CANNABIS AND DRIVING: A REVIEW OF CURRENT EVIDENCE

Lenné, M., Triggs, T., & Regan, M.
Accident Research Centre, Monash University

Abstract

There is currently much debate in the road safety and wider communities concerning the extent to which licit and illicit drugs are a road safety problem. Cannabis is the most widely used illicit drug in Victoria, and is being used by a growing proportion of the population, particularly younger people. Contrary to data from the early to mid-1990s, recent Victorian crash data suggest that cannabis does elevate crash risk. It is therefore timely to draw together the international literature in regard to the issues around cannabis use and road safety. This paper is based on a report that is currently being prepared for the baseline sponsors of MUARC. The full report reviews the key issues concerning cannabis and road safety, including: patterns of cannabis use in the population; the prevalence of cannabis in the driver population, drivers suspected of driving under the influence, and drivers killed or injured; effects on simulator and on-road driving; detecting cannabis use in bodily samples; and measuring impairment using performance tests such as the Standardised Field Sobriety Test. The report highlights the current gaps in knowledge and documents the specific areas of research that need to be pursued in future studies in order to move closer to resolving the issue about whether (and how) cannabis influences driving skills. This paper summarises the key themes that emerge from the full report.

Cannabis use in Australia

Cannabis is the most commonly used illicit drug in Australia is used by a wide section of the community. The 1998 National Drug Strategy Household Survey reported that 39% of Australians over 14 years of age had used cannabis at least once, while 18% had used recently (1). The proportions are higher for the younger males – 68.3% of males aged 20-29 have ever used cannabis (59.3% for females), and 44.8% reported using recently (compared to 28.9% for females). Of the recent users aged 14-19 years, 60.3% of males and 45.8% of females reported using at least once a month. For those aged 20-29, 64.7% of males and 53.6% of females reported using at least once a month.

Cannabis and driving

Epidemiological evidence

In order to gain a clear understanding of the extent to which drivers around the world are driving while impaired by drugs, it is critical that substantial data be collected on the prevalence of drug use in the general driving population. While such epidemiological studies are yet to be conducted, some data had been collected from roadside surveys that provide some insight into the extent of drug-impaired driving worldwide.

Roadside surveys conducted in Germany and The Netherlands suggest that the prevalence of alcohol and cannabis in drivers sampled is alcohol (6-12%) and cannabinoids (1-5%) (2). The incidence of drugs increases when data from both drivers suspected of driving under the influence and from drivers killed or injured are considered. European data shows that alcohol is clearly the most common drug detected, being found in up to 95% of suspected drivers (3). Cannabinoids are confirmed to be present for between 2.4% in Finland (3) and 57% in Switzerland (4). Data have also been collected on the prevalence of drugs in (European) drivers who are injured or killed. The most prevalent drug is by far alcohol, present in up to 63% of injured drivers (5). Cannabinoids have been found in 7.6% of injured drivers (5) and 1.5% of drivers killed (6).

Alcohol and cannabinoids have been found in 27% and 11% fatally injured drivers in Australia (7), and in 8.6% and 7.1% of drivers injured in South Australia (8). Olaf Drummer's paper in these proceedings addresses more recent accident data and culpability analyses.

While the epidemiological studies have demonstrated that cannabinoids are present in the blood of a significant proportion of drivers involved in accidents, the contribution of the drug to the accident remains unclear. Further studies are required to gain a better understanding of the patterns of drug use in the driving population, and to conduct definitive analyses of crash data that demonstrate a casual link between cannabis use and crashes, as well as characterising those crashes.

Driver performance studies

While much research has shown that cannabis impairs performance on simple tasks in the laboratory (9), the effects on simulated and on-road driving remain less clear.

There have been several reviews of the effects of cannabis on driving (10-13). Briefly, the simulator and on-road studies conducted pre-1990 used doses ranging from around 4 mg to 16 mg THC (approx. up to 200 ?g/kg). The decrements associated with cannabis include increased braking time, increased lateral deviation, increased number of cones hit, increased speed variability, and impaired secondary task performance. Increased headways and reduced mean speed (or increased lap times) have also been reported, but are interpreted in these studies as being indicative of the participants' abilities to compensate for the effects of the drug. These effects are not always apparent in all studies. In fact, the majority of studies only report decrements to one or two measures of performance at most. Although there are some inconsistencies, in general it is agreed that cannabis does appear to impair driving performance as measured in these settings, although it is also apparent that the quantitative and qualitative nature of this impairment remains unclear.

