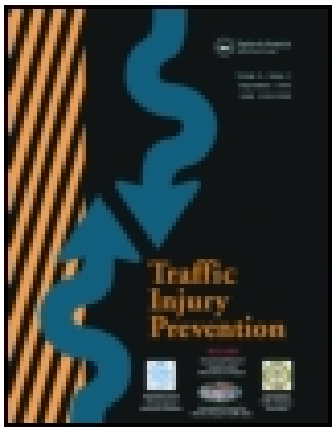

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SAM Survey on "Drugs and Fatal Accidents": Search of Substances Consumed and Comparison between Drivers Involved under the Influence of Alcohol or Cannabis

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Objectives. *A survey was conducted to produce reliable epidemiological data concerning the role played by alcohol and drugs in fatal road accidents in France. The aims are to describe the conduct of the survey, evaluate the overall quality of the findings, and analyze the substances consumed by the involved drivers. A comparison between drivers involved under the influence of alcohol only, cannabis only, or both substances is emphasized.*

Methods. *By a June 1999 law, all drivers in France involved in an immediate fatality accident between October 2001 and 2003 had to undergo a urine test and, if that was not possible or the test proved positive, had a blood sample taken in order to test for drugs (cannabis, cocaine, heroin, amphetamines). The results were combined with the usual procedures of the police force, which include the results of tests for illegal alcohol levels. A unique and reliable set of accident data on the role of drugs was thus compiled for epidemiological purposes: 10,000 accident reports involving over 17,000 drivers were analyzed. The responsibility level of each driver involved in an accident was determined. Results were generated for a representative sample of about 11,000 drivers.*

Results. *Alcohol levels above the legal limit (0.5 g/L of blood) were found in 21% of all drivers involved in accidents (killed, injured, or unharmed). Cannabis headed the list of illicit drugs detected, with a prevalence of 6.8% (THC $\geq$ 1 ng/mL); it was present in the under-35s and especially the under-25s. About 40% of drivers under the influence of cannabis also had an illegal alcohol level. The other drugs, whether alone or in association with cannabis, are relatively rare. Accident characteristics of drivers detected positive for cannabis only are markedly different from drivers under the influence of alcohol. The overrepresentation of drivers responsible, from 1.7 over the whole population, rises to 2.3 for cannabis alone (THC $\geq$ 1 ng/mL), to 9.4 for alcohol alone ($\geq$0.5 mg/L), and to 14.1 for the alcohol-cannabis combination.*

Conclusions. *The high incidence (26%) of alcohol or drugs among the population of drivers involved in fatal accidents highlights the importance for road safety of the consumption of these substances. Alcohol remains the major risk at any age. Young drivers consuming alcohol and cannabis represent a priority target for prevention.*

Keywords Accident (fatal); Driver; Testing; Illicit Drug; Alcohol; Cannabis; Responsible; Prevalence

INTRODUCTION

The exponential growth in accident risk as a function of alcohol levels was clearly highlighted 40 years ago (Borkenstein, 1964) and since then, the crash risk associated with drivers' blood alcohol concentrations (BAC) has been assessed by number of other studies in the world. The more recent impressive case-control study, confirming and updating Borkenstein's results with a special attention to low BACs, was conducted by Blomberg et al. (2005). In France, a legal blood-alcohol limit was introduced in 1970 (0.8 g/L) and accompanied by checks for any illegal alcohol concentration in the event of a personal injury accident or when certain offences had been committed. The overall consumption of alcohol declined appreciably over 30 years, while the campaign against drinking and driving gathered pace with the introduction of important measures such as random checks in 1978, the level in breathed air in 1983, and the reduction in the legal blood limit to 0.5 g/L in 1995. At the same time, surveys of the consumption of psychoactive substances carried out for some 30 years now, and especially in France since the 1990s, attest to the importance of the phenomenon represented today by the consumption of illicit drugs,

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and especially the growing use of cannabis among the young (OFDT, 2005).

In 1996, a white paper on the relationship between drugs, medicines, and road safety was published in France (Lagier, 1996). Our basis of knowledge has been considerably filled out since then, both in France and in Europe (Pompidou (Groupe), 1999, 2004; Assailly and Biecheler, 2002). Whereas a large number of drugs (including cannabis, opiates, amphetamines, and benzodiazepines) are detected in accident victim populations, there nevertheless remains some uncertainty about the translation of this consumption into duly quantified risks because of the substantial methodological difficulties that surround epidemiological studies.

The most controversial aspect of this issue of the involvement of drugs in causing road accidents is the role of cannabis, which is nevertheless still at the top of the list of illicit substances detected in drivers. Experimental studies show the deterioration of certain faculties useful in driving under the influence of cannabis (Moskowitz, 1985) and more markedly at high doses (Smiley, 1986; Robbe, 1994; Sexton et al., 2000), but up until now, epidemiological studies have not generated a set of homogeneous and robust conclusions proving that the use of cannabis is a significantly important factor in accidents. Due to the complexity of the phenomenon, these studies, which, apart from a few exceptions (Dussault et al., 2002; Movig et al., 2004), employ the responsibility approach, generally lack the statistical power to show that the consumption of cannabis alone increases the probability of being responsible in the event of an accident (Robertson and Drummer, 1994). The small numbers of drivers tested positive, the individual variability of the phenomenon, and the frequent association of cannabis and alcohol or other drugs limit the possibility of detecting the effects attributable to cannabis alone (Inserm, 2001; Huestis, 2002). In addition to that, because of the complex metabolism of cannabis, there is the fact that it is hard to measure driving under the influence with any precision (Huestis et al., 1992; Verstraete, 2002).

In this context, France lacked reliable epidemiological data concerning the role played by drugs in road accidents. To remedy that, the law of 19 June 1999 (known as the Gayssot Act) and the statutory order bringing it into effect on 27 August 2001 introduced systematic testing for drugs in all drivers involved in a fatal traffic accident, thereby opening the way to a scientific study of considerable size. The study, coordinated by the Observatoire Français des Drogues et des Toxicomanies (OFDT), was commissioned from a pluridisciplinary group of researchers bringing together expertise in the fields of health and accident research. The resulting epidemiological study "Drugs and Fatal Road Accidents" (or SAM, for Stupéfiants et Accidents Mortels de la circulation routière) was thus carried out in a context of legal requirements and on a scale never attained before, since its findings are derived from a representative population of over 10,000 drivers, whereas the largest samples until then did not exceed 3,500 subjects (Inserm, 2001).

