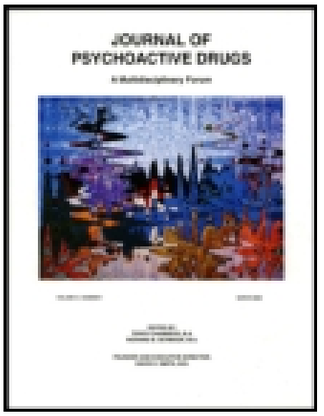

Journal of Psychoactive Drugs
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ujpd20

Marijuana, Driving, and Accident Safety

Dale H. Gieringer [a]

[a] Decisions and Ethics Center, Department of Engineering-Economic Systems , Stanford University , 130 Wilding Lane, Oakland , California , 94618

Published online: 02 Aug 2012.

To cite this article: Dale H. Gieringer (1988) Marijuana, Driving, and Accident Safety, Journal of Psychoactive Drugs, 20:1, 93-102, DOI: 10.1080/02791072.1988.10524377

To link to this article: http://dx.doi.org/10.1080/02791072.1988.10524377

Marijuana, Driving, and Accident Safety

DALE H. GIERINGER*

Public safety concerns about drug abuse have made urine testing for marijuana increasingly popular. In a recent survey, nearly half of the major companies surveyed reported using preemployment drug tests (Unsigned 1987), and random drug testing programs have been implemented in the armed forces and other safety- and security-sensitive jobs. Concern about drug abuse has been especially acute in the transportation industry, where accidents directly involve public safety. The threat was dramatized by the highly publicized collision of a Conrail freight train into an Amtrak passenger train on January 4, 1987, in which 16 persons were killed and 175 injured. When subsequent drug tests revealed traces of marijuana in the blood of the engineer and brakeman of the Conrail train, the Senate Commerce Committee voted 19 to one for legislation to require random drug testing of the nation's three million transportation workers. Suspicions of drug use by the Conrail crewmen were later confirmed by admission (Fram 1988).

Drug testing (and random urinalysis in particular) poses acute privacy issues in the case of marijuana because it is highly sensitive to past use, as opposed to current impairment. Because nonpsychoactive cannabinoid metabolites can reside in urine at high concentrations for several days, urinalysis is useless for discriminating present impairment. Urine tests can detect marijuana four to 10 days after a single use, and up to five weeks in chronic users; low positive readings have been noted in passive smokers (Mason & McBay 1985). Random urinalysis thus effectively precludes even the most casual weekend use of marijuana. In contrast, for other illicit drugs (such as cocaine and opiates), drug tests typically register positive for two to three days after use, while alcohol breathalyzers and blood tests only register positive when one is actually under the influence.

Blood tests provide a somewhat better, though still unsatisfactory, indication of marijuana use. Blood levels of the psychoactive ingredient Δ^9-tetrahydrocannabinol (THC) peak during smoking and then decay quickly. There is no clear correlation between THC blood levels and actual impairment: Blood levels of 0.5 to 2.5 ng/ml (1.0 to 5.0 ng/ml in plasma) have been observed 12 hours or more after smoking, and also within only 30 to 90 minutes (McBay 1985b; Reeve et al. 1983). THC tends to persist in the blood of chronic smokers and has been observed at levels of 1.0 to 4.0 ng/ml after 48 hours. The nonpsychoactive metabolite carboxy-THC decays more slowly than THC and can be detected in blood for several hours or days (McBay 1985a, 1985b). In practice, blood tests are too physically intrusive for routine use in random or preemployment testing programs, so employers commonly rely on urinalysis.

Against the extraordinary imposition on personal privacy posed by marijuana testing, it is necessary to weigh the potential safety benefits. A review of the literature indicates considerable differences of opinion on the actual accident hazards posed by marijuana. This reflects a scarcity of valid statistical data on the involvement of marijuana accidents as well as differences in interpretation of

*Decisions and Ethics Center, Department of Engineering-Economic Systems, Stanford University, 130 Wilding Lane, Oakland, California 94618.

existing evidence. It is therefore worthwhile to review the literature on marijuana and accident safety.

The following analysis will focus on studies of traffic and transportation safety, which are by far the leading source of statistics in the area. These consist of (a) laboratory studies of marijuana impairment, (b) reports of marijuana involvement in accidents, and (c) epidemiological data based on blood and urine tests of automobile accident victims. A summary of the major findings in each area is presented here.

LABORATORY STUDIES OF MARIJUANA IMPAIRMENT

Potentially deleterious effects of marijuana on driving skills have been found in laboratory tests of perceptual and psychomotor skills, driving-simulator studies and road-performance tests. The significance of these effects is a matter of debate, inasmuch as their relevance to actual road safety is in many cases unclear and the evidence for impairment has been equivocal in several cases. The following effects have been prominently mentioned in recent surveys of the literature (Chesher 1986; Smiley 1986; Moskowitz 1985).

Psychomotor Skills

Studies have found that marijuana degrades attentiveness, short-term memory, tracking, and coordination, especially where complex tasks are involved. Simple reaction time does not appear to be adversely affected, but response to complex and unforeseen situations is degraded.

