numerous counts, including transportation concerns (Johnston et al. 1989).

Figures. Reports about the THC content of currently available marijuana falls on the negative side of the ledger. Marijuana is at least three times more potent than that available during the early 1970s. Growers have become increasingly sophisticated in the science of horticulture and can now produce material with high delta-9-THC content (El Sohly and Abel 1988).

There is evidence that users who smoke high potency marijuana do not titrate the amount obtained, as has been suggested, but actually do obtain more THC than if they were smoking less potent material. They do this even when their stated intent is to reach the same high (Perez-Reyes et al. 1982).

Given that THC content currently may be as high as 15 percent, it is highly questionable whether valid conclusions about its effects can be reached by extrapolation from laboratory experiments which used marijuana of 2 percent THC or less. There is no evidence to suggest that a linear function would adequately describe the drug effect curve.

There is considerable evidence that marijuana contributes to injuries and deaths, although with the interesting speculation that possibly it contributes less frequently to driving fatalities than to other kinds of fatal accidents. Maryland medical examiners found cannabinoids in 6 percent of victims from traffic crashes and in 10 percent of victims of other kinds of accidents (Isenschmid and Caplan 1988). In Los Angeles County coroner examinations, marijuana was detected in 19 percent of the samples (Budd et al. 1989).

Marijuana impairs a number of human skills. The effects of marijuana and alcohol, a common combination, are essentially additive although with distinct qualitative differences in the effects of the two substances. Since THC is not a CNS depressant, deficits are not attributable to a slowing of central processes, as with alcohol. They appear to be related to failures of attention and perception. The evidence suggests an intermittency of attention rather than, as with alcohol, generalized slowing and an inability to attend to multiple sources of information.

Laboratory study of marijuana is complicated by the interaction of the drug's effects with personality, situational, and social variables. Based largely on driving

simulator data, Smiley (1986) believes that marijuana impairs driving skills, but that drivers recognize their impairment and appropriately adjust their driving behavior to compensate. She also concedes that in emergency situations or where the task demands continuous attention, compensation is not possible.

As with alcohol, the large number of reports prohibits complete citations. A very limited, illustrative selection of marijuana-and-performance experiments includes work by Bird et al. (1980), Burns and Moskowitz (1981), Chesher et al. (1984, 1986), Casswell and Marks (1973), MacAvoy and Marks (1975), and Moskowitz (1985).

Cocaine

> If it goes well, I will write an essay on it (cocaine) and I expect it will win its place in therapeutics, by the side of morphium and superior to it. ...I take very small doses of it regularly against depression and against indigestion, and with the most brilliant success.
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> —Sigmund Freud (May 7, 1884)

> The melancholy vanishes, the eyes shine, the wan mouth smiles. Almost manly vigor returns, or seems to return. At least faith, hope and love throng very eagerly to the danger; all that was lost is found. ...To one the drug may bring liveliness, to another languor, to another creative force, to another tireless energy, to another glamor, and to yet another lust.
>
> —Crowley (1917)

Cocaine is a sympathomimetic local anesthetic, which has been used for thousands of years as a euphoriant and to combat fatigue. Freud's monograph, Uber Coca (1884) coincided with a period of considerable interest in the drug, which then was followed by a period of little attention from either the scientific or popular press. It re-emerged as a recreational drug-of-choice during the 1970s but until very recently, it has been widely viewed as safe and nonaddicting (Grinspoon and Bakalar 1980).

Cocaine use peaked in 1985-86. Currently, in the U.S. population age 12 and older, 11.3 percent have used cocaine at least once, 3.1 percent used it during the past year, and 0.8 percent used it during the past month. It is most popular among 18-34 year olds, and among users in that age range, 35-40 percent have used it more than 100 times (NIDA 1990).

Although cocaine is reputed to have many effects, only five appear reliably: local anesthesia, increased pupil size, increased heart rate, increased blood pressure, and mood elevation. If a police officers observes that an arrestee's pupil size and vital signs are increased and outside the normal range, that alerts him to possible stimulant influence. Although hyperactivity, agitation, and anxiety are frequently observed in the custodial setting, cocaine-related mood elevation or euphoria is not typically obvious in that setting. Strangely, moods also are not elevated, as measured with mood scales, at the dose levels and in the setting of laboratory studies (Burns 1991).