A first series of results on the risk of cannabis was published in December 2005 (Laumon et al., 2005; Groupe SAM et al., 2005). The aim of this article is to describe the conduct of the survey (data collection arrangements, chain of information), while showing the complexity of the field analyzed, evaluate the overall quality of the findings, and analyze the substances consumed by this population of drivers involved in fatal accident accidents. A comparison between drivers involved under the influence of alcohol only, of cannabis only, or of the two substances will be emphasized.

METHODS

Implementation of the SAM Survey

From 1 October 2001 until 30 September 2003, all drivers involved in accidents where a death was recorded at the scene were subjected to a urine test. If that was not possible or if the test was positive, a blood sample was taken in order to screen for drugs. The OFDT was designated as the recipient body for the documents needed for carrying out the epidemiological study. A note was thus circulated to police forces informing them that they were required to send the OFDT copies of accident reports in all cases where a death was recorded at the scene during the period of the survey. The OFDT then had to record these reports, ask for complements if necessary, and transmit them to the research team responsible for analyzing them. At the end, polices forces submitted about 10,600 reports to the OFDT as part of this survey. Knowing that they represented 95% of the expected reports (accidents resulting in an immediate fatality), the survey yielded not only a large basis to work with, but an almost exhaustive one.

Legal Requirement to Search for Drugs

Every driver involved in an accident resulting in an immediate death (including a pedestrian death) had to be tested for the presence of cannabis, amphetamines, opiates, and cocaine. The testing requirement included neither pedestrians nor vehicle passengers. The stages through which this research into drugs passed were encoded in the relevant legislative and regulatory instruments (law of 18 June 1999, decree of 27 August 2001, statutory orders of 4–5 September 2001). The driver is first required to undergo a urine test (which enables negative cases to be ruled out); if the urine test is positive, or it is not possible or the driver refuses, he/she is required to give a blood sample, and a certified laboratory or expert is then requisitioned to screen it for the presence and level of drugs. Police officers have the task of conducting drivers to the places where urine or blood samples are taken, which are located in a medical environment, and the sample has to be taken within the "shortest" possible time after the accident.

Urine testing equipment (reactive tests, sterile bottles) is provided by the hospitals themselves (their path labs) if the test takes place in a hospital (which it does in 80% of cases) or is given to a general practitioner by the police in the other 20% of cases.

The results are theoretically recorded on forms provided to that effect and normally attached to the accident report: form D for the result of the urine test and form F for the result of the

Table I Components and detection limits of whole blood GCMS analysis

Drug category	Components	Detection limits
Cannabis	THC (active agent)	1 ng/mL
	11-OH-THC (active metabolite)	
	THC-COOH (inactive metabolite)	
Amphetamines	MDMA (ecstasy)	50 ng/mL)
	MDMA (ecstasy metabolite)	50 ng/mL)
	Other amphetamines (amphetamine, methamphetamine, MDEA, MDDB)	50 ng/mL)
Cocaine	Cocaine	50 ng/mL
	BZE (inactive metabolite)	50 ng/mL
	Autre (EME, inactive metabolite)	50 ng/mL
Opiates	Heroin	20 ng/mL
	6-MAM (metabolite de l'heroïne)	20 ng/mL
	Morphine (of which administrated morphine)	20 ng/mL
	Other opiates (of which codeine, codethyline, subutex, methadone)	20 ng/mL

blood test, with form E reserved for the clinical examination of the driver's behavior (forms A, B, and C are used for the research of alcohol).

Hence, for each accident event concerned, the conduct of the drugs research study requires the immediate and coherent mobilization of the various professionals involved (police officers, departmental directorates of health and social services [DDASS], and doctors), as well as good physical coordination with the laboratories and medical personnel responsible for performing the toxicological analyses. The generation of reliable results thus depends on the cooperation of these participants in gathering the data required by the legislation and circulars in as short a time as possible after the accident and their effective transmission to the OFDT.

Definition of Testing Positive for Drugs

A driver is said to test positive for drugs if the result of the blood test is positive; he is said to test negative if the result of the blood test is negative or the urine test is negative (without the results of a subsequent blood test being known). Under this definition, determining whether the driver "tests positive for drugs" remains relative, since it depends on several elements: the performance of the urine test to eliminate the negative cases effectively; the blood test used for each family of drugs, especially for the molecules being looked for and the legal detection levels in relation to the legal concentration limits; and lastly, the way in which the information obtained from the accident reports is coded.

The most commonly performed urine test—the Syva Rapid test—is basically a specific, sensitive, and accurate test for each of the four families of drugs (Verstraete and Samyn, 2003). Whereas the urine test rules out non-consumers, the blood test isolates drivers really under the influence from among all consumers.

Screening for the presence and concentration of drugs in the blood is carried out using the technique called gas-phase chromatography coupled with mass spectrometry (GCMS). Forty certified laboratories and experts could be asked to test for concentrations of drugs. The different products looked for and analyzed through blood tests are cannabis (THC) and its metabolites (11OH-THC and THC-COOH, which is psychoinactive); amphetamines (MDMA or ecstasy, MDA, and other amphetamines); opiates (morphine and other opiates); and cocaine. The fixed regulatory detection levels were the following: 1 ng/mL for ?^{9}-THC, 50 ng/mL for amphetamines, 50 ng/mL for cocaine, and 20 ng/mL for opiates (Table I).

A blood test is found positive, under the current legislation, if the blood concentration of a component is measured over the regulatory concentration limit. Nevertheless, the substance may be present with a concentration under this level. We then will have to distinguish between blood tests over the regulatory limit (found positive) and non-null blood tests under the regulatory limit found negative.

