NDLERF

An evaluation of the Standardised Field Sobriety Tests for the detection of impairment associated with cannabis with and without alcohol

Monograph Series No. 17

Funded by the National Drug Law Enforcement Research Fund
An Initiative of the National Drug Strategy

An evaluation of the Standardised Field Sobriety Tests for the detection of impairment associated with cannabis with and without alcohol

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Funded by the National Drug Law Enforcement Research Fund, an initiative of the National Drug Strategy

Produced by the National Drug Law Enforcement Research Fund (NDLERF)
298 Payneham Road, Payneham SA 5070

ISBN: 0 642 47435 4

ISSN: 1449-7476

Opinions expressed in this publication are those of the authors and do not necessarily represent those of the National Drug Law Enforcement Research Fund (NDLERF) Board of Management or the Australian Government Department of Health and Ageing.

The research on which this report is based was funded by the National Drug Law Enforcement Research Fund, an initiative of the National Drug Strategy.

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Acknowledgements

The authors wish to acknowledge the contribution of the research officers and assistants Amy Fredrickson, Beata Silber, Cindi Hinch, Dana Sullivan and Karen Hansen; the research nurses Kristine Lim and Jenny Lloyd; and Victoria Police personnel Senior Sergeant Vic Little.

The authors acknowledge the financial support of the National Drug Law Enforcement Research Fund (NDLERF) and would like to thank Roger Nicholas and Vicki Hancock from the NDLERF Secretariat for their support throughout the study.

The authors also wish to thank the National Institute on Drug Abuse (NIDA) for the donation of the cannabis cigarettes used in the project.

Finally, much thanks goes to the individuals who participated in the experimental sessions of the project, as without their commitment and motivation the project would not have been possible.

Abbreviations

AB	Arms Used to Maintain Balance
ANOVA	Analysis of Variance
BAC	Blood alcohol concentration
BS	Body Swaying
CBD	Cannabidiol
CBN	Cannabinol
DECP	Drug Evaluation and Classification Program
DREs	Drug Recognition Experts
DUI	Driving Under the Influence
FD	Foot Down
FIT	Field Impairment Test
H	Hopping
HGN	Horizontal Gaze Nystagmus
HJ	Head Jerks
HM	Head Movements
HMJ	Head Movements/Jerks
IT	Improper Turn
LAPD	Los Angeles Police Department
LSP	Lack of Smooth Pursuit of the Eyes
MHT	Misses Heel to Toe While Walking the Straight Line
N45	Nystagmus at 45 degrees
NB	No Balance During the Instruction Stage
NMax	Nystagmus at Maximum Deviation
OLS	One Leg Stand
PCP	Phencyclidine
S	Swaying
SFSTs	Standardised Field Sobriety Tests
SOL	Steps off the Line
STS	Starts Too Soon
SW	Stops Walking During the Test
TAC	Transport Accident Commission
THC	Tetrahydrocannabinol
VGN	Vertical Gaze Nystagmus
WAT	Walk and Turn

Executive Summary

Reports indicate that in Victoria, New South Wales and Western Australia, 23.5% of drivers in fatal accidents had consumed drugs other than alcohol, and that 29.1% of drivers had a Blood alcohol contentration (BAC) level of 0.05% or higher. Alcohol has been detected in combination with drugs in almost 10% of cases. Cannabis was most prevalent among drugs other than alcohol detected in specimens (13.5%) (Drummer et al., 2003). The combination of drugs as an influence on road traffic accidents is becoming a growing concern and research has been conducted to identify how these drugs impair performance. Krueger & Vollrath (2000) reported that recent consumption of cannabis improved lane positioning; however, when combined with alcohol, lane position deviated, and participants drove faster. The consumption of low dose and high dose cannabis alone has also been associated with an increase in vehicle lane weaving (straddling solid and barrier lines) (Papafotiou, 2004b). Furthermore, a trend towards greater braking latency after consumption of higher doses of cannabis has been reported (Ligouri et al., 1998). Generally, alcohol has been reported to increase hazardous simulated driving, and cannabis has been reported to slow a driver's speed (Stein et al., 1983). The findings of several studies have directly suggested that the effect of Tetrahydrocannabinol (THC) consumption on driving performance may be greater for non-regular cannabis users than for regular cannabis users (Marks & MacAvoy, 1989; Wright and Terry, 2002; Papafotiou, 2004c). Wright and Terry (2002) also provide evidence to suggest that regular cannabis users may develop cross-tolerance to the effects of drugs and alcohol.