Heart rate and blood pressure changes possibly are related to cocaine fatalities. In the laboratory with subjects at rest, increases of 50 bpm and 20 mm Hg have been noted (Foltin et al. 1987, 1989). Since stress also increases heart rate and blood pressure, and since users take higher doses than those given to subjects, the cardiovascular effects together with the stress of physical exertion could explain some of the cocaine-related deaths of athletes. Also, because of the cardiovascular effects, the interaction of cocaine and the stress of high risk or emergency traffic events may be a dangerous combination.

Collecting cocaine blood level data, which could contribute to an understanding of its role in traffic crashes, is complicated by the enzymatic and spontaneous hydrolysis which results in rapid metabolization. The parent drug continues to metabolize in a blood sample unless the tube contains sufficient amounts of sodium fluoride or physostigmine (Jatlow 1988) or is frozen immediately. In illustration, blood samples obtained from drug-impaired drivers in a Los Angeles study were refrigerated but not frozen. Apparently, the preservatives were insufficient to stop degradation of the cocaine in the tube. The result was that the analysis found high levels of BE and only low or zero levels of cocaine (Compton 1986).

A Cocaine Bibliography (NIDA 1975) offered more than 100 pages of papers and books reporting anecdotal data, drug abuse trends, biochemical and pharmacological studies, and studies of addict populations. They did not address questions germane to skills performance. The consequences of cocaine use for traffic safety were considered only indirectly. That aspect of the literature has changed very little since 1975.

Williams et al. (1985) reported that cocaine was found in 11 percent, or 47, of the fatally injured young male drivers in California. It is important to note, however, that cocaine was the sole substance in only two drivers. Thirty-six had combined cocaine and alcohol, and seven had combined cocaine and some other drug.

Moskowitz and Burns (unpublished) carried out a laboratory study of the effects of 96 mg cocaine, with and without alcohol, with 16 healthy men, average age 24 years. Immediately after cocaine administration, performance on a battery of complex tasks was improved and the impairment from 0.05 percent BAC was almost completely counteracted. Enhanced performance persisted through a second test battery which began 2

hours post-dose.

Early data from the first experiment in a 2-year NIDA-funded study of cocaine essentially parallels the Moskowitz and Burns findings; that is, 96 mg cocaine enhances the performance of complex tasks by healthy male subjects (Burns 1991).

A more recently-completed experiment in the same project established laboratory times and usage as similar as possible to typical social conditions. Sessions were conducted at night and cocaine doses included 126 mg. Subjects "snorted" the cocaine as a series of three lines at 30 min intervals. They performed a battery of tests immediately after the last line, again near midnight, and again the following morning after sleeping overnight at the laboratory. Data analysis is in progress, and it appears that the findings are complex, reflecting differences by task and by test time. At this point, the only conclusion that can be offered with certainty is that the effects of cocaine are neither uniformly negative or positive.

Narcotic Analgesics

Although heroin use currently is receiving considerable attention, it is not because of performance issues but rather because of the HIV crisis. The practice of addicts gathering in shooting galleries to use drugs and share works is a common route of HIV infection. "Speed-balling," which is the combining of heroin and cocaine, is believed to be associated not only with HIV infection but also with bacterial endocarditis and hepatitis (NIDA 1991).

Household survey samples do not provide good heroin data since they exclude some of the populations among whom use is likely to be high (homeless, transient, imprisoned). The estimate that less than 1 percent of the population has ever used heroin is probably a significant underestimate (National Household Survey 1990). Using mathematical modeling, Brodsky (1985) estimated in 1982 that there were about 500,000 addicts in the U.S.

Whatever the actual size of the population, the lifestyle of active heroin addicts typically is incompatible with either employment or vehicle ownership. Thus, adverse effects on performance may not be a problem of great consequence. On the other hand, those addicted individuals who have entered methadone maintenance programs are able to be regularly employed and to be driving, and the effects of methadone on their performance is of considerable interest. In addition, the effects of codeine are pertinent, simply because it is so widely used as an analgesic.

The brief, following discussion is drawn largely from a recent, very capable review by Chesher (1989). The original document is highly recommended both as a source of information about narcotic analgesics and for references to the literature.