The Data Basis (SAM-BAAC) and the Study Population

Initially, the study based on the OFDT reports included a complete list of 17,409 drivers involved in fatal accidents; it has been possible to link 16,391 of them with the injury analysis forms of the national accident data file (the BAAC file, for "bulletin d'analyse des accidents corporels"). This linkage provided the SAM file with complete information on accident occurrence (location, category of road, type of day and time, obstacle hit, manœuvre, etc.) besides information on drug presence.

It was thus possible to determine through automatized procedures the responsibility level of each driver involved in an accident. The method applied here, using the BAAC data, is similar to that described by Robertson and Drummer (1994). It has been verified that this method, when compared with responsibility assessments made in total agreement by experts in accidentology, gives a reliable estimate of the responsibility attributable to each driver (Groupe SAM et al., 2005).

Table II describes the characteristics of the drivers and crashes included in the study. They are compared to the entire population of drivers and crashes in the same period (October 2001–September 2003).

The SAM population includes in proportion more men and more single-vehicle accidents than the entire population involved in injury accidents; this is linked to the greater severity of these accidents as the SAM study included only fatal crashes with an immediate death. No difference appears in age

Table II Characteristics of the drivers involved in SAM study compared with the total population of drivers

	Drivers involved in SAM study	% Column	All drivers involved in injury accidents	% Column
	16,391	100	352,872	100
Age				
Under 18 yrs	334	2.0	17,977	5.1
18–19 yrs	776	4.7	17,634	5.0
20–24 yrs	2634	16.1	55,911	15.8
25–29 yrs	2098	12.8	45,427	12.9
30–34 yrs	1839	11.2	41,139	11.7
35–39 yrs	1686	10.3	36,836	10.4
40–44 yrs	1572	9.6	32,653	9.3
45–49 yrs	1357	8.3	27,586	7.8
50–54 yrs	1213	7.4	24,022	6.8
55–59 yrs	865	5.3	17,052	4.8
60–64 yrs	461	2.8	9528	2.7
65–69 yrs	448	2.7	7591	2.2
70–74 yrs	421	2.6	6649	1.9
75 yrs and over	687	4.2	9037	2.6
Sex				
Male	13,673	83.4	268,539	76.1
Female	2718	16.6	84,333	23.9
Injury				
Not injured	4896	29.9	167,505	47.5
Slightly injured	2219	13.5	9781	2.8
Seriously injured	1403	8.6	31,345	8.9
Fatal injured	7873	48.0	144,241	40.9
Number of vehicles				
Single vehicle	5143	31.4	77,071	21.8
Two vehicles	8190	50.0	22,9234	65.0
Two vehicles or more	11,203	68.3	275,476	78.1

distribution except for the categories under 18 years and over 75 years.

Responsibility was determined without ambiguity (yes or no) for 15,471 drivers, including 4,672 drivers involved in single-vehicle accidents and 10,799 drivers involved in accidents with two or more vehicles (7,870 of them in two-vehicle accidents).

All the data about drug concentrations were verified and completed after late and final reception of some of the blood tests, resulting in very marginal changes of the data basis. The last introduction of corrections was in September 2006.

RESULTS

Data Collected and Results for Illicit Drugs and Alcohol

The successive screening tests and biological confirmations, and the results obtained, are analyzed, for illicit drugs as well as for alcohol, for the list of 16,391 drivers included in the study after linkage to the national BAAC file.

Illicit drugs. The flow chart reproduced in Figure 1 shows how the process of looking for drugs was applied to the 16,391 drivers involved in accidents who were included in the study. It indicates "positive" for any blood test that yields a non-negative result for at least one of the families of drugs.

The urine test, when it can be performed, is a way of distinguishing between drivers who could be under the influence and those who are not. But only a blood test yields proof of driving under the influence. Overall, 10,799 clear test results were obtained. We will deal further with missing data.

We distinguish between two main procedures for generating the results of the screening for drugs:

- The procedure of direct blood tests without prior urine tests, the latter having been impossible or refused: 10,404 blood samples taken and 6,848 known results (of which 5,843 are

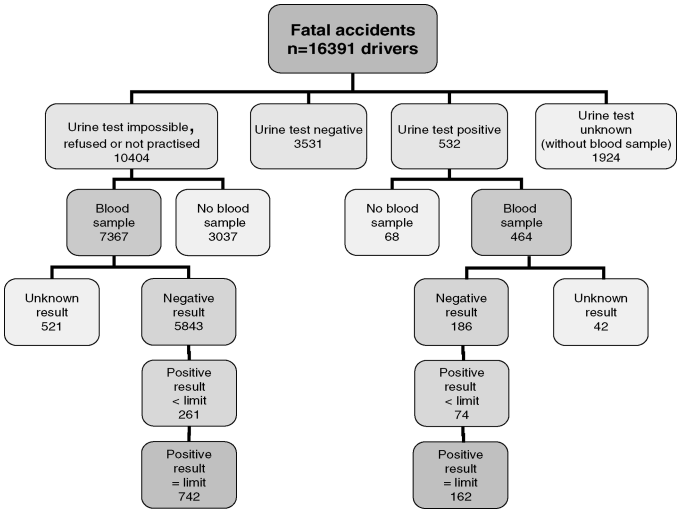

Figure 1 Searching for illicit drugs ($n = 16,391$ drivers): urine tests and blood analysis.

negative and 1,030 positive, with 742 over the regulatory detection level).

- The procedure of urine tests followed possibly by blood tests: a total of 4,063 urine tests and 3, 953 known results (of which 3,717 are negative and 236 positive, with 162 over the regulatory detection level).

These procedures are of unequal weight: the direct blood test procedure represents two thirds of the known results (63% of known results at the base). Deceased drivers, in particular, as well as the majority of the seriously injured, go through this procedure, while the majority of those suffering no or only minor injuries undergo the prior urine test.

All the research studies looking for the prevalence of drugs in populations of drivers involved in accidents carried out abroad involve deceased or hospitalized subjects. It is usually necessary to select hospitalized subjects in order to obtain blood samples. The French data collection procedure made it possible to circumvent this constraint and to work on a base comprising every driver involved in a fatal accident, including uninjured people who may also have been the cause of the accident. Furthermore, the subgroup of those who pass through the direct blood test procedure is comparable to the populations studied in research studies conducted in other countries.