Impact on Driving

Several driving-simulator and on-road studies have detected adverse effects on lane position variability, emergency response, performance of subsidiary tasks, and other indicators of car control. In general, adverse effects seem clearer at higher doses, although not all studies have detected them (Sutton 1983). One commonly reported finding is that marijuana produces a significant decrease in speeding and risk-taking behavior. A common interpretation of this is that marijuana users reduce their speed to compensate for their impairment. In this regard, marijuana is sharply contrasted with alcohol, which consistently increases speed and risk-taking behavior (Smiley 1986).

Tolerance

There is evidence that experience can mitigate some of the adverse effects of marijuana in practiced users (Peck et al. 1986; Mason & McBay 1984). Improvements in performance have been noted in some drivers (Klonoff 1974). Some marijuana enthusiasts say that the drug improves their driving by making them more relaxed or "in the groove." However, subjective reports of this kind are notoriously unreliable and may indicate an overconfidence that is both unwarranted and dangerous.

Alcohol and Marijuana

Studies of marijuana and alcohol in combination have generally found that their effects are additive, and that their combination is worse than either alone (Chesher 1986; Peck et al. 1986; Sutton 1983). However, there is some evidence that at low doses of marijuana, the combined effects of alcohol and marijuana may be antagonistic. For instance, marijuana may counteract the tendency of alcohol to make drivers go faster. Comparative studies of alcohol and marijuana in driving appear to support Chesher's conclusion that "at the dose levels used in the studies completed to date, alcohol appears to produce the greater impairment."

Duration of Effects

The effects of marijuana are greatest immediately after smoking (unlike alcohol) and decline slowly over a period of hours. In one study (Reeve et al. 1983), 60 percent of subjects failed a police field-sobriety test two and a half hours after smoking ad lib doses of marijuana, even though the THC plasma content of some had declined to negligible levels. Barnett, Licko and Thompson (1985) found evidence of adverse effects persisting four to seven hours after smoking. Evidence for impairment after four hours is equivocal: One driving study (Smiley 1986) found evidence of impairment six hours after ingestion of THC; four other studies failed to find any effects three to eight hours afterward. Intriguing evidence of a 24-hour hangover effect of marijuana on flying skills was found in a flight-simulator experiment by Yesavage and colleagues (1985). Similar subtle hangover effects have been observed for alcohol (Yesavage & Leirer 1986).

Studies of marijuana impairment invite differing interpretations. On the one hand, Moskowitz (1985) wrote, "Clearly, marijuana is a substance which produces serious behavioral toxicological effects. Any situation in which safety both for self and others depends upon alertness and capability of control of man-machine interaction precludes the use of marijuana." On the other hand, Peck and colleagues (1986) concluded the following:

> Several investigators have reported that marijuana reduces risk-taking propensity and driving speed. Because of these compensating tendencies, it is presently not possible to assess the *net impact* of marijuana as a causal agent in traffic accidents. Although some increased risk appears likely, the magnitude of the risk remains obscure. . . .
>
> Many of the laboratory marijuana studies which have shown the greatest psychomotor impairment have utilized tasks that are only abstractly related to

driving. . . . it does not necessarily follow that performance on a highly novel and complex laboratory task designed to magnify performance decrements is correlated with actual "real world" performance in a vehicle. The fact that attempts to measure response to simulated accident situations have not consistently detected a marijuana-induced decrement, even at high dose levels, underscores the need for much research.

ANECDOTAL REPORTS OF ACCIDENTS

Despite the rising popularity of drug testing, there is little hard evidence on the extent of marijuana involvement in accidents in the transportation industry. In aviation, there have been anecdotal reports of marijuana use by pilots and other airline personnel, and marijuana has been linked to a couple of private plane crashes (Jones & Lovinger 1985). However, no scheduled commercial airline accident has been attributed to alcohol or other drug abuse (Stone 1987). Marijuana has been cited as the possible cause of the 1983 fatal crash of a Central Air transport plane. However, the evidence for impairment has been disputed because the pilot may have used marijuana 24 hours or more prior to the accident (McBay 1986; Yesavage et al. 1985).

Drug use has been more of an issue among railway workers. In 1985, the Federal Railroad Administration (FRA) found that 30 percent of prospective employees were positive for marijuana in preemployment urine tests, and 23 percent of the railroad personnel were problem drinkers. The FRA cited 77 train accidents to show the need for antidrug rules. Alcohol was mentioned as the sole cause in 73 accidents, while marijuana was mentioned twice, with one of these being in combination with alcohol and methamphetamine (McBay 1986).

Most recently, the 1987 Conrail-Amtrak collision noted above has figured prominently in the political debate over drug testing. While urine tests showed that the Conrail engineer and brakeman had definitely used marijuana (plus phencylcidine, PCP, in the case of the brakeman) in the past, blood tests taken some hours after the accident provided only ambiguous evidence for impairment, showing at most traces of THC at levels below the lowest reading of the gas chromatograph-mass spectrometer; around 2.5 ng/ml in blood (Federal Railroad Administration 1987). The accuracy of the tests was called into further question by the fact that one of the laboratories performing them had a history of incompetent and dishonest work, and the samples were squandered so that it was impossible to perform backup tests (Bogdanich 1987). The most that could be determined from these data was that the crew had probably smoked marijuana in the past 12 to 24 hours before the accident. Only later when the crewmen confessed to smoking before the accident did it become clear that they were actually under the influence of marijuana at the time. Nevertheless, it was on the basis of the test results, not the confession, that the National Traffick Safety Board (NTSB) cited marijuana impairment as a prime cause of the accident (Birky 1988).