Narcotic analgesics are either (a) the naturally occurring opioids (morphine, codeine) (b) semi-synthetic opioids (heroin, hydromorphone, oxycodone, dextromethorphan), or (c) synthetic opioids (meperidine, fentanyl, methadone, pentazocine, meptazinol). The first two categories are derived from the opium poppy. The synthetics are laboratory products.

Effects in common for the three categories include the modulation of pain, pupil constriction, euphoric/dysphoric moods, respiratory depression, gastrointestinal effects (chronic constipation), and tolerance/dependence. Tolerance develops to all effects except pupil constriction and the gastrointestinal action.

Although opioids have both CNS stimulant and depressant effects, therapeutic doses in humans are characteristically depressant. Effects depend on (a) the drug, specifically, its potency and the receptors on which it acts (b) the route of administration and (c) the drug history of the user.

For obvious reasons, study of the effects of heroin and morphine on performance have been rare. Two experiments can be cited as illustrative (although in this writer's view both the ethics of heroin administration to "ex-addict" prisoners and the sensitivity of pursuit rotor as a performance measure are open to question). Fraser et al. (1963) administered heroin to prisoners in a lengthy, complicated study of addiction. The investigators' interpretation of pursuit rotor data was that chronic heroin does not affect psychomotor performance. Bauer and Pearson (1956) reported no effects of morphine on a pursuit test.

Since methadone maintained patients are more likely to be driving and working than active heroin addicts, the studies by Moskowitz and Robinson (1985) and Robinson and Moskowitz (1985), as well as earlier work by Gordon (1970) are more relevant to safety issues. In the Moskowitz and Robinson research, methadone-maintained patients performed tests of driving-related skills. Compared to matched controls, they showed impairment only on a test which measures the rate of information processing. The investigators concluded that methadone-maintained patients should not be considered impaired in terms of their ability to perform complex tasks such as driving.

Chesher (1989) concludes that it is not possible to determine the role of narcotic analgesics in crashes. Based on his review of the evidence, he asserts that the risk of these drugs does not approach that associated

with alcohol.

Prescription Drugs

Sedative, hypnotic, and anxiolytic drugs are prescribed to treat anxiety, insomnia, spasticity, convulsions, and alcohol withdrawal, as well as various other kinds of psychological and physical distress. These drugs offer the patient both potential benefits and possible adverse effects. Judged by the number of prescriptions and emergency room mentions, the benzodiazepines are perceived as being superior to barbiturate and non-barbiturate sedatives in terms of both benefit and liability. They currently are the most widely prescribed, and their trade names (e.g., Valium, Librium, Miltown) have become part of the average person's vocabulary.

In 1975, 90 percent of sedative, hypnotic, and anxiolytic prescriptions were for benzodiazepines. Since that time, the absolute numbers have declined, perhaps because the liabilities have received considerable publicity, including Congressional investigation, and physicians have begun to exercise more prescribing discretion. Still, 81 million prescriptions for benzodiazepines were filled in 1985 (FDA 1981, 1986). Diazepam (Valium) use declined, leaving alprazolam (Xanax) the most prescribed in 1988 (American Druggist 1989). Xanax has moved into a favored position with abusers, perhaps because it is more difficult to detect in blood or urine samples than is Valium.

In terms of safety issues, it is most important to note that most of these benzodiazepine prescriptions are not for hospitalized patients but for people who engage in their normal daily activities while taking the drugs. If the drugs do degrade performance, millions of people may be at increased risk as a direct result of their drug therapy.

A large number of laboratory and on-the-road studies, which were undertaken to examine the performance effects of the benzodiazepines, have reported that they cause significant impairment. Important as those findings are in terms of drug effect per se, their translation into real-world risk is less than straightforward.

Many experiments have examined a single therapeutic dose in comparison to placebo, possibly including a drug-plus-alcohol condition. Although the acute dose study provides important data, it is incomplete data. Patients rarely take a single therapeutic dose, and it is equally important to understand chronic dose effects. Do adverse effects diminish as blood levels reach steady state? Are blood levels of the drug's psychoactive metabolite increasing to a potentially impairing level?