Drivers who have tested negative were not screened for medicines, and very few of the drivers who tested positive were found to be under medication alone. Furthermore, laboratories' testing practices proved to be heterogeneous. Finally, the medicine issue, which deserves a study for itself, was not dealt with in this research.

Blood concentrations were found to be positive for one of the families of drugs in 1,239 drivers, independently of the minimum regulatory thresholds: 1,003 cases were identified through direct blood tests and 236 through urine tests prior to the blood tests.

However, for more than one in four drivers the concentrations found were below the regulatory detection limits currently fixed by law: actually 904 drivers were found to be under the illegal influence of drugs (according to the regulatory norms).

Out of the 16,391 drivers analyzed, the outcome of the screening for drugs is known in 10,799 cases. Therefore, no result is available for 34% of drivers. Several possibilities could explain this general failure to produce a result, which affects 5,592 drivers altogether. Blood samples that are not taken where the urine test was not possible or refused (although this last case is very rare) form part of the many data that are missing (55% of the missing data); after this come urine tests that are possible but not carried out (34% of the missing data); and about 10% of the blood samples taken did not produce any result. It is significant that the proportion of positive tests not followed by a confirmatory blood test is low (1%). Apart from the state of the injured person, a lack of equipment is the reason most frequently cited by doctors to justify the non-performance of a urine test or a blood test.

This overall proportion of missing data (34%; that is, one third) may seem considerable. But one might point out that it is of the same order as the proportion of missing data in the first epidemiological survey conducted into the role of alcohol (carried out in 1970). Regarding the SAM study, when one compares the proportion of missing data in the case of testing for alcohol (10%) with that in the case of testing for drugs (35%), one appreciates to what extent the system of testing for alcohol is now operating smoothly.

An analysis of the drivers concerned by this absence of results yields profiles according to age, sex, the state of the victim, and responsibility for the accident, which are similar to the entire population, and enables one to consider the results as representative.

The time that elapses between the accident and the moment the blood sample is taken for the purpose of testing for drugs is of paramount importance in confirming a case of driving under the influence, especially regarding cannabis when the blood marker is THC. In this regard, one would point out that the dose absorbed after smoking a joint varies, but THC, whose peak concentration is reached within 10 minutes of an isolated intake, remains detectable in the blood (with the usual detection limits of 1–2 ng/mL) for a maximum of 4–5 hours (Verstraete, 2002); it can be more reliably detected within 2 hours. THC-COOH, which can be detected within minutes of being consumed, may remain present in the blood a longer time (12 hours or more). 11-OH-THC is detectable for 4–5 hours, but the concentrations are low, which is why it is rarely mentioned in road safety research. One generally considers that the presence of THC in the blood is evidence of a recent consumption, while the presence of THC-COOH may indicate a past consumption.

The time taken depends greatly on the place where the blood sample is taken (at the site of the accident, in a hospital or clinic, on other specialist premises, or in a doctor's surgery). In more than half of cases, the blood sample is taken directly at the site of the accident, while the others are taken in a hospital environment. As has been seen, a large proportion of the results (63%) originate from the direct blood test procedure, but the procedure involving prior urine tests accounts for 37% of the results. However, the urine test procedure considerably increases the time lapse between the accident and the taking of the blood sample. The urine test is usually carried out in a hospital or clinic after a lapse of time following the accident that exceeds 2 hours in the majority of cases, and often 3 hours.

The time between the accident and the taking of the blood sample, which averages 3 hours without a prior urine test (it is less than 4 hours in 83% of cases), increases to 41/2 hours in the procedure involving prior urine tests (less than 4 hours in 61% of cases). For the total population studied, the lapse of time between the accident and the taking of the blood sample remains less than 4 hours in a very large majority of cases (82%), which ensures a high degree of reliability for the results as a whole.

As a general rule, drivers involved in accidents who are identified by the system put in place as under the influence of drugs certainly are under the influence. The main exception of note

concerns the opiate class of drugs, whose presence is quite frequently found to be linked to a therapeutic usage prior to the accident or to a medical administration just after it (morphine).

Whereas the presence of drugs is established solely through a blood test, diagnosing their absence is not effected uniformly. It is established solely on the basis of the urine test in some cases (about one third) and on the basis of the blood test in the others (about two thirds). But the reliability of the urine tests selected for correctly sorting out the negative cases cannot be questioned, unless more ample information is provided by specific experiments. The possibility of false negatives resulting from urine tests cannot be excluded, however. Because a more reliable, quick method is not available at present, the procedure involving prior urine tests remains relevant, although in practice it lengthens considerably the time lapse before confirmation.

In the conditions in which they were applied during the survey, urine tests seemed more suitable for detecting drivers under the influence of cannabis than of other drugs, especially cocaine and amphetamines.

Overall, the quality of the data collected, although they vary according to the substance, are found to be perfectly satisfactory in the case of cannabis, which is by far the most common situation encountered.

Alcohol. Searching for alcohol levels (which serves as a paradigm for searching illicit drug levels) has also, since 1970, taken place in two steps: a screening breath test is performed by means of an ethylotest to see whether it is above the legal limit, and in the event of a positive result, a confirmatory measure is performed either by mean of a blood sample analysis or a ethylometer breath sample analysis; the blood analysis can be conducted directly if the breath screening is impossible or refused.

The results are shown in the flowchart reproduced in Figure 2. Among the 16,391 drivers involved, 9,568 preliminary breath tests (ethylotests) were impossible or refused, 6,758 preliminary breath tests were performed, while no information or measure appeared for 65 drivers.