In Victoria, Australia, Standardised Field Sobriety Tests (SFSTs) have been introduced as means of testing for impairment in drivers who have consumed drugs other than alcohol. The use of SFSTs, although designed for the detection of alcohol-intoxicated drivers (up to 0.08%), has been implemented in programs for the detection of drugs other than alcohol. To date, one study exists that has evaluated the sensitivity of the SFST battery to predict drug intoxication and driving impairment. This project assessed the relationship between each individual sobriety test (Horizontal Gaze Nystagmus, Walk and Turn, and One Leg Stand test) and individual scored signs of the SFSTs with the administration of cannabis (Papafotiou et al., 2004a). Papafotiou et al. (2004a) found that, unlike in the case of alcohol where the HGN test is reported to be the best test for impairment associated with the administration of alcohol, in the case of cannabis the test best related to impairment is the One Leg Stand test. This finding highlights the need for additional research into the relationship between performance on the SFST battery and drug intoxication (drugs other than alcohol).

The present study had several aims: to examine the effects of cannabis and cannabis together with alcohol on driving performance; to examine the effects of cannabis and alcohol on Standardised Field Sobriety Tests (SFSTs) performance; to examine the efficiency of SFSTs to predict driving performance associated with the administration of cannabis and alcohol; to examine any differences between the effects of cannabis and alcohol on performance in regular cannabis users and non-regular cannabis users; and to examine any differences between SFSTs ratings by researchers (Swinburne University) and SFSTs ratings by police officers (Victoria Police) in order to identify the inter-rater reliability of SFSTs.

The project consisted of two parts: cannabis (0% THC, 1.8% THC and 3% THC) with low dose alcohol (0.03% BAC); and cannabis (0% THC, 1.8% THC and 3% THC) with high dose alcohol (0.05% BAC). Each part was made up of six randomized, double-blind sessions and both utilised the same experimental design and procedure. The total sample comprised 80 individuals; 31 female and 49 male. Age varied between 21 and 35 years ($\underline{M}$ = 26.45, $\underline{SD}$ = 5). Part one was comprised of 40 participants; 15 females and 25 males. Of these participants, 24 were regular

cannabis users and 16 non-regular cannabis users. In part two, 40 participants included 16 females and 24 males. Of those participants, 24 were regular users, and 16 were non-regular cannabis users. In each experimental session, after the administration of cannabis and alcohol, participants were asked to perform a driving simulator task and the SFSTs. Blood samples were taken throughout each session in order to determine the level of drug in plasma associated with observed impairment.

The results of the present study are consistent with past research in which the level of THC detected in blood is higher when cannabis (THC) is consumed with alcohol, than when cannabis is consumed only (Lukas & Oronzco, 2001). Also consistent with past research, regular cannabis users reported higher levels of THC in plasma than non-regular users (Papafotiou, et al., 2004c). Data from the driving simulator indicated that the mean number of times the errors of 'straddling the solid line', 'straddling the barrier line', 'insufficient stopping clear space' and 'slower initial speed on freeway' occurred increased with the consumption of THC (with or without alcohol). This suggests that individuals who have consumed cannabis are more likely to drive with two or more wheels of the vehicle moving over lines marked out for traffic moving in the same direction, or lines marked out for traffic moving in the opposite direction. In addition, individuals who have smoked cannabis are more likely to have insufficient clear space between their own vehicle and the vehicle in front of them if required to stop (driving too close to the vehicle in front). Although the consumption of THC was associated with slower initial speed when entering the freeway, this does not appear to be related to safe driving. The observation of an increase in straddling barrier and solid lines, and insufficient stopping clear space, indicates that driving slowly is associated with deficiencies in cognitive processes necessary to safely drive a motor vehicle.