In fact, several other important factors were involved in the accident, as noted by the NTSB (Unsigned 1988). The engineers of both trains had a record of drunken driving, and the Conrail engineer (an admitted alcohol abuser) had had 11 traffic convictions, two license suspensions and a recent arrest for drunken driving while running a red light and a stop sign. The crew also failed to report that three separate safety devices were disabled. The fact that the crew went on to miss three consecutive warning signals may thus be indicative of systemic carelessness going beyond simple marijuana impairment. In addition, the railroad lacked an automatic red-light braking system, a basic safety feature that could have averted the accident. It therefore seems clear that prior drug testing was by no means needed to avert the crash, as apparently recognized by the NTSB, which restricted its recommendations to improvements in equipment and management. Nonetheless, the chief of the FRA joined numerous politicians in calling for random drug testing as well (Karr 1988).

The most extensive evidence on the accident hazards of marijuana use concerns off-the-job automobile accidents. Numerous anecdotal reports suggest that marijuana degrades driving performance, and accidents have been specifically linked to marijuana in a few cases (Jones & Lovinger 1985). Surveys have found that most marijuana users believe that smoking impairs their driving, yet they frequently drive when stoned. The statistical evidence on accident risks is more ambiguous. Some surveys have found that marijuana users are more likely to have accidents, while others have not (Smart 1974). In a survey of college students, Smart found that 62 percent of marijuana users reported driving soon after use. Three times fewer accidents were reported to have occurred under the influence of marijuana than alcohol, but the difference could be entirely explained by more frequent use of alcohol.

An anonymous survey of Toronto high-school students by Smart and Fejer (1976) found a statistically significant increase of nearly 100 percent in accidents and driving offenses among marijuana users. Surprisingly, a similar increase was found for tobacco smokers, but not for alcohol drinkers. This may be because nearly all (93%) of the students interviewed drank alcohol, while only a minority used marijuana, tobacco or other drugs. The higher accident rates may hypothetically coincide with a population of intensive, accident-prone, multiple drug users. The survey did not ask whether or not any accidents actually occurred under the influence of marijuana or other drugs, and it is possible that the marijuana and tobacco users were

under the influence of alcohol.

In another survey of teenagers, Hingson and colleagues (1982) found that those who smoked marijuana before driving at least six times per month and did not drink were 2.5 times more likely to have accidents, while those who drank before driving but did not smoke marijuana were 2.0 times more likely to have accidents than other drivers. Marijuana was not significantly associated with injury-producing accidents and the survey made no attempt to determine whether or not any accidents actually occurred while drivers were under the influence of marijuana or alcohol.

Yet another line of evidence comes from police examinations of erratic drivers. Roadside sobriety tests developed by Los Angeles police have proven accurate in detecting the influence of marijuana and other drugs (Compton 1986). A survey of 1,792 California drivers arrested for driving under the influence found a 14.4 percent incidence of blood THC at levels above 5.0 ng/ml (Zimmerman et al. 1983). Half the sample consisted of drivers whose blood-alcohol level was below the standard of legal intoxication, a population that accounted for less than 10 percent of all arrestees. A strong negative correlation was found between the presence of THC in blood and involvement in crashes (Mason & McBay 1984).

EPIDEMIOLOGICAL ACCIDENT STUDIES

The best epidemiological data on marijuana impairment come from statistics on the THC blood content of automobile accident victims. The most useful data come from fatal accidents because they afford the unique opportunity for collecting blood samples without informed consent.

Accident studies are complicated by the difficulty of interpreting drug test results (Terhune 1986). A somewhat arbitrary blood level of 5.0 ng/ml THC, indicating probable marijuana use in the past two hours, has been suggested as a conservative standard for significant impairment (Mason & McBay 1984; Zimmerman et al. 1983). Levels below 5.0 ng/ml are more ambiguous, being consistent with present or recent impairment or chronic smoking. Inasmuch as the THC content of blood decays quickly, it is essential that samples be obtained promptly; however, this degradation ceases at the moment of death. The use of THC blood tests to measure impairment involves a substantial risk of false positives because of the fact that detectable levels of THC can persist for at least two days in chronic smokers, well after significant impairment seems likely (McBay 1985b).

The question remains whether or not chronic smokers may not suffer long-term adverse behavioral effects from heavy use. While more research in this area is needed, studies of chronic users have so far found remarkably little evidence of serious long-term impairment (Hollister 1986). It therefore seems likely that the chronic effects of marijuana on accident safety are mild compared to those of acute intoxication.

Fatality Studies

The following is a summary of fatality studies published to date, all but one of which have been reviewed in recent literature (McBay 1986; Simpson 1986; Moskowitz 1985).

Mason and McBay (1984). The study surveyed 600 drivers killed in one-car accidents in North Carolina from 1978 to 1981. THC was found in the blood of 7.8 percent of all drivers, alcohol in 79.3 percent, methaqualone in 6.2 percent, and barbiturates in 3.0 percent. Of the 47 drivers with THC in their blood, 41 (87%) were also positive for alcohol, and 32 (68%) of these had blood alcohol contents (BACs) above 0.10 percent, the standard level for legal intoxication. THC levels below 3.0 ng/ml were not counted. However, in an examination of 35 drivers with detectable THC in blood, the authors found THC levels between 0.1 and 2.9 ng/ml in 11 (31%). Had such low levels been counted, the total proportion of THC-positive drivers may be estimated at 11.3 percent. The drivers tended to be younger and to have a higher incidence of multiple drug use than other drivers, with only four (8%) showing no other evidence of drug use than marijuana. THC levels were generally low: 10 cases (21%) above 10.0 ng/ml and 19 cases below 5.0 ng/ml. The authors concluded that at least nine but no more than 28 drivers could have experienced significant adverse effects from marijuana, of whom probably only one was not significantly affected by other drugs.