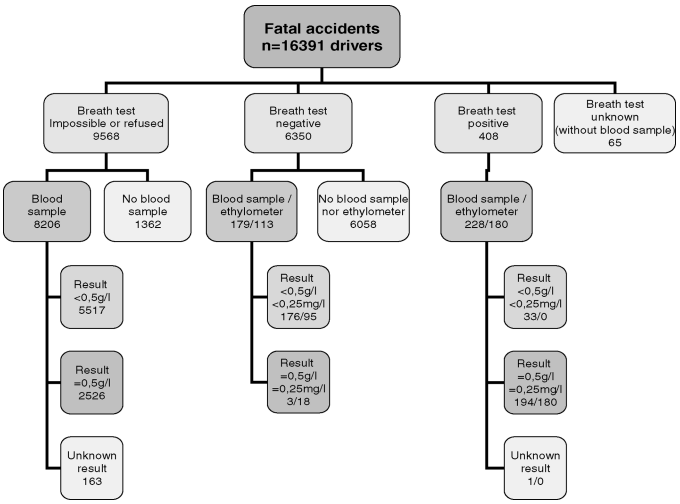

Figure 2 Searching for illegal alcohol levels ($n = 16{,}391$ drivers): prior tests and confirmatory results (by ethylometer or blood sample).

For 8,206 drivers, the blood sample was taken directly (86% of the drivers for whom the preliminary breath had been impossible or refused).

The evidence test after a positive preliminary test was performed in every case, more often by means of blood sample than by ethylometer.

In summary, the investigation of illicit alcoholization gave results for 14,800 drivers out of the 16,391 entered in the study: 11,879 were under the legal alcohol limit and 2,921 over the limit. The missing data rate is thus about 10% (9.7% exactly).

So far, drug levels are known for 10,799 drivers and alcohol levels for 14,800 drivers. Data on the presence or absence of drugs (at regulatory detection levels) and data on blood alcohol levels above or below the legal limit are often present together. Where there is information available about drugs, there is almost always information available on alcohol levels. The reverse is not always true.

Blood drug concentrations and blood alcohol concentrations are known for a subsample of 10,682 drivers. When examined from the point of view of sex, age, day and time of accident, and responsibility, this group is similar to the population study. So according to the main variables, no bias affects the representativity of this subsample. We may therefore perform the analysis of the drug consumed on this subsample.

Prevalence and Characteristics of Drivers Under Alcohol and/or Drug Influence

The concentrations of drugs in the blood are known for the subgroup of 10,682 drivers for which the testing procedure effectively produced a result. The substances consumed are analyzed for that subgroup, which was ascertained to accurately represent all the drivers involved.

Prevalence of alcohol and drugs. A total of 26% of the population (2,796 among 10,682) were under the influence of illicit consumptions, either above the blood alcohol limit or above the detection limit for at least one of the other drugs.

As shown on Figure 3, alcohol remains the substance more largely consumed at illegal levels among these drivers: 21% are above 0.5 g/L. Following alcohol, cannabis is by far the most frequently observed substance since 6.8% of drivers test

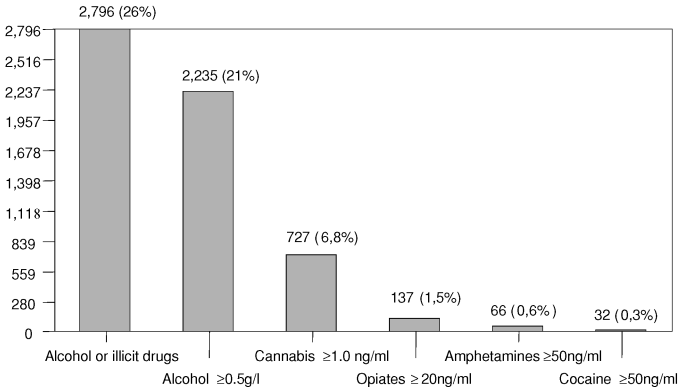

Figure 3 Prevalence by type of drugs ($n = 10{,}682$).

positive for cannabis over the detection limit, while 1.3% are positive for opiates, 0.6% for amphetamines, and 0.3% for cocaine.

As THC is the psychoactive agent of cannabis and its presence in blood over a fixed detection level generally reveals a recent consumption that can impair driving behavior, the risk assessment in the SAM study (Laumon et al., 2005) is based on blood THC concentrations, with a regulatory detection limit of 1 ng/mL.

Nevertheless, a number of drivers were found with a THC measure non-null but under the regulatory limit of detection (80 drivers); moreover, for other drivers, only the presence of metabolites (without THC) was observed (184 drivers). Taking these results into account raises the proportion of drivers involved in accidents after cannabis consumption: 9.3% of drivers have consumed cannabis in the past (some hours or even some days before the accident), compared with 6.8% who consumed recently (within 4 hours before the accident).

Analysis of the drugs consumed alone or in combination. Out of the 10,682 drivers with known alcohol and drug concentrations, 1,908 (17.9%) were under the influence of alcohol alone (over the legal limit of 0.5 g/L; Table III). For the whole set of other drugs, 888 drivers out of 10,682 (8.3%) were positive over the regulatory limit: 327 (3.0%) combined alcohol with other drugs, 561 (5.3%) were under the influence of other drugs without alcohol.

Table III shows the prevalence of drugs according to all possible combinations.

Among these drug-positive cases, 821 drivers (that is, 92% of them) consumed only one drug. That drug was primarily cannabis (669 drivers, 75% of the population under the influence), with opiates far behind in second place (107 drivers, 12%). The proportion of those having consumed solely amphetamines was about 3% (28 drivers) and those solely cocaine about 1% (9 drivers).

Alcohol is often associated with the consumption of drugs: 37% of people involved in accidents who are under the influence of drugs also have illegal blood alcohol levels. It is first and foremost cannabis that is most often combined with alcohol: of 727 drivers who were under the influence of cannabis, 292 drivers, or 40% (2.7% of the total population), were under the influence of alcohol at the same time.

A study of the combination of substances according to this table shows that, apart from the notable association of alcohol and cannabis, multiple consumption by the population of drivers involved in accidents is relatively rare.

Differences between drivers under the influence of alcohol alone, cannabis alone, and the combination alcohol-cannabis. Three main groups of drivers are to be focused upon as they represent the major stakes: the 1,908 drivers under the influence of alcohol alone, the 391 drivers under the influence of cannabis alone, and the 278 drivers who combine alcohol and cannabis. The drug-free group, 7,886 drivers with neither illicit drug nor alcohol, serves as a reference group. When comparing these subpopulations, clear differences can be observed and are analyzed below.