In the present study, the driving variables 'straddling the barrier line' and 'insufficient stopping clear space' were impaired by THC consumption. These errors occurred significantly more often in conditions that included the administration of alcohol. In addition, the error 'straddling the solid line' occurred significantly more often in the 0.05% BAC condition than the 0.03% BAC condition. With respect to impairment associated with the administration of alcohol (irrespective of THC consumption), several driving variables were impaired. 'Dangerous skidding', 'unsafe stopping distance between vehicles', 'violation of the speed limit', 'collisions', 'straddling the barrier line', 'wandering', and 'insufficient clear space' occurred significantly more frequently in alcohol conditions than placebo conditions. The results also indicated that the errors 'straddling the barrier line' and 'unnecessary stopping' occurred significantly more often in the 0.05% BAC condition than the 0.03% BAC condition. There were also significant interactions observed between the THC condition and the alcohol condition. In other words, the results showed that THC consumed with alcohol was significantly more impairing than consuming either drug alone. Specifically, while there were significantly more skidding errors in the alcohol condition compared to the placebo condition, the greatest number of errors occurred when alcohol was consumed with THC. In addition, while there were more inappropriate signaling errors in the alcohol condition compared to placebo condition, the greatest number of errors occurred when alcohol was combined with THC. Generally, regular cannabis users displayed more driving errors than non-regular cannabis users. Regular cannabis users drove fast, displayed dangerous skidding, stopped unnecessarily and were involved in collisions more often than non-regular users.

A difference in SFSTs performance was observed between the THC only condition and the THC with alcohol condition. During the Horizontal Gaze Nystagmus (HGN) test, the percentage of individuals exhibiting each sign of the HGN test increased with the administration of low THC and high THC when compared to placebo. When THC was administered together with alcohol, the percentage of individuals exhibiting each sign increased. The data reported that the sign Head Movements/Jerks (HMJ) was exhibited in a high percentage of individuals compared to traditionally scored signs of the HGN test. Furthermore, the use of the SFSTs (three test battery), when scoring

HMJ in the HGN test, classified the highest percentage of participants as impaired than any other individual SFST test sign (high THC with alcohol condition). There was no significant difference between the presence of signs observed during the Walk and Turn (WAT) test during the THC only condition or the THC with alcohol condition (with the exception of Steps off the Line (SOL)). Analysis of the One Leg Stand (OLS) test suggests there was a significant relationship between all scored signs of the OLS test and the THC only condition and THC with alcohol condition. Specifically, more errors were observed during the OLS test the higher the dose of THC administered. Overall SFST performance was significantly related to the administration of THC only and THC with alcohol. When THC was administered with alcohol, the percentage of individuals classified as impaired using the SFSTs more than doubled than when no alcohol was administered. These results highlight the sensitivity of SFSTs to test for the presence of alcohol. Overall SFST test scores including HMJ increased the percentage of individuals classified as impaired.

At best, the use of SFSTs resulted in the correct classification of up to 73.9% of participants as either impaired or not impaired on driving (this rate was reported after the administration of low dose THC). In this case, the best test of impairment was the OLS test. Driving ability was impaired when the level of THC in plasma was between 3.1 and 11.2 ng/ml. Regular users performed worse on the driving task than non-regular users. When this occurred, the level of THC in plasma in regular users was between 3.6 ng/ml and 13 ng/ml (higher than the level of THC detected in non-regular users).

Results from the present study support a high level of agreement between researcher ratings (Swinburne University) and police officer ratings (Victoria Police) on impairment using the SFSTs. There was statistically significant agreement between raters on the presence of 17 out of 23 SFSTs errors. Primarily, non-agreement was recorded for errors that involve eye signs, such as Lack of Smooth Pursuit (LSP), and Nystagmus at 45 degrees (N45). These errors were reported to be present more often by the researchers than the police officers. This non-agreement can be explained by the police officers having to score SFST performance via video footage. With respect to identifying impairment on each individual test (HGN, WAT and OLS) and impairment on the SFST battery as a whole, there was statistically significant agreement in all cases between police officer ratings and the researcher ratings. This result supports that, when administered correctly (by a trained individual), the SFSTs are reliable tests of impairment, and that it is unlikely that scores on the SFSTs would alter if administered by a different rater. Overall, the results suggest that SFSTs have reliable scoring procedures and that test results are accurate and replicable.

In conclusion, the use of the SFSTs is a moderately good predictor of driving impairment and the consumption of THC only and THC together with alcohol. In the absence of reliable and accurate physical tests of THC plasma levels and driving ability, the SFSTs can provide relevant information concerning drug intoxication and driver fitness, in particular associated with the consumption of cannabis.