A significant study in the area of cannabis and driving was completed very recently (14). This UK study examined issues such as the effects of cannabis on driving, mood, and hazard perception, the link between saliva and blood levels of THC, and the link between sobriety test performance and driving simulator performance. For this reason it is pertinent to discuss the methodology and findings from this study in some detail.

Participants were 15 males with a mean age of 27 years. All smoked cannabis at least once a week, all drank alcohol at least once a week, and 46% used other drugs – ecstasy easily being the most frequently used other drug (72%).

Four doses of cannabis were used in this study, and they were: Placebo, 0.005% ? 0.002 of THC; Low dose, 1.70% ? 0.14 THC; High dose: 2.67% ? 0.04 THC; and Cannabis resin (about 1.7% THC). Blood, urine, and saliva samples were taken upon arrival, and 10, 25-35, and 95-100 minutes post-smoking.

Performance was measured using a driving simulator, a hazard perception task, and a compensatory tracking task. The driving simulator used was a silicon graphics powered computer system that seems very similar to the Mid Range Driving simulator at MUARC. There were three components to the simulator drive. The first was a motorway drive which consisted of a 3-lane road. Other vehicles on the road were programmed in a way that their actions were linked to the speed of the participants' car. However, other vehicles were programmed to place the driver in a situation that required an immediate response, such as a car pulling out in front or braking suddenly.

The second component of the drive involved driving a 'figure of eight' loop. Participants were asked to drive between 30 and 40 mph through two large loops with constantly changing curve radii. The participants were therefore required to make continuous steering corrections in order to stay in the middle of the lane. The third and final component of the drive was a dual-carriageway with four intersections with traffic lights. The signals changed colour as the driver approached and the reaction time to these changes was measured.

The hazard perception task involved viewing video recordings of situations that would require the driver to take immediate action such as swerving or braking suddenly. The reaction time to detect hazards and the proportion of hazards detected were the dependent measures. Finally, the compensatory tracking task involved tracking a moving circle on a computer screen with the mouse while concurrently responding to the changing colour of symbols in the four corners of the screen. Visual Analogue Scales were used to assess mood.

Sobriety testing was also conducted. The impairment testing included pupil size, measured by a Pupilometer; presence of lateral and vertical nystagmus and convergence; the walk and turn test, one leg stand; finger-nose test; and Romberg's test with internal clock. A physical examination comments on general demeanour and behaviour, examination of speech, pulse, temperature, ears, eyes, heart, lungs, blood pressure and reflexes. Results from the impairment testing and physical examination were used by the expert to determine whether the individual was impaired, and whether that impairment might be due to the presence of a drug.

Further analyses were conducted using simulator and subjective mood data to compare the performance of those participants who were judged by the forensic medical expert to be impaired with the performance of those participants who were not impaired. For only three of the eight simulator measures was there a difference between those participants who were and were not impaired (mean speed, and SDLP on the figure of eight for both left and right curves). For only one of the eight driving measures was there a difference between those participants whose condition was due to a drug compared to those whose condition was not due to a drug, as judged by the forensic medical expert.

There was, however, strong agreement between the subjective estimates (by participants) of the levels of impairment and intoxication with the forensic medical expert's determinations of impairment and whether a drug was likely to have caused that impairment. This suggests that the participants were acutely aware of their impairment under the influence of cannabis.

The mean maximum levels of cannabis across the conditions were 11.5 mg for the low dose, 17.9mg for the high dose, and 4.7 mg for the resin condition. The blood levels of delta-9-THC (in ng/ml) at 10 and 30 minutes after smoking for the high dose were 478 and 105, for the low dose were 370 and 102, and for the resin condition were 116 and 58. The 10 minute time point was selected because it has been suggested as the time that THC concentrations are at their peak. While the blood levels for the high dose were considerably greater at 10 minutes post-smoking than for the low dose, the blood levels are almost identical for the high and low dose conditions at 30 minutes post-smoking.