The typical subject is a young, healthy adult, most often male, and as noted by Benjamin (1977), "If a normal healthy subject is given a psychoactive drug, it would be surprising if his performance were not impaired." Patients for whom the drugs actually are prescribed are more likely to be middle-aged and female. Since the medical and emotional problems which prompted them to seek treatment may also impair performance, it is difficult to assign risk specifically to the drug.

Drug studies, including studies of the psychotropics, too often fail on two crucial counts: 1) The laboratory tests, which are used in an experiment and which are degraded by the drug, have neither theoretical nor demonstrated practical significance for safe driving or performance of other complex tasks, and 2) statistically significant performance changes are reported, but the magnitude of the change is small and may or may not make a practical difference in a real-world task.

It is clear from national surveys that anxiolytics/sedatives are used for other than medical reasons. Emergency room overdose cases often involve their combination with alcohol (NIDA 1991). In the illicit drug culture they are used by polydrug abusers, and extraordinarily high blood levels have been found. Although there is a lack of correspondence between plasma concentrations and performance, it seems reasonable to assume that the driver whose blood sample contained 2478 ng/ml diazepam or 3873 ng/ml chlordiazepoxide was "under the influence." Those levels were reported from the analysis of blood samples obtained from suspected drug-impaired drivers in Los Angeles (Burns 1985).

Published papers concerning the effects of therapeutic drugs are too numerous to cite here. The proceedings of the Second International Symposium on Medicinal Drugs and Driving Performance (1987, Maastricht, The Netherlands) and the "Medication-Induced Performance Decrements" issue of the *Journal of Occupational Medicine* (Vol 32, No 4, 1990) address the issues of prescription and OTC drugs and are valuable sources of information and references.

CONCLUSIONS–DISCUSSION: THE NEEDED RESEARCH

Alcohol

Although alcohol study exceeds the study of any other substance, gaps in the knowledge base remain. The following topics require further study in relation to performance:

- Tolerance;

- Low BACs;
- Inexperienced, infrequent drinkers;
- Chronic, heavy drinkers;
- Alcohol-drug combinations;
- Hangover effects;
- Alcohol–aging interaction; and
- Alcohol effects in the young driver.

The effects of many alcohol-drug combinations and alcohol-other variable interactions remain inadequately specified. It is not feasible to examine all doses, all combinations, and all interactions, but examination of basic, safety-critical skills should be systematically extended over a range of doses. Combinations would be examined over a range of both alcohol doses and doses from the several drug categories, which have the greatest potential for impairment. Systematic, as contrasted with scattered and incomplete, examination of key interacting variables (e.g., fatigue, circadian effects, sleep loss, age, health) should be undertaken.

Marijuana

The 22nd Annual Report of the California Research Advisory Panel shows no active studies by California investigators of the effects of marijuana on performance. The state of research inactivity is strangely at odds with the continuing popularity of the drug. There is need for additional research, including the following:

- Examination of the effects of high THC content marijuana,
- Study of the duration of marijuana effects,
- Examination of the effects on driving skills of high THC marijuana in combination with alcohol and other popular drug combinations,
- Marijuana effects on young (adolescent) drivers, and
- Further study of the relationship of blood/urine levels to performance effects.

Hangover effects require further examination. There is some evidence that behavioral and subjective effects may persist for at least 9 hours (Chait et al. 1985). A report by Yesavage et al. (1985) that marijuana affects the complex skill aspects of pilot performance 24 hours after smoking generated considerable interest and controversy, but to date no replication has appeared in the literature.

Since marijuana remains a drug of choice for many teenagers, and since the introduction to marijuana coincides with the acquisition of driving skills, it is a matter of considerable urgency to understand how marijuana effects, beginning driver skills, and the recklessness of immaturity interact. Admittedly, the study of alcohol and drugs with underage subjects is a difficult task, but one that could be addressed with innovative methods for gathering data.

Cocaine

Cocaine effects on performance are not well understood. The task of first priority is to define the what and how of measurement. It appears that laboratory methods which served well for depressants, for example, do not measure the stimulant effects of interest.

A common observation is that cocaine-influenced individuals become aggressive, risk-taking drivers. Although difficult to operationalize in the laboratory, risk taking, aggression and judgment need to be measured in order to understand cocaine effects on performance. Within the constraints of laboratory ethics, research needs to examine not only the arousal and improved performance of low doses but the extent to which the user becomes overstimulated as blood levels increase.