Chapter one: Introduction

Project aims

The project aim was to examine the effectiveness of sobriety testing in detecting impairment due to the consumption of cannabis and alcohol by:

- Examining the effects of cannabis and alcohol on driving performance;
- Examining the effects of cannabis and alcohol on Standardised Field Sobriety Tests (SFSTs) performance;
- Examining the efficiency of SFSTs to predict driving performance associated with the consumption of cannabis and alcohol;
- Examining any differences between the effects of cannabis and alcohol on performance between regular cannabis users and non-regular cannabis users; and
- Examining any differences between SFSTs ratings by the researchers (Swinburne University) and SFSTs ratings by police officers (Victoria Police) in order to examine inter-rater reliability of SFSTs.

Summary of method

The project involved 80 participants (49 male, 31 female). Participants were required to undergo a medical examination and a drug screen to ensure that they were fit to participate in the study. Once participants were judged as fit to participate they were asked to read an Information Sheet (Appendix B1) detailing the aims and protocol of the study. If participants agreed to continue, they were asked to sign a Consent Form (Appendix B2). A Demographics questionnaire and a Frequency of Cannabis Use questionnaire were then completed (Appendix C and Appendix D). Responses on the Frequency of Cannabis Use questionnaire were used to separate participants into regular cannabis users and non-regular cannabis users. Participants were required to undergo 6 experimental sessions that involved the consumption of cannabis cigarettes containing either no THC, 1.8% THC and 3% THC together with the consumption of alcohol to obtain either 0% BAC, 0.03% BAC or 0.05% BAC. The 6 sessions were double blind, counter-balanced and placebo controlled. Forty participants were allocated to the cannabis with low alcohol (0.03% BAC) group and forty participants were allocated to the cannabis with high alcohol (0.05% BAC) group.

In the experimental sessions, after the administration of alcohol and THC, participants performed a driving simulator task and the Standardised Field Sobriety Tests (SFSTs). Blood samples were taken before and after the driving and SFSTs tasks in each session. Performance on the driving tasks was correlated with the drug condition and frequency of cannabis use (regular and non-regular cannabis users). Performance on the SFSTs was correlated with drug condition and driving performance.

Chapter two: Alcohol and cannabis

What is alcohol?

The term alcohol is used to describe a family of organic chemicals with common properties, which include ethanol, methanol, isopropanol, and others. Alcohol is a clear, volatile liquid that oxidises easily and is very soluble in water. Alcohol is an organic compound that is composed of carbon, oxygen and hydrogen (see Figure 1).

Figure 1: Chemical structure of ethyl alcohol

Alcohol consumption and levels of alcohol in blood

When alcohol is consumed, it passes from the stomach and intestines into the blood (absorption phase). Alcohol is then metabolised by enzymes, which are body chemicals that break down other chemicals. In the liver, an enzyme called alcohol dehydrogenase (ADH) mediates the conversion of alcohol to acetaldehyde. Acetaldehyde is rapidly converted to acetate by other enzymes and is eventually metabolised to carbon dioxide and water. Alcohol is also metabolised in the liver by the enzyme cytochrome P450IIE1 (CYP2E1), which may be increased after chronic drinking. Most of the alcohol consumed is metabolised in the liver, but the small quantity that remains un-metabolised permits alcohol concentration to be measured in breath and urine (National Institute on Alcohol and Alcoholism, 2001).

The liver can metabolise only a certain amount of alcohol per hour, regardless of the amount that has been consumed. The BAC curve, shown in Figure 2, provides an estimate of the time needed to absorb and metabolise different amounts of alcohol. Table 1 (for males) and Table 2 (for females) clearly display the average number of alcoholic drinks containing 30ml of spirit required to reach particular blood alcohol concentrations (in percentage BAC), taking into consideration weight in pounds.