Cimbura et al. (1986, 1982). The most extensive data to date cover 1,169 drivers and pedestrians killed in fatal accidents in the Province of Ontario from 1982 to 1984 (Cimbura et al. 1986). In the drivers examined, THC was found in the blood of 10.9 percent and alcohol in 57.1 percent. Of the marijuana users, 84 percent also had alcohol in the blood and 68.5 percent had blood alcohol concentrations (BACs) above 0.8 percent. The study was sensitive to THC levels of 1.0 to 1.5 ng/mg (Cimbura 1987). THC levels below 5.0 ng/ml were found in 84 percent of THC-positive drivers. In an earlier study by the same group covering 401 fatalities in the years 1978 to 1979 (Cimbura et al. 1982), three percent of drivers showed THC in the blood, 12 percent in urine, and 57 percent showed alcohol in the blood. Of the THC positives, 93 percent also showed alcohol. The differences between the two studies are at least partially due to changes in methodology that made the latter study more sensitive.

Williams et al. (1985). A strikingly higher rate of THC involvement was found in a survey of 440 young male drivers (ages 15 to 34) killed in Southern California and

Sacramento in 1982 and 1983. THC was found in the blood of 37 percent, alcohol in 70 percent, and cocaine in 11 percent. Alcohol was found in 81 percent of THC positives, with 83 percent of these at BACs above 0.10 percent; another seven percent showed evidence of drugs other than alcohol. The population was deliberately chosen to have a high rate of drug use: Adjusted for the age and sex, the rate of THC involvement translates to about 20 percent in the general population (Simpson 1986). It has been suggested that the marked difference between these results and those of Mason and McBay (1985) reflects cultural differences between California and North Carolina. However, it also seems due to differences in sensitivity. Williams and colleagues (1985) detected 38 percent of the THC positives at concentrations of 0.2 to 0.9 ng/ml, 22 percent between 1.0 and 1.9 ng/ml, and 26 percent from 2.0 to 4.9 ng/ml. Had they adopted the 3.0 ng/ml cutoff of Mason and McBay, their age-adjusted rate of detection would have been closer to eight percent than 20 percent, while the 1.0 to 1.5 ng/ml threshold of Cimbura's studies (Cimbura et al. 1986, 1982) would have yielded a rate of about 12 percent.

Williams's group proceeded to evaluate the responsibility of drivers in each accident of their study: Drivers who used marijuana in conjunction with alcohol or other drugs had the highest rate of accident responsibility—over 95%; for those who used alcohol alone the rate was 92 percent; for drug-free drivers the rate was 71 percent; and for those who used marijuana alone the rate was only 53 percent. One possible interpretation of the anomalously low responsibility rate among marijuana-only users is that marijuana actually improves driving by making drivers more cautious. Alternatively, there may be problems with the study's method for assigning crash responsibility: Marijuana users may drive more slowly and erratically so as to invite crashes that end up being blamed on others.

Fortenberry, Brown and Shelvin (1986). An analysis of urine samples of 510 accident victims in Alabama from 1982 to 1984 found that 16.8 percent tested positive for marijuana. Of the drivers testing positive for marijuana, 82 percent showed alcohol in the blood, and 67 percent were legally intoxicated. The data were derived from a larger population of 1,518 drivers, 480 passengers and 191 pedestrians killed in the period 1980 to 1984, of whom 61.6 percent showed alcohol in blood. Positive BACs were found in 63 percent of drivers, 54.4 percent of passengers and 68.1 percent of the pedestrians. No comparable breakdown was provided for THC. Marijuana use was heavily skewed toward younger drivers, with 25.4 percent of fatalities aged 16 to 35 testing positive. The authors concluded that "marijuana is a problem of young drivers, generally those under the age of 40." However, because the data were based on urine tests, it is unclear how many (if any) were actually under the influence of marijuana.

Other Accident Studies

A few investigators, mostly foreign, have analyzed blood samples of victims in nonfatal accidents (Simpson 1986). Results are complicated by the difficulty of obtaining informed consent and the rapid decline of blood THC in living subjects. The only American study appears to be that of Terhune and Fell (1982), which surveyed 497 drivers hospitalized in Rochester, New York, during 1970 and 1980. The study found 9.5 percent with THC in blood, 38 percent with alcohol and 7.5 percent with tranquilizers; 53 percent of THC-positive drivers also showed alcohol. The lower rate of alcohol involvement in nonfatal as opposed to fatal accidents is consistent with other studies (Simpson 1986). A full 29.3 percent of potential subjects refused to consent to give samples, raising the possibility of serious bias in the data. The authors evaluated driver culpability in each accident. Legally intoxicated drivers were judged 74 percent culpable, drivers with low BACs were 54 percent culpable, drivers with THC were 53 percent culpable, and drug-free drivers were 34 percent culpable. Because of the low number of blood samples, the results for THC were not statistically significant. Reanalyzing the data with a broader definition of accident responsibility that included drivers who were only partially culpable in accidents, Terhune (1986) found statistically significant responsibility rates of 76.4 percent for THC-only drivers, compared to 90.2 percent for legally intoxicated drivers, 69.2 percent for lower-BACs drivers, and 42.5 percent for drug-free drivers.