Cannabis did not have a dramatic influence on driving performance. Cannabis reduced mean speed, which was interpreted as the participants being aware of their impairment, and adjusting their performance to make the task easier, thereby compensating for the effects of cannabis by reducing speed. The primary degrading effects of cannabis were on tracking ability, as seen by impaired performance on the figure of eight task. This is consistent with previous research that shows that cannabis initially affects psycho-motor performance as opposed to higher-order cognitive processes.

With regard to on-road studies, the most comprehensive series of on-road experiments were conducted by Robbe (15) in Maastricht, The Netherlands. Because his research contributes significantly to the cannabis and driving debate, it will be discussed in some detail. The first driving experiment examined the effects of cannabis on restricted highway driving. Twenty-three people participated, all who used cannabis more than once a month but less than weekly, and all who attended four sessions with THC doses of 0 (placebo), 100, 200, and 300 ?g/kg. The average amount consumed for the three cannabis conditions was 6.8, 13.6, and 20.4 mg THC, which equals 94, 186, and 282 ?g/kg. The participants drove along an 11 km stretch of highway that was closed to traffic. This was done for 20 minute periods at 30 and 90 minutes after smoking had finished. Blood samples were taken immediately before the driving tests. The mean plasma concentrations of THC at 30 and 90 minutes post-smoking for each condition were: 100 ?g/kg (9.5 & 3.5 ng/ml); 200 ?g/kg (15.9 & 4.8 ng/ml); 300 ?g/kg (20.7 & 6.2 ng/ml).

Females displayed higher standard deviation of lateral position (SDLP) than males, although this effect was not related to cannabis dose. All three doses of cannabis increased SDLP compared to placebo, but there were no differences in SDLP across cannabis dose. There was no difference in SDLP for the two driving tests. Changes in mean speed and standard deviation of speed and steering angle were not affected by cannabis. Perceived driving quality was lower for all three cannabis doses than placebo, and perceived effort increased with increasing doses. Cannabis decreased alertness, particularly for the first driving test.

SDLP was not correlated with plasma levels of THC, or the participants' frequency of cannabis use. Excessive SDLP occurred in four subjects for each of the two highest cannabis conditions, but occurred in the second drive, when plasma levels were lower. This illustrates the futility of estimating SDLP from single measures of THC (15). Finally, the decrements in SDLP after high dose THC were estimated to be equivalent to impairments at a BAC of around 0.07%.

Following on from restricted highway driving, Robbe's second experiment was conducted in normal highway traffic. The doses of cannabis used were the same as in the first study, and the mean amounts of cannabis consumed in the three cannabis conditions by the 15 participants were 6.9, 13.8, and 20.7 mg. A car following task was performed between 55–85 and 140–170 minutes after cannabis use. This required the participants to respond to changes in the behaviour of a lead (experimental) car while maintaining a headway of 50 metres and travelling at 100 km/h. A standard driving test was conducted for 50 minutes and began 85 minutes after cannabis use. Participants were asked to maintain a constant speed of 95 km/h.

SDLP was significantly higher after the two highest cannabis doses. Mean speed, and standard deviations of speed and steering wheel angle were not significantly affected by cannabis. In the car following task, mean headway was significantly greater in the low THC dose condition but the two higher doses had no effect. When adjusted for headway, cannabis did not affect the reaction time to respond to changes in the speed of the lead car.

To summarise the work by Robbe (15), Robbe himself concludes that his findings corroborate the findings from other simulator and on-road studies in that "THC in single inhaled doses up to 300 ?g/kg has significant, yet not dramatic, dose-related impairing effects on driving performance." (p. 170). The effects of cannabis are indeed small because the participants attempt to compensate for the adverse effects of cannabis (15). The participants were aware of the effects of cannabis as shown by the lower ratings of driving quality and higher ratings of perceived effort after smoking cannabis. However, despite compensating by increasing headway and slightly reducing mean speed, the participants were not completely able to compensate for the adverse effect on SDLP. Robbe (15) suggests that this is because SDLP is primarily controlled by an automatic information processing system that operates beyond conscious control.

Finally, Robbe (15) suggests that the compensatory effects of cannabis come at a cost to the driver. The increased ratings of perceived effort after smoking cannabis, perhaps by focussing attention, would lead to a reduction in spare capacity. So while drivers were able to maintain basic levels of driving skill (with the exception of increased SDLP) after using cannabis, they may not be equally able to perform in situations of higher mental load. One of the clear messages to come from this research is that there is a need to research the effects of cannabis in situations where the driver is required to perform several tasks simultaneously or when confronted with a situation that requires a rapid adaptive response. This is one of the recommendations that Robbe makes in relation to future research.