The drivers involved under the influence of alcohol and/or cannabis were mainly young adults: 55% were aged 20–34 years compared to only 37% in this same age group in the drug-free population (with neither alcohol nor other drugs).

The profiles by age (percentages of drivers by age group in each of the subsamples) are represented on Figure 4.

Cannabis is noteworthy insofar as its consumption is concentrated in young drivers. Drivers involved under the influence of cannabis alone as well as those involved under a cannabis/alcohol combination are mainly found in the 20–24

Table III Breakdown by combinations of drugs ($n = 10{,}682$)

		Total	With alcohol (≥0.5 g/L)	Without alcohol (<0.5 g/L)
No drug		9,794	1,908	7,886
Only one drug	Cannabis ≥ 1 ng/mL	669	278	391
	Opiates ≥ 20 ng/mL	107	4	93
	Amphetamines ≥ 50 ng/mL	28	1	7
	Cocaine ≥ 50 ng/mL	17	5	12
	Total one drug	*821*	*308*	*513*
Two drugs	Cann/Amph	26	8	18
	Cann/Opia	20	5	15
	Cann/Coca	6	1	5
	Opia/Amph	5	3	2
	Amph/Coca	2	2	
	Opia/Coca	2		2
Three or more drugs	*Total two drugs*	*61*	*19*	*42*
	Total 3 or more drugs	6		6
	Total drugs	*888*	*327*	*561*
	Total	10,682	2,235	8,447

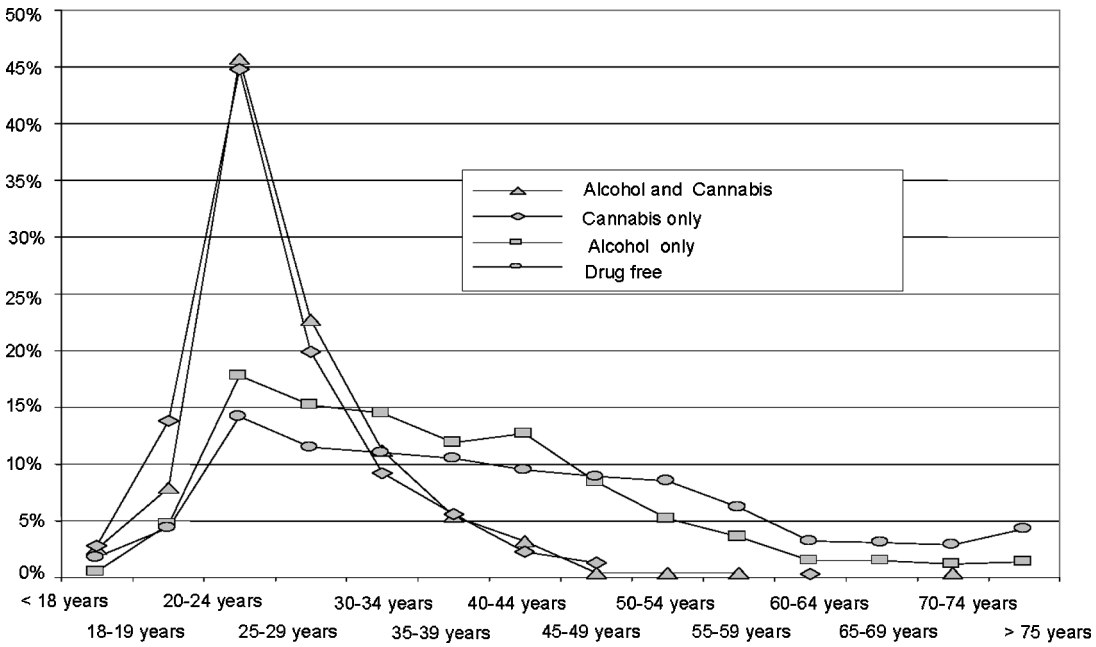

Figure 4 Age profiles of the four groups of drivers: alcohol alone ($n = 1{,}908$), alcohol in combination with cannabis ($n = 278$), cannabis alone ($n = 391$), and drug free ($n = 7{,}886$).

age group (respectively, 45 and 46%), then among these 25–29 (respectively, 20 and 23%). There is a very significant overrepresentation of those 18–29 in the cannabis (78.5% of the group) and cannabis/alcohol (76.1%) groups in comparison with the drug-free group (30.1%).

As to drivers involved with alcohol alone at illegal levels, they are overrepresented in the 20–44 age group: the proportion is 72.1 vs. 56.7% in the drug-free group, but the overrepresentation of young drivers with alcohol alone is less spectacular than for cannabis.

The breakdown of the drivers involved under the influence according to age groups reflects the breakdown of alcohol or cannabis consumers in the global French population (OFDT, 2005).

Partly in relation to age, drivers involved under the influence of alcohol, and even more under the influence of cannabis, were more often moped riders or motorcyclists than drug-free drivers (22.5% of drivers under cannabis alone vs. 11% in drug-free drivers).

The proportion of drivers involved in single-vehicle accidents is higher in the group of drivers under the influence of alcohol with or without cannabis (62%) than in the group of drivers under the influence of cannabis alone (34%). As this proportion of drivers in single-vehicle accidents is 23% in the drug-free group, it makes sense to consider that there is less difference between accidents under cannabis and accidents without any substance than under cannabis and alcohol.

Alcohol (alone or in combination with cannabis), by comparison with cannabis or absence of drugs, is more characteristic of involvement on weekends. Respectively, 58, 32, and 27% of the drivers involved on weekends are under the influence of alcohol, cannabis, and no drug. A more detailed analysis of the drugs detected according to the day of the week (Figure 5) shows a fairly uniform breakdown of drivers involved with cannabis and of drivers drug-free all week long. Conversely, the share of drivers involved with alcohol strongly rises at the end of the week.

More precisely, drivers under the combined influence of alcohol and cannabis are particularly involved at night from 9 pm to 7 am, especially on weekend nights; the same feature is observed for drivers involved under the influence of alcohol alone (Figure 6).