Figure 2: Blood alcohol concentration (BAC) after the rapid consumption of different amounts of alcohol (Wilkinson et al., 1977)

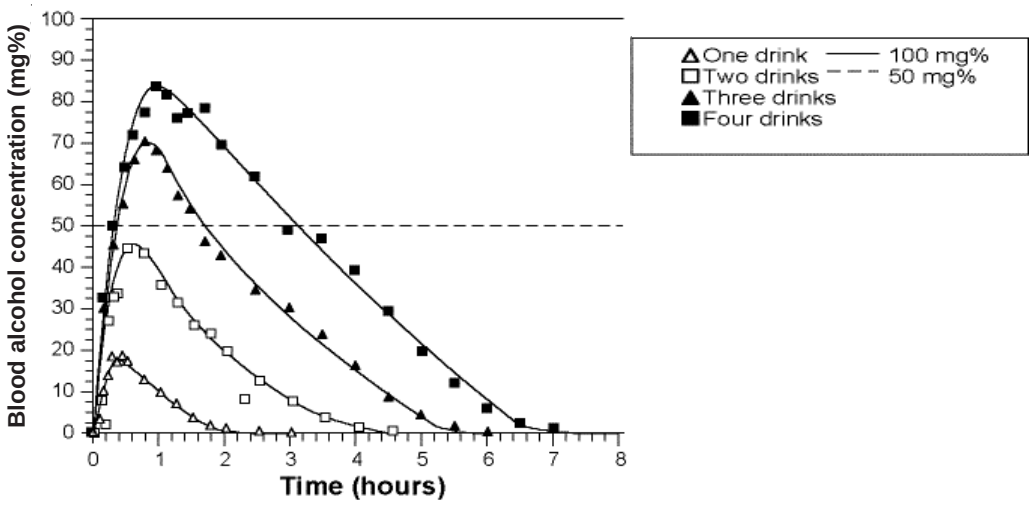


Table 1. Blood alcohol levels in males.

	Bodyweight in pounds							
Drinks needed	100	120	140	160	180	200	220	240
2	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02
4	0.08	0.06	0.05	0.05	0.04	0.04	0.03	0.03
6	0.11	0.09	0.08	0.07	0.06	0.06	0.05	0.05

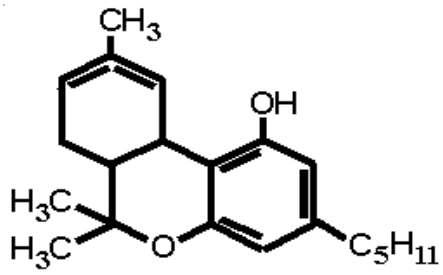
Table 2. Blood alcohol levels in females.

	Bodyweight in pounds							
Drinks needed	100	120	140	160	180	200	220	240
2	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.02
4	0.09	0.08	0.07	0.06	0.05	0.05	0.04	0.04
6	0.14	0.11	0.10	0.09	0.08	0.07	0.06	0.06

What is cannabis?

Cannabis is a drug that is derived from the plant *Cannabis sativa*. The cannabis plant contains more than 400 chemicals and over 60 different cannabinoids among other constituents. The cannabinoids are secreted in a resin and the most common cannabinoids found in high concentrations are delta-9-tetrahydrocannabinol (THC), cannabidiol (CBD) and cannabinol (CBN). It is THC that is responsible for most of the mood-altering effects of cannabis and it is 10 times more potent than CBN. CBD is devoid of mood changing effects (Cannabis: A Discussion Paper, 1978). The chemical structure of THC is shown in Figure 3.

Figure 3: Chemical structure of tetrahydrocannabinol



Cannabis has three forms: the dried tops of the female plant are referred to as Marijuana (about 1%-2% THC); the resin collected from the flowers and topmost leaves is referred to as hashish (about 10% THC); and the extract of the cannabinoids prepared from the plant by the use of organic solvents is referred to as hash oil (10%-60% THC). The greater the THC concentration, the greater the physical and psychological effects experienced (Cannabis: A Discussion Paper, 1978).

Cannabis consumption and the level of THC in blood

Unlike alcohol, which is distributed exclusively in body water, the components of cannabis are lipophilic (very soluble in fat) and have a higher volume of distribution. When cannabis is smoked, the cannabinoids are rapidly absorbed from the lungs into the bloodstream. As a consequence of the high fat-solubility, the cannabinoids readily cross membranes, leave blood circulation and are 'dumped' into various tissues of the body, including the brain. Because of this pattern, the level of the cannabinoid THC in the blood declines rapidly. The bioavailability of oral THC varies from 4% to 12% depending on the way in which it is delivered; however, the availability of THC when smoked can be as high as 50%, where a 1mg cigarette can lead to the delivery of up to 10mg of THC to the blood stream (Leonard, 1994).