MARIJUANA USE AND ACCIDENT RISKS

In sum, the preceding studies have shown that detectable blood levels of THC are present in 11 to 20 percent of drivers in fatal accidents, or as many as 37 percent of young California males. They also have shown that 81 to 87 percent of THC-related fatalities involved alcohol, with 59 to 68 percent at levels of legal intoxication. Blood levels of THC tend to be low: eight to 11 percent of all fatalities have shown more than 2.0-3.0 ng/ml, a level that may persist in chronic users with little or no impairment. Levels above 5.0 ng/ml, which are more strongly indicative of impairment, occur infrequently (2.8% to 4.8% of all fatalities). Taking a lower cutoff of 1.0-1.5 ng/ml, a reasonable upper estimate of the proportion of fatalities with significant impairment due to marijuana would appear to be around 11 to 12 percent.

In order to evaluate the relative risk of marijuana use from these data, it is necessary to compare the THC blood levels in accident drivers with those of a control sample of nonaccident drivers. Unfortunately, no studies of this sort have been conducted for marijuana. However, they have

been done for alcohol. In a classic study of drivers in Grand Rapids, Michigan, Borkenstein and colleagues (1964) compared BACs of all drivers involved in accidents with BACs of other drivers at similar locations and driving conditions. It was found that the risk of accident involvement increases steeply for BACs over 0.04 percent: five times as high at 0.10 percent and 10 times as high at 0.15 percent. Comparable risks were inferred in several other studies (Honkanen 1976). A later study (Farris, Malone & Lilliefors 1976) of injury-producing accidents in Huntsville, Alabama, found the risk of accident involvement to be twice as high at BACs of 0.10 percent and four times as high at 0.15 percent.

In the absence of comparable studies for marijuana, a rough perspective on accident risks can be obtained by trying to estimate the prevalence of marijuana use in the population. Unfortunately, such estimates vary widely, ranging by a factor of two or more (Gettman 1987). Perhaps the best available data come from the NIDA household survey (Miller et al. 1983), which indicated that 27 percent of young adults (ages 18 to 25) and seven percent of older adults are "current users," meaning that they have used marijuana in the past month. The survey tends to be conservative about marijuana use, as it is based on polling people about illegal activity. In addition, it excludes college students, prisoners, servicemen, and other persons living away from home among whom marijuana consumption is apt to be significant. A reasonable estimate of "at least once a month" marijuana usage might therefore be 24 to 33 percent for young adults and six to nine percent for older adults, corresponding to 10 to 14 percent of the total adult population.

It should also be noted that marijuana users belong to a population group that is more accident prone than the general population, insofar as they tend to be young, male, socially rebellious, and academic underachievers (Terhune 1986). For example, drivers 20 to 25 years old are nearly twice as likely to be involved in accidents as average drivers (National Safety Council 1982). This means that accident rates for marijuana users will naturally tend to be high regardless of the effects of marijuana.

It is worth noting that the percentage of marijuana users in the population appears to roughly equal the percentage of drivers in fatal accidents with THC in their blood. Remarkably, a similar relation seems to hold for alcohol: 67 percent of the population is estimated to be current alcohol users (Clark & Midanik 1982), whereas 57 to 87 percent of accident drivers showed alcohol in blood in the studies cited above. This suggests that marijuana users as a group are proportionately as likely to be involved in fatal accidents as alcohol drinkers.

A more detailed look at marijuana usage patterns yields a rough estimate of the percentage of the population that might be expected to test positive for marijuana. According to the NIDA survey (Miller et al. 1983), two thirds of current marijuana users ages 18 to 25 used marijuana three or more times in the past month; one quarter (7% of the age cohort) are "daily users," smoking at least 20 times per month; and one seventh (4%) are "heavy smokers," smoking at least two joints per day 20 times per month. Unfortunately, the NIDA survey does not include comparable statistics for older smokers. However, it does indicate that 40 to 50 percent of older users are "serious users," meaning that they smoked marijuana three or more times as well as purchased marijuana in the preceding month, whereas 60 percent of young adult users are serious users. From these data, it might be estimated that about three to five percent of older adults smoke marijuana three or more times per month, and one to three percent smoke daily.

DISCUSSION

In principle, these figures might be used to estimate the distribution of THC in blood or urine of the general population, given the average THC levels for each user group. However, present knowledge in this regard is woefully imprecise. A large-scale statistical study of THC blood levels in chronic and occasional marijuana smokers is urgently needed. In the meantime, the opinion of most experts seems to be that chronic marijuana users are likely to manifest a continual low background of THC in blood, while occasional users are unlikely to show detectable levels after a few hours. On this basis, it seems reasonable to suppose that the number of persons with THC in blood is roughly equal to the population of daily users: seven to eight percent of younger adults and one to three percent of older adults, or about two to four percent in the general population. On this assumption, it appears that *significant blood levels of THC occur three to five times more frequently in fatal drivers than in the general population.*

In the case of urine tests, which detect marijuana for several days after use, it seems reasonable to assume that a large majority of persons who smoke three or more times a month will register THC-positive, plus a fraction or more occasional users. This translates to perhaps 16 to 24 percent of young adults and three to six percent of older adults, or about six to 11 percent of all adults. These figures seem to be significantly lower than the 16.8 percent of accidents with THC in urine observed by Fortenberry, Brown and Shelvin (1986). The discrepancy is greatest for drivers ages 25 to 35, among whom the aforementioned authors found a 25 percent rate of marijuana use, but who were classified among low-use older persons by NIDA. Among drivers under 25, the rate of marijuana involvement found in accidents was just marginally higher at 25 percent.