If cocaine-related decrements can be demonstrated, then there will be a further need to attempt to specify the associated blood and urine levels. Although the attempt may fail, the effort must be made because of the potential importance of knowing the relationship between cocaine dose level, blood and urine levels of both cocaine and benzoylecognine, and the performance decrements. At the present time, fluid levels confirm recent use but provide almost no other useful information.

It may be found that cocaine alone at typical use levels does not produce significant performance deficits and that risk escalates only when it is used in combination with alcohol and other drugs. The combination of cocaine and alcohol is frequently observed in arrestees. Users explain that alcohol, diazepam, or some other depressant is used to "take the rough edges off the cocaine high."

A speedball, a dangerous combination of heroin and cocaine, is also frequently found among arrestees. Differences in duration of effects (heroin 4 hours, cocaine 90 mins) and differences in action (narcotic vs. stimulant) sometimes lead to inadvertent overdose. A user who repeatedly re-injects as the effects of cocaine dissipate, eventually accumulates multiple doses, and potentially fatal levels, of the longer-acting heroin.

Narcotic Analgesics

There is no urgent need for additional research with the narcotic analgesics.

Prescription Drugs

Defining research needs for medications is perhaps the most complex of the topics at hand. Issues of personal need and choice vs. heavy-handed regulation vs. unacceptable social costs and consequences will not be easily resolved.

Millions of people use drugs non-medically for relief of pain (whatever its nature) and for pleasure (however esoterically defined). The numbers and diversity of drugs, dosages, and combinations renders futile an attempt to estimate the potential for personal harm and social cost. Nor can research examine all questions and provide all answers concerning safety issues.

Given the numbers of potentially impairing drugs together with the new compounds that will be marketed, there is no obvious research agenda. The following are offered as a guidelines for whatever research objectives may be defined:

- Examine the effects of a prescription or OTC medication systematically, including:
  - Acute dose studies with healthy volunteers to specify drug effects per se,
  - Acute and chronic dose studies with patients to clarify the net effect of drug-disorder interactions, and
  - Examine dosing regimens that represent typical therapeutic use.

MISCELLANY

The body of knowledge in 1992 about alcohol and drug effects on performance varies by substance from extensive and/or adequate to scattered and incomplete. In many areas, it has grown sporadically without design in response to a mixed bag of "needs to know."

The topic is complicated by numbers and diversity of substances and users, and by its dynamic character in the face of continually changing availability and personal choice. A consensus recommendation for research will not be easily reached. Perhaps the objective should be a direction and a strategy to facilitate more systematic research.

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APPENDIX D4
IMPAIRED DRIVING DETECTION AND ENFORCEMENT

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Enforcement of impaired driving laws is conducted by police officers who are members of municipal departments, state police agencies, highway patrols, sheriff's department and a variety of other police agencies. Collectively, these agencies have more than 500,000 sworn personnel and make approximately 1.8 million arrests each year for "driving under the influence" (FBI Uniform Crime Reporting estimates). Arrest rates have been relatively stable at this level during the 1985-90 period.

Many of these arrests are being made by officers assigned to police entities whose primary mission is traffic. The officers may be part of the highway patrol, other state police agencies dedicated to traffic, the traffic division of a municipal or county level department or a dedicated DWI Patrol. Such officers comprise only a portion of the total complement of sworn personnel. Regular or precinct patrol officers may or may not be conducting impaired driving enforcement depending on their training, their department's emphasis on impaired driving enforcement and the demands placed upon them for other types of police services.

The purpose of the present paper is to provide a framework for the discussion of research and development activities that may assist these officers in their efforts to enforce impaired driving laws. The paper provides a brief history of impaired driving enforcement, followed by current issues and suggested research topics. The reader is cautioned that a complete discussion of these issues would require several volumes and thus the present paper is only an overview as seen from the authors' perspective.

Throughout this paper, the term DWI encompasses driving while intoxicated; driving under the influence; operating while intoxicated; operating under the influence; and similar. It should be noted that this general use of the term DWI obscures important distinctions between each charge as defined uniquely in the laws of each state. The term DWID is used to