The relationship between the concentration of cannabinoids (THC) in the blood and time can be explained by three main phases of action: absorption, re-distribution, and elimination. Diagrammatically, Figure 4 displays the initial upward curve in the graph that represents the absorption phase, where the inhalation of THC is absorbed by the lungs. The equally sudden drop in the graph represents the re-distribution phase where the THC is 'dumped' from the bloodstream into fatty tissue. This phase then flattens out where the 'dumped' THC then re-enters the bloodstream and is then metabolised in the liver, constituting the elimination phase. It is important, therefore, to note that the sudden decline in the level of THC in the bloodstream is not indicative of the metabolism of THC, but rather the rapid re-distribution of THC from the bloodstream into other tissues. The metabolism of THC occurs when the 'dumped' THC is released back into the bloodstream, where it passes through the liver and is metabolised to more soluble compounds,

which are subsequently excreted (Chesher, 1997). The first metabolite, 11-hydroxy-THC (11-OH-THC) is formed in the lungs and liver. 11-OH-THC is equipotent to its parent (THC) and therefore contributes to the total effect of cannabis. 11-OH-THC is converted by the liver into a number of inactive metabolites, the most abundant being 11-nor-THC-9-carboxylic acid (THC-COOH) (Robbe & O'Hanlon, 1993). Figure 5 represents the mean plasma concentrations of 11-OH-THC and THC-COOH compared to THC during and after smoking a cannabis cigarette containing 3.55% THC.

Figure 4: Mean THC concentrations during smoking of a single cannabis cigarette (Cone & Huestis, 1993)

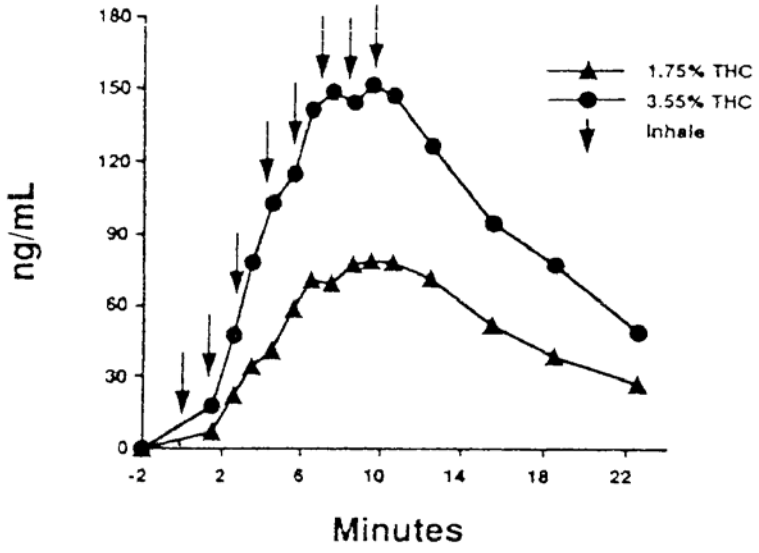
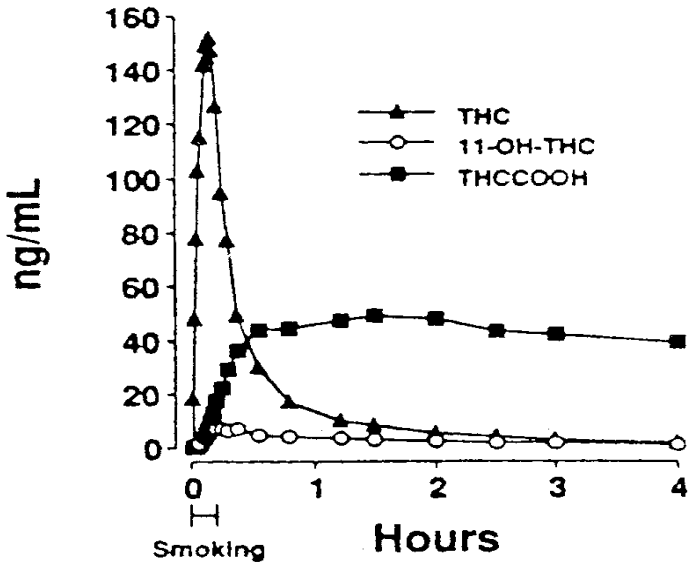