Fortunately, there exists independent evidence to check these figures. A voluntary roadside survey of 317

male tractor-trailer drivers in Tennessee by the Insurance Institute for Highway Safety (Lund et al. 1987) found that three percent of all drivers had THC in blood and 11 percent tested positive for cannabinoids in urine. Remarkably, only two or three drivers (less than one percent) tested positive for alcohol (BACs≤0.03%), and one of these showed blood traces of marijuana and cocaine (Lund 1987). The distribution of THC levels among drivers was similar to that found by Mason and McBay (1984), as was the cutoff detection level of about 2.5 ng/ml.

Although the results were widely publicized as evidence of potential widespread drug abuse, they largely confirm the usage estimates derived from the NIDA data. Data gathered by Lund and colleagues (1987) imply that THC in blood is associated with a fourfold increase in accident risks, comparable to that of driving under the influence of alcohol. It also indicates that THC in urine is associated with a 50 percent increase in accident involvement, based on the data of Fortenberry, Brown and Shelvin (1986). This is comparable to the risk of "frequent drinkers of substantial quantities" of alcohol found by Brenner, Cisin and Newcomb (1966). As an upper estimate, an increased risk of perhaps 100 to 150 percent might be inferred from the accident data of Williams and colleagues (1985). This is comparable to the risk increase observed in high-school tobacco smokers by Smart and Fejer (1976), though less than the 350 percent observed in alcoholics (Brenner 1967). In sum, *marijuana users who test positive in urine appear comparable in accident risk to heavier drinkers.* To this extent, marijuana tests appear to be a valid indicator of accident risk.

However, the picture changes when one takes into account the high incidence of alcohol use among THC-positive accident drivers. Given that 81 to 87 percent of THC-related fatalities also have BACs, it seems quite possible that the increased accident rate among THC-positive drivers is explained by alcohol, not marijuana. A resolution of this issue requires better statistics on the prevalence of combined alcohol-marijuana use than are presently available. However, a rough estimate can be ventured on the basis of data from the NIDA household survey (Miller et al. 1983). These showed that 45 percent of "experienced" marijuana users (i.e., those who have smoked 10 times or more) said they combined it with alcohol "usually" or "half the time," 48 percent said they did so "occasionally" or "rarely," and seven percent said "never." From these murky data, it might be conjectured that 40 to 50 percent of smoking episodes involve alcohol. A considerably smaller proportion of users might be expected to manifest both alcohol and marijuana in blood simultaneously, as they dissipate at dissimilar rates. Assuming that 20 to 35 percent of all THC-positive drivers also have alcohol in their blood, it might be estimated that, at most, one percent of all drivers have both drugs in their blood, while two to three percent have THC only. In comparison, some nine to 16 percent of all fatal accidents involve both THC and alcohol, while only two to four percent show THC alone. Thus, *marijuana use by itself appears to be a minor or negligible risk factor in fatal accidents.*

On the other hand, drivers who combine the use of alcohol and marijuana appear to be heavily overrepresented in fatal accidents by a factor of 10 or more. This is comparable to the increased risk of accidents for drivers with BACs of 0.15 percent, as observed by Borkenstein and colleagues (1964) as well as other investigators, though more than twice the risk deduced by Farris, Malone and Lilliefors (1976). Coincidentally, the average BACs observed among alcohol-THC-positive accident drivers in the studies of Mason and McBay (1985, 1984), Cimbura and colleagues (1986, 1982), Williams and colleagues (1985) and Fortenberry, Brown and Shelvin (1986) are all around 0.15 percent. These data are obviously quite inexact and do not rule out some differential risk due to marijuana. However, it seems that the *increased accident risk of THC-positive drivers may be largely explained by alcohol use.*

Once again, these results can be checked with the roadside study of truck drivers. Remarkably, only one of the 47 THC-positive drivers also showed alcohol in blood, both at low levels. The rest of the THC-positive drivers must therefore be classified as "marijuana only." Taking these results at face value, combined alcohol-marijuana use would seem quite rare, yet responsible for virtually all of the increased risk in observed THC-positive accident drivers.

However, the extraordinarily low incidence of alcohol use in the roadside study demands explanation. In the Grand Rapids study (Borkenstein et al. 1964), 14 percent of all control drivers showed positive BACs, over 15 times the rate seen in the truck drivers. One explanation is that truckers are particularly careful compared to other drivers in avoiding the use of alcohol on the job. Indeed, fatality statistics have shown that only 15 percent of fatally injured tractor-trailer drivers have positive BACs (National Highway Safety Admistration 1985), a rate that is four to five times lower than for other drivers. Even so, the incidence of alcohol in the roadside study still seems anomalous. Perhaps the data were biased by the fact that they excluded 12 percent of the drivers interviewed, who refused to give samples.