By comparison, drivers under the influence of cannabis alone are more specifically involved during the week at any time of the day but especially in the afternoons; in that, they are similar to drug-free drivers.

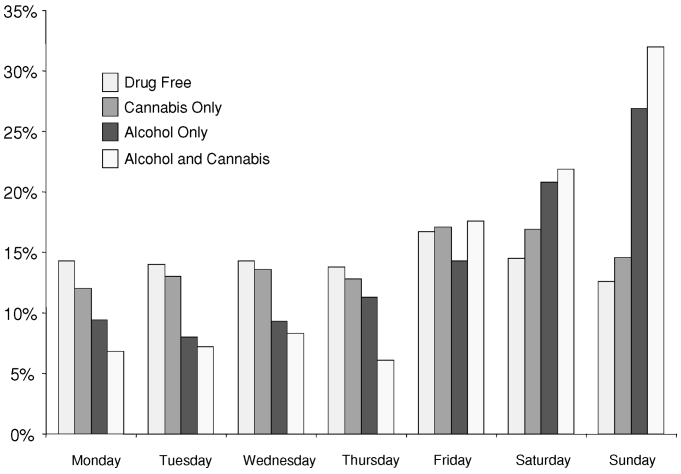

Figure 5 Prevalence of alcohol and cannabis by day of the week.

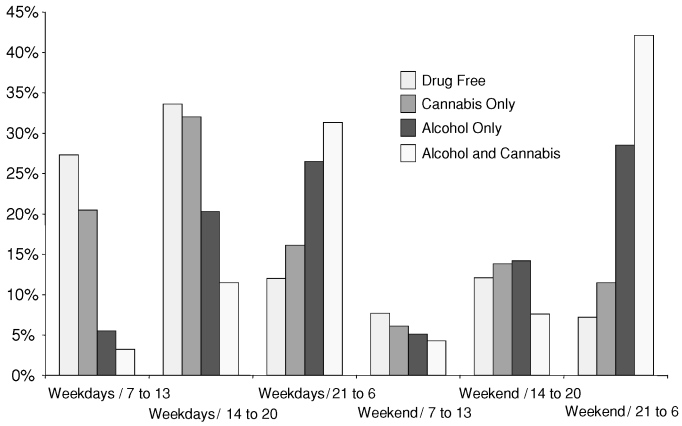

Figure 6 Prevalence of alcohol and cannabis by type and time of day.

On the whole, in the population under study (10,682 drivers), more than half of the drivers (56%) are involved during a leisure trip. This share is higher for drug-positive drivers: 60% in case of cannabis alone, 74% in case of alcohol alone, and 79% in case of an alcohol-cannabis combination.

The drivers involved during a professional or home-to-work trip represent 31% of the drug-free drivers; this share is 10% for drivers under the influence of alcohol alone and 5% for drivers under alcohol and cannabis, while it is 26% for drivers under cannabis alone. This observation shows, once again, a greater similarity between accident-involvement features of drug-free and cannabis-influenced drivers than between accident involvement of cannabis- and alcohol-influenced drivers.

More than one in two of the drivers involved under the influence of cannabis (54%) are killed; this proportion is markedly higher for drivers with alcohol alone (75%) and, as expected, for drivers combining alcohol and cannabis (79%). At the opposite, the percentage of uninjured drivers is 9% for drivers under alcohol alone (5% for drivers under the combination alcohol-cannabis) and 24% for drivers under cannabis alone, whereas this share is 35% for drug-negative drivers.

It was possible to assess the responsibility of 9,998 drivers out of the 10,682 under study; for the other 6.4% of drivers, the responsibility has remained undetermined.

The proportions of drivers responsible are calculated for the different subsamples of interest (Table IV).

The index measuring the overrepresentation of drivers responsible (%responsible/% not responsible) is 1.7 over the whole population; this reflects the fact that drivers involved in single-vehicle accidents are usually judged responsible for their accident. The responsibility index falls to 1.2 in the drug-free population. It rises to 2.3 for cannabis alone (THC $\geq$ 1 ng/mL), to 9.4 for alcohol alone, and to 14.1 for the alcohol-cannabis combination. So the drivers under the influence of alcohol, whether also under cannabis influence or not, are more often responsible for their accidents than drivers having consumed cannabis alone or drivers detected negative to alcohol as well as any other drug. The rise of the responsibility index for alcohol is remarkable.

Comparison with other countries. Like all accident surveys, cannabis is at the top of the list of drugs detected in this survey: it is found in 9.3% of the drivers (non-null THC or metabolites concentration). A comparison with other countries, or even with other research studies in France, requires extreme rigor both in terms of the populations studied (killed, injured, unscathed) and in terms of toxicological levels, which are often not very explicit.

The samples obtained and the definition of "positivity" used, which vary from one study to another, are the reason why the prevalence of cannabis varies greatly between countries and surveys (Biecheler, 2006): the figure ranges from 4 to 14% (and from 6 to 14% in France).

If one looks solely at drivers who pass through the direct blood test procedure (who are usually killed or seriously injured), 11.5% of them are found to have cannabis (THC or metabolites) in their blood and 8.6% are under the influence of its active ingredient THC (Biecheler et al., 2006). These last levels prove to be quite close to those reported elsewhere on populations of killed or injured, since in the majority of surveys carried out over the past decade using blood as the detection milieu, whether in Europe, the United States, Canada, or Australia, cannabis use is found in about 10% of drivers killed or injured in road accidents—and sometimes in more than that, in as many as 14% when prevalence is also assessed on the basis of THC metabolites (Drummer et al., 2003; Pépin et al., 2003).