Figure 5: Mean plasma concentrations of 11-OH-THC and THC-COOH compared to THC during and after smoking a cannabis cigarette containing 3.55% THC (Cone & Huestis, 1993)



Pharmacokinetics of THC and alcohol

There is evidence to suggest that the absorption of alcohol and THC into the bloodstream is influenced by the ingestion of the other (Consroe et al., 1979; Lukas et al., 1992; Lukas & Orozco, 2001). THC has been reported to reduce the time it takes for alcohol to reach peak plasma concentrations, as well as attenuating the overall blood alcohol level (Consroe et al; Lukas et al.). This trend was observed in the ascending phase of the blood alcohol absorption curve, but no difference was observed in the descending phase (Consroe et al., 1979; Lukas et al., 1992).

On the other hand, alcohol has been reported to enhance the absorption of THC (Lukas & Orozco, 2001). The level of THC in plasma peaked five minutes earlier when a moderate dose of ethanol was consumed prior to smoking a THC cigarette, than when placebo alcohol was consumed (Lukas & Orozco, 2001). Furthermore, significantly greater levels of THC were observed in participants who had consumed alcohol before smoking marijuana cigarettes (Lukas & Orozco). This trend was observed in the ascending phase or the THC absorption curve, similar to the effect of alcohol on THC (Lukas & Orozco, 2001).

Chapter three: The effects of cannabis and alcohol on driving performance

Road deaths – role of alcohol and other drugs

Over the past 50 years the number of road accidents and deaths have been well documented in Victoria, Australia, with more recent analysis concentrating on the number of accidents and deaths involving the presence of alcohol and other drugs (Drummer et al., 2003).

The Transport Accident Commission (TAC) has reported the number of road deaths in Victoria from 1989 to 1998. Over the years the number of deaths on Victorian roads has decreased by almost half from 776 in 1989 to 391 in 1998 (TAC, 2000). The patterns of alcohol-related deaths from 1990 to 1999 have been previously reported by Drummer and colleagues (Drummer et al., 2003). From 1990 to 1993, the percentage of drivers killed on Victorian roads with alcohol detected in their blood was 33%. This figure dropped to 26.9% from 1995 to 1996, and to 27.7% from 1997 to 1999.

These reports also tabulate the percentage of drivers killed who tested positive for drugs. From 1990 to 1993, 22.2% of drivers killed tested positive for drug use. The drugs identified were: cannabis (10.9% of cases); benzodiazapines (3.4% of cases), stimulants (3.6% of cases) and opioids (3.4% of cases). From 1995 to 1996 the percentage of drug-related deaths increased to 26.6%, in which 13.5% of cases had cannabis involved, 3.8% benzodiazapines, 3.5% stimulants, and 4.1% opioids. Finally, from 1997 to 1999, a high 30.1% of drug-related deaths involved primarily cannabis (15.6% of cases) followed by benzodiazapines (4.7%), stimulants (4.8%), and opioids (6.6%). The most obvious trend is that the number of cases involving cannabis has increased over the years, while, in comparison, the number of cases involving other drugs has remained relatively constant, and the number of cases involving alcohol has decreased.

Over this nine-year period it was reported that, in Victoria, New South Wales and Western Australia, 23.5% of drivers in fatal accidents had consumed drugs other than alcohol, and that 29.1% of drivers had a BAC level of 0.05% or higher. Alcohol was detected in combination with drugs in almost 10% of cases. Cannabis was the most prevalent drug other than alcohol detected (13.5%) (Drummer et al., 2003).