In sum, the underlying risk factor in fatal accidents appears to be alcohol, not marijuana. Use of alcohol is not uncommon among marijuana users. Indeed, the NIDA survey showed that fully 90 percent of marijuana users drink alcohol, and at least half use other drugs. Thus it appears that *the value of drug testing lies not in detecting actual marijuana impairment, which appears to be at most*

a secondary hazard, but rather in the fact that marijuana use is an indicator of multiple drug use and particularly heavy drinking, which is a major risk factor. There is no reason to think that marijuana attracts users to alcohol; rather, it seems likely that serious drug and alcohol users gravitate toward marijuana. Hence, eliminating marijuana per se is unlikely to have an appreciable impact on public safety inasmuch as users are likely to continue using other drugs, notably alcohol.

CONCLUSION

The evidence suggests that marijuana impairment presents a real, but secondary, safety risk; and that alcohol is the leading drug-related accident risk factor. In this light, it is ironic that current drug urinalysis technology reflects the opposite bias, being highly intolerant of marijuana but not of alcohol. Given the current technology, the popularity of marijuana testing appears to rest more on deep social and political prejudices than on actual scientific evidence. Much more research is needed before the costs and benefits of marijuana testing can be evaluated. Depending on how it is implemented, testing could reduce marijuana use in the working population. However, it seems unlikely that this would result in appreciable gains in public safety given the continuing availability of alcohol and other drugs.

REFERENCES

Barnett, G.; Licko, V. & Thompson, T. 1985. Behavioral pharmacokinetics of marijuana. *Psychopharmacology* Vol. 85: 51-56.

Birky, M. 1988. Personal communication.

Bogdanich, W. 1987. Federal lab studying train, airline crashes fabricated its findings. *Wall Street Journal* July 31.

Borkenstein, R.; Crowther, R.; Shumate, R.; Zeil, W. & Zylman, R. 1964. The role of the drinking driver in traffic accidents. (Research report). Indiana University.

Brenner, B. 1967. Alcoholism and fatal accidents. *Quarterly Journal of Studies on Alcohol* Vol. 38: 517-528.

Brenner, B.; Cisin, I.H. & Newcomb, C. 1966. Drinking practices and accidental injuries. Transcript of a presentation at the session on alcohol use and accidents of the Society for the Study of Social Problems. Miami Beach, Florida, August 28.

Chesher, G.B. 1986. The effects of alcohol and marijuana in combination: A review. *Alcohol, Drugs, and Driving: Abstracts and Reviews* Vol. 2(3-4): 105-120.

Cimbura, G.B. 1987. Personal communication.

Cimbura, G.B.; Lucas, D.M.; Bennett, R.C. & Donelsen, A.C. 1986. Incidence and toxicological aspects of cannabis and ethanol detected in 1,394 fatally injured drivers and pedestrians in Ontario, 1982-1984. Abstract and presentation at the Meeting of the American Academy of Forensic Sciences. New Orleans, February.

Cimbura, G.B.; Lucas, D.M.; Bennett, R.C.; Warren, R.A. & Simpson, H.M. 1982. Incidence and toxicological aspects of drugs detected in 484 fatally injured drivers in Ontario. *Journal of Forensic Sciences* Vol. 27: 855-867.

Clark, W. & Midanik, L. 1982. Alcohol use and alcohol problems among young adults: Results of the 1979 national survey. In: *Alcohol Consumption and Related Problems*. NIAAA Alcohol and Health Monograph No. 1. Rockville, Maryland: National Institute on Alcohol Abuse and Alcoholism.

Compton, R.P. 1986. *Field Evaluation of the Los Angeles Police Department Drug Detection Procedure*. Technical Report for the National Highway Traffic Safety Administration, U.S. Department of Transportation, NTIS Report No. DOT-HS-807-012. Springfield, Virginia: National Technical Information Service.

Farris, R.; Malone, T.B. & Lilliefors, H. 1976. *A Comparison of Alcohol Involvement in Exposed and Injured Drivers, Phases I and II*. Technical report for the National Highway Traffic Safety Administration, U.S. Department of Transportation, NTIS Report No. DOT-HS-801-826. Springfield, Virginia: National Technical Information Service.

Federal Railroad Administration. 1987. Results of toxicological analysis: Collision of January 4, 1987, between Amtrak and Conrail trains at Chase, Maryland. Press Release, January 14.

Federal Railroad Administration. 1985. Control of alcohol and drug use in railroad operations. Final rule and miscellaneous amendments. *Federal Register* Vol. 50: 31508-31579.

Fortenberry, J.C.; Brown, D.B. & Shelvin, L.T. 1986. Analysis of drug involvement in traffic fatalities in Alabama. *American Journal of Drug and Alcohol Abuse* Vol. 12(3): 257-267.

Fram, A. 1988. Associated Press report 0730. February 26.

Gettman, J.B. 1987. Marijuana in America—1986. Report of the National Organization for the Reform of Marijuana Laws. Washington, D.C.: NORML.

Hingson, R.; Heeren, T.; Mangione, T.; Morelock, S. & Mucatel, M. 1982. Teenage driving after using marijuana or drinking and traffic accident involvement. *Journal of Safety Research* Vol. 13: 33-37.

Hollister, L.E. 1986. Health aspects of cannabis. *Pharmacological Reviews* Vol. 38(1): 1-20.

Honkanen, R. 1976. *Alcohol Involvement in Accidents*. Academic dissertation to the Medical Faculty of the University of Helsinki.