DISCUSSION

The search for drugs targeted at immediately fatal road accidents was designed as far as possible to be an exhaustive study of all the drivers involved, which gives an idea of the considerable data-collection work involved over the 2 years concerned. This wish for exhaustiveness is an essential virtue of the study. The regulatory framework that determined the conditions for the collection of the data encouraged the particularly rapid im-

Table IV Index of responsibility (% responsible/% not responsible) according to alcohol and/or cannabis presence

	Alcohol or other drug free	Cannabis alone THC $\geq$1 ng/mL	Alcohol alone $\geq$0.5 g/L	Alcohol and cannabis	Total population
All drivers	7,886	391	1,908	278	10,682
Known responsibility	7,339	360	1,823	272	9,998
Responsible	3,996 (54.4%)	252 (70%)	1,647 (90.3%)	254 (93.3%)	6,294 (63%)
Not responsible	3,343 (45.6%)	108 (30%)	176 (9.7%)	18 (6.6%)	3,704 (37%)
Resp/not resp	1.2	2.3	9.4	14.1	1.7

plementation of a homogeneous and better assimilated set of actions by the police force insofar as it was based on the research model for testing for alcohol. The two-year period, which was relatively short, was also a factor in the consistency of the data collected. The large scale of the sample—about 17,000 drivers involved in fatal accidents—is the essential virtue of this study, which is now the study of reference in France (Groupe Sam et al., 2005; Laumon et al., 2005).

The high incidence of alcohol or drugs among the population of drivers involved in fatal accidents (at levels above the legal limits in 26% of the drivers involved in accidents) highlights the very great importance for road safety of the consumption of these substances. Cannabis is top of the list of illicit drugs detected, with a prevalence of 9.3% (THC or metabolites) or 6.8% (THC $\geq$1 ng/mL). The prevalence of drivers involved in fatal accidents who are under the influence of cannabis is relatively high but somewhat lower than the 10% rate often observed in studies of the injured taken to hospital. However, if one takes only drivers who are killed or injured, as is the case in the majority of studies conducted in other countries, these rates rise to 11.5% (THC or metabolites) and 8.6% (THC $\geq$1 ng/mL), respectively. France thus remains within the average for the generally observed prevalence levels of cannabis observed in people involved in accidents in Europe, the United States, and Australia.

We would point out that the French survey conducted 10 years earlier on a population of about 2,500 drivers hospitalized after accidents (Schermann et al., 1992) indicated the presence of THC in about 6.5% of drivers. This proportion of the most comparable cases (the direct blood test procedure and THC > 0) would be of the order of 9.5% today. The similarity of these rates of prevalence suggests an increase in the proportion of drivers involved in accidents who are under the influence of cannabis over the past 10 years.

Although cannabis is at the top of illicit substances, its prevalence arrives far behind alcohol, which affects nearly 21% of drivers. The combination of the two substances affects 2.7% of the drivers involved in fatal accidents.

According to their consumption (alcohol alone, cannabis alone, cannabis and alcohol in combination, no substance), drivers involved can clearly be distinguished by the age criteria: drivers detected as alcohol-positive, and even more as cannabis-positive, are younger than in the general population.

The surprise is to note that, from the point of view of accident characteristics (number of vehicles, type of trip, accident day and time, severity, responsibility), drivers detected negative for all substances are similar to drivers detected positive for cannabis only but markedly different from drivers under the influence of alcohol at an illegal level (combined with cannabis or not).

As the underlying populations are different, as sharply illustrated by age differences, this suggests that the circumstances at the origin of the accident are not of the same nature in case of alcohol consumption or in case of cannabis consumption without alcohol. Some further investigations are necessary to clarify this point.

The overrepresentation of drivers responsible (% responsible/% not responsible) from 1.7 over the whole population rises to 2.3 for cannabis alone (THC $\geq$1 ng/mL), to 9.4 for alcohol alone ($\geq$0.5 g/L) and to 14.1 for the alcohol-cannabis combination. This is a strong indication of the graduation of risks.

Further analysis of alcohol risk by the SAM Group, aimed at establishing an appropriate methodology the risk curve especially at low doses, is in progress in France and the results expected at the end of 2007. In the United States, the study by Blomberg et al. (2005) conducted with robust experimental design and advanced multivariate statistical methods confirms, as shown by the authors on their final adjusted risk function, the dose relationship beginning since 0.4 g/L as well as the extraordinary magnitude of the crash risk at high BAC (>1 g/L). This study found no significant elevations of the risk at BAC under 0.4 g/L. This is a point of particular interest to be investigated from French data.

With the use of a case-control design and after adjustment for different cofactors, the relative risks calculated by Laumon et al. (2005) allow us to say that the recent use of cannabis (THC) doubles the risk of being responsible for an accident, the combined use of cannabis (THC) and alcohol multiples the risk by 15.

In other respects, the SAM study was able to show that, during the 2 years of the study, the annual number of road accident fatalities attributable to cannabis in France was of the order of 230 (Laumon et al., 2005). By comparison, the annual number of road accident fatalities attributable to alcohol was nearly 10 times higher, or 2,270.

Today, with 6.8% of drivers involved in accidents being under the influence of cannabis, as attested by THC levels, and 2.7% under the simultaneous influence of alcohol and cannabis, the phenomenon seems to be contained, but the significant upward trend in regular cannabis consumption among the general population (Beck et al., 2006, 2007) could amplify the corresponding road safety risks in the future.

Among people involved in accidents, one finds relatively few who are multiple drug consumers. It was not possible to quantify the specific effects of amphetamines, cocaine, and opiates, essentially due to the limited number of drivers who test positive. One may assume that these three families of drugs are not a major road safety factor in France today, even though they have to be monitored closely in relation to their health risks.

Over and beyond the increasingly precise evidence of the role of cannabis as a factor of risk in road accidents at the level of a given population (quantified risk), substantial progress has been made in the observation system itself: biological environments, thresholds, and testing devices adapted to road use. Given the laboriousness of the current system, entailing urine tests in a medical environment, saliva tests that are usable by police officers are very eagerly awaited. While none of the commercial devices currently available have been able to show sufficient precision when compared with blood tests (Verstraete, 2005), substantial progress has been made in this area over the past few years and work is continuing. Correlations between saliva/blood

concentrations of THC (analogous to air/blood concentrations for alcohol) create the hope that devices usable in road surveys will emerge, opening the way to other epidemiological studies on the model used by Borkenstein in the case of alcohol and to easier means of prevention on the road.

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