The effects of cannabis and alcohol on simulated driving

The consumption of cannabis and alcohol has been reported to impair simulated driving performance. Drivers who consumed alcohol were involved in more simulated accidents and took greater risks than drivers who consumed placebo alcohol (Arnedt et al., 2000; Stein et al., 1983). The consumption of cannabis, on the other hand, effected driving in a different manner, in which drivers were more likely to drive slowly, and braking times were increased, in comparison to the consumption of placebo or alcohol (Tunbridge, 2002; Rafaelsen et al., 1973). Errors in variables such as accelerating, braking, signalling and responding to signs have been related to the consumption of alcohol than either placebo or cannabis (Crancer et al., 1969). More errors have been reported after the consumption of alcohol than cannabis in simulated driving tasks; however, when these drugs are consumed together, a cumulative effect has been observed (Crancer et al., 1969; Krueger & Vollrath, 1998; Stein et al., 1983). Stein et al. (1983) reported an increase in simulated accidents and increase in speeding tickets when drivers' blood alcohol levels were 0.10%. Furthermore, the number of off-road accidents was increased at a lower blood alcohol

level (0.08%) compared to placebo (Arnedt et al., 2000). Krueger & Vollrath (1998) reported that recent consumption of cannabis improved lane positioning; however, when combined with alcohol, lane position deviated more, and participants drove faster. In contrast, low doses of cannabis alone have been reported to impair lane positioning, produce deficits in speed control, and steering movements (Smiley et al., 1981). The consumption of low and high cannabis alone has also been associated with an increase in vehicle lane weaving (Papafotiou, 2004b). Furthermore, a trend towards greater breaking latency after consumption of higher doses of cannabis has been reported (Ligouri et al., 1998). Generally, the consumption of alcohol increased hazardous simulated driving, and the consumption of cannabis slowed travelling speed (Stein et al., 1983).

Differences between regular cannabis users and non-regular cannabis users

A pair of studies performed by Robbe and O'Hanlon highlights the contrasting nature of findings across studies (Robbe & O'Hanlon, 1993; 1999). The findings of Robbe and O'Hanlon's (1993) initial study were consistent with the findings of a meta-analysis performed by Berghaus et al. (1995) that provided evidence of a causal relationship between the level of THC in blood and driving performance. Robbe and O'Hanlon (1993) reported that driving impairment is subtle when compared to the impairment that is observed following the consumption of alcohol. The researchers also reported that the adverse effects of THC on driving performance are relatively small when compared to the effects of medicinal drugs and alcohol, and they suggested that drivers can compensate for the adverse effects of THC by slowing down or increasing their effort. In a later study, however, Robbe & O'Hanlon (1999) found that the impairing effects of THC on driving performance were far greater than the findings of their initial study had indicated. Noting that the subject group in the latter study was less experienced with smoking THC than the subject group in the earlier study, the authors suggested that the contrasting findings across the two studies may be attributable to differences in the subjects' history, or regularity, of THC use.

The suggestion that the effect of drug consumption on driving performance may be dependent on the individual's drug-use history has been supported by a number of findings. Kirk and De Wit (1999) found that infrequent users of THC experience greater subjective feelings and greater sedative effects than frequent users of THC, when a high dose of D^9-THC (15mg) was administered. When a lower dose D^9-THC (7.5mg) was administered, however, frequent users reported higher ratings of subjective feelings than did infrequent users. From these findings, the authors suggested that an individual's history of cannabis use may influence the subjective effects that are experienced after the consumption of cannabis and, in addition, the influence of the drug-use history may be dependent on the dose of drug that is administered. This finding may partly explain why the effects of THC consumption on driving performance have differed across studies.

The findings of several studies have directly suggested that the effect of THC consumption on driving performance may be greater for non-regular users of THC than for regular users of THC (Marks & MacAvoy, 1989; Wright and Terry, 2002, Papafotiou, 2002c). Marks and MacAvoy found that, when intoxicated by either cannabis and/or alcohol, cannabis users were less impaired in peripheral signal detection than were non-users, suggesting that regular cannabis users may develop a tolerance to the effects of cannabis and also a cross-tolerance to the effects of other drugs. Wright and Terry (2002) also provided evidence to suggest that regular cannabis users may develop cross-tolerance to the effects of drugs and alcohol. They found that infrequent cannabis users were more impaired on a tracking task, following the consumption of a low dose of alcohol, than were chronic cannabis users. Given that the study investigated the effects of alcohol on tracking performance, the findings suggested that chronic cannabis use may lead to cross-tolerance

to the effects of drugs including alcohol. Finally, Papafotiou et al. (2004c) reported that non-regular cannabis users, who had consumed cannabis, performed worse on