To conclude with this benchmark research into the effects of cannabis on actual driving, it is interesting to reflect upon Robbe's final remarks (p. 177):

"Of the many psychotropic drugs, licit and illicit, that are available and used by people who subsequently drive, cannabis may well be among the least harmful. Campaigns to discourage the use of cannabis by drivers are certainly warranted. But concentrating a campaign on cannabis alone may not be in proportion to the safety problem it causes."

Summary

Discussions here have focussed primarily on two particular series of studies, because these studies stand alone in the cannabis and driving literature. In her comprehensive review of the effects of cannabis on simulator and on-road performance, Smiley (11) concluded that, when driving under the influence of cannabis, the more realistic the driving situation the better the performance. People experiencing the effects of cannabis appear to be aware of their impairment and where possible they compensate by, for example, slowing down, focussing attention and not taking risks (like overtaking). However, this compensation is not possible when the driver encounters unexpected events and/or when the driver is placed in situations requiring increased mental load or continuous attention (11, 15).

In short, there appears to be some driving-related performance impairment associated with cannabis consumption, particularly in relation to SDLP. However, unlike alcohol, the potential link between this impairment and any changed crash risk has not yet been fully determined.

Detecting cannabis use in the field

Cannabis is present in small but meaningful proportions of drivers who are suspected of driving under the influence or who are injured, and that cannabis does seem to impair aspects of simulator and on-road driving performance. The next question, from an enforcement viewpoint, is how to detect drivers who are driving under the influence of drugs such as cannabis.

Broadly speaking there are two approaches that are being researched and used world-wide to detect drug use, including cannabis use, at the roadside. The first, and the one that is very actively being researched, is the ability to screen for drugs of abuse in body samples. The major samples under investigation are blood, urine, sweat, and saliva. The second approach is to determine drug-related impairment by measuring performance on standardised tests. This approach is currently being used for law enforcement world wide, including Victoria.

Measuring cannabis use in bodily specimens

There is currently a race world wide to develop a validated measure of drug use that can be used in the field, and the majority of this research is taking place in Europe. The samples that can potentially be used to conduct drug analyses are blood, urine, sweat, saliva, and hair (16). There is no doubt that blood sampling represents the most accurate means for conducting drug analyses. However, it is not a practical means of testing for drug use in the field, such as at mining sites or on the roadside. Aside from the practical issues of mass screening drivers and taking blood in the field, it takes several hours to obtain results from a blood drug screen, which is not suitable for roadside screening purposes. Furthermore, there is still much that remains unknown about the relationship between blood levels of a drug such as cannabis and subsequent performance levels. Robbe (15) states that a single measurement of blood cannabis levels bears little relationship to the levels of performance observed at that time. Even less is known about the relationships between levels of drugs in other specimens, such as saliva and urine, and performance levels.

While much research is being directed towards researching these alternative samples, the majority of effort seems to be directed towards developing a saliva-based measure of drug use (17-20). Saliva has also been identified as the preferred specimen by police forces and experts across the European Union (19). It has been suggested that while sweat testing may be an appropriate means for drug screening for prisoners on weekend leave, it is likely to be of little use for roadside testing (21).

As already mentioned, saliva has been identified as the preferred specimen for drug screening in the European Union (19). This report also identified a preference for a device that could give clear and unambiguous test results, and one that could do so within five minutes. The five drug types in order of decreasing priority were cannabis, benzodiazepines, amphetamines, cocaine, and opiates. A device was preferred that could screen for these five drug types as part of the one test.

Two such saliva-based devices, the Rapiscan and Drugwipe, are currently being evaluated in Norway in drivers who are suspected of driving under the influence of drugs (17). Early results suggested that the devices may need further research to enhance the ease of operation by police on the roadside, and to refine the pharmacological cut-off levels for the drugs being tested.

The Drugwipe screening test has been evaluated in several studies (22). While very few false positives or negatives were found when testing for cocaine and amphetamines, a high rate of false positives was found for opiates (35%). The results for cannabinoids were the poorest with high proportions of false negatives (40%) and false positives (28%). It was therefore suggested that, until new antibodies with a higher sensitivity for THC or opiates are developed, that the Drugwipe should not be considered as a good tool for on-site detection of these drugs of abuse in saliva (22, 23).

Using a different approach, the Rapiscan unit was recently evaluated in Melbourne (24). Results from this device were compared with blood levels and self-reported levels of drug use in injecting drug users. While results were not encouraging for cannabis and benzodiazepines, the results for opioids were promising. Given that cannabis and benzodiazepines are more widely used, and so are more of a road safety concern, it was recommended that further work be done refining the device to improve the sensitivity to these drugs, and as such, that the device not be used for road safety purposes at present.

Cannabis (THC) is present in very low levels in saliva, which makes finding an appropriate saliva cut-off for THC more difficult. Nonetheless, it is likely that an appropriate device will be available in the next couple of years. Saliva screening for cannabis (and other drugs) is however only likely to be a precursor for a blood drug analysis, as the presence of cannabis in saliva is not necessarily indicative of impairment. THC levels in saliva can be contaminated by the smoking process in that saliva readings can often be artificially high resulting from residual cannabis in the mouth from the inhaled smoke. Furthermore, there are quite marked differences in the concentrations of cannabis taken from unstimulated saliva compared to stimulated saliva (that is, saliva that has been produced by stimulation such as the chewing of gum, etc) (18).

The availability of such a device will have huge implications for occupational health and safety, such as in the mining and transport industries, as well as providing Police with an additional means for quickly confirming drug use by drivers, pedestrians, and other road users.

Concluding remarks

There is clearly an ever increasing number of Australians, and particularly young Australians, using cannabis. Cannabis is prevalent in meaningful proportions of drivers randomly screened at the roadside, in drivers suspected of driving under the influence of drugs, and in injured drivers. While it remains unclear to what extent members of the community and recreational cannabis users drive while impaired by cannabis, there is preliminary evidence that regular cannabis users drive very frequently at times at which they are highly likely to be impaired, that is, immediately after using or while using cannabis (25). Further research should consider the prevalence of drug use in the general driving population, and also further consider the drug-driving behaviours and attitudes for specific groups such as recreational cannabis users.

While it is clear that blood THC levels cannot be used to predict the time course or magnitude of the effects of the drug, it appears that they can be used to predict the timing of cannabis use. Mathematical models have been successfully developed for the prediction of elapsed time since cannabis use on the basis of an analysis of plasma concentrations of THC and THCCOOH (26, 27). The failure to observe a direct relationship between plasma THC levels and the time course and magnitude of subjective, physiological and behavioural effects brings into question the value in attempting to relate measures of cannabis-related driving impairment to blood THC levels (15).

While space restraints have not permitted a full review here, the review in the report to the baseline sponsors of the effects of cannabis on simulated and on-road driving highlights the complex effects that cannabis exerts on driving skills. Cannabis typically impairs lateral placement, resulting in a greater degree of lane weaving. Other changes in behaviour, such as a reduction in average speed or an increase in headway to the car in front, in combination with the high levels of awareness that experimental participants have of the fact that they are impaired by cannabis, leads to the notion that drivers are able to compensate, to an extent, for the effects of

cannabis. The effects of cannabis on other variables such as reaction time and decision time, in the context of driving, are less clearly defined.

In light of the extent of cannabis use, the prevalence of cannabis in various driver samples, and the evidence for the potentially impairing effects on driving, it is important that continued research be conducted to further enhance the understanding of the effects of cannabis on driving. As previous researchers such as Smiley and Robbe have suggested, it is critical to examine the effects of cannabis when the driver is placed in situations involving increased cognitive load. This represents a shift in the experimental research away from looking simply at the effects of cannabis on traditional measures of driving performance such as lateral placement and speed, and a shift towards supplementing traditional measures with investigation of the effects of cannabis when a driver is placed in situations involving increased demands (through the use of secondary tasks), and in unexpected high accident risk situations that require an immediate decision and response. The research examining the levels of cannabis found in blood (and other specimens), and the race to develop a suitable and validated drug screening device for use in the field, highlights the need for a much greater understanding of the relationship between the levels of cannabis in blood and other specimens, and the associated impairments in driving skills. These and other issues are being addressed in a cannabis and driving simulator study that is currently being conducted at MUARC by a project team involving the Monash University Department of Psychology, Turning Point Alcohol & Drug Centre, and MUARC.

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