Jones, H.C. & Lovinger, P.W. 1985. *The Marijuana Question*. New York: Dodd, Mead.

Karr, A. 1988. U.S. cites drug use by Conrail workers in '87 train wreck. *Wall Street Journal* January 21.

Klonoff, H. 1974. Marijuana and driving in real-life situations. *Science* Vol. 186: 317-324.

Lund, A.K. 1987. Personal communication.

Lund, A.K.; Preusser, D.F.; Blomberg, R.D. & Williams, A.F. 1987. Drug use by tractor-trailer drivers. Washington, D.C.: Insurance Institute for Highway Safety.

Mason, A.P. & McBay, A.J. 1985. Cannabis: Pharmacology and interpretation of effects. *Journal of Forensic Sciences* Vol. 30(3): 615-631.

Mason, A.P. & McBay, A.J. 1984. Ethanol, marijuana and other drug use in 600 drivers killed in single-vehicle crashes in North Carolina, 1978-1981. *Journal of Forensic Sciences* Vol. 29(4): 987-1026.

McBay, A.J. 1986. Drug concentrations and traffic safety. Alcohol, Drugs, and Driving: Abstracts and Reviews Vol. 2(3-4): 51-60.

McBay, A.J. 1985a. Cannabinoid testing: Forensic and analytical aspects. *Laboratory Management* January: 36-41.

McBay, A.J. 1985b. Marijuana testing and litigation. *Journal of Forensic Sciences* Vol. 30: 987-994.

Miller, J.D.; Cisin, I.H.; Gardner-Heaton, H.; Harrell, A.V.; Wirtz, P.W.; Abelson, H.I. & Fishburne, P.M. 1983. *National Survey of Drug Abuse: Main Findings 1982*. Rockville, Maryland: NIDA.

Moskowitz, H. 1985. Marihuana and driving. *Accident Analysis and Prevention* Vol. 17(4): 323-345.

National Highway Traffic Safety Administration. 1985. Fatal Accident Reporting System. Washington, D.C.: National Highway Traffic

Safety Administration.

National Safety Council. 1982. *Accident Facts, 1982 Edition.* Chicago: NSC.

Peck, R.C.; Biasotti, A.; Boland, P.N.; Mallory, C. & Reeve, V. 1986. The effects of marijuana and alcohol on actual driving performance. *Alcohol, Drugs, and Driving: Abstracts and Reviews* Vol. 2(3-4): 135-154.

Reeve, V.C.; Robertson, W.B.; Grant, J.; Soares, J.R.; Zimmermann, E.G.; Gillespie, H.K. & Hollister, L.E. 1983. Hemolyzed blood and serum levels of Δ^9-THC: Effects on the performance of roadside sobriety tests. *Journal of Forensics Sciences* Vol. 28(4): 963-971.

Simpson, H.M. 1986. Epidemiology of road accidents involving marijuana. *Alcohol, Drugs, and Driving: Abstracts and Reviews* Vol. 2 (3-4): 15-30.

Smart, R. 1974. Marihuana and driving risk among college students. *Journal of Safety Research* Vol. 6(4): 155-158.

Smart, R. & Fejer, D. 1976. Drug use and driving risk among high school students. *Accident Analysis and Prevention* Vol. 8(1): 33-38.

Smiley, A. 1986. Marijuana: On-road and driving simulator studies. *Alcohol, Drugs, and Driving: Abstracts and Reviews* Vol. 2(3-4): 121-134.

Stone, R.B. 1987. Testimony in Hearings on the Airline and Rail Service Protection Act of 1987. Senate Committee on Commerce, Science and Transportation, 100th Congress, February 20.

Sutton, L.R. 1983. The effects of alcohol, marihuana and their combination on driving ability. *Journal of Studies on Alcohol* Vol. 44(3): 438-445.

Terhune, K.W. 1986. Problems and methods in studying drug crash effects. *Alcohol, Drugs, and Driving: Abstracts and Reviews* Vol. 2(3-4): 1-14.

Terhune, K.W. & Fell, J.C. 1982. *The Role of Alcohol, Marijuana, and Other Drugs in Accidents of Injured Drivers.* Technical report for the National Highway Traffic Safety Administration, U.S. Department of Transportation, NTIS Report No. DOT-HS-806-181. Springfield, Virginia: NTIS.

Unsigned. 1988. Drug use blamed for Amtrak crash. *New York Times* January 21: 13.

Unsigned. 1987. Drug tests spread. *Wall Street Journal* April 7: 1.

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* Vol. 100: 19-25.

Yesavage, J.A. & Leirer, V.O. 1986. Hangover effects on aircraft pilots 14 hours after alcohol ingestion: A preliminary report. *American Journal of Psychiatry* Vol. 143: 1546-1550.

Yesavage, J.A.; Leirer, V.O.; Denari, M. & Hollister, L.E. 1985. Carry-over effects of marijuana intoxication on aircraft pilot performance: A preliminary report. *American Journal of Psychiatry* Vol. 142: 1325-1329.

Zimmermann, E.G.; Yeager, E.P.; Soares, J.R.; Hollister, L.E. & Reeve, V.C. 1983. Measurement of Δ^9-tetrahydrocannabinol (THC) in whole blood samples from impaired motorists. *Journal of Forensic Sciences* Vol. 28(4): 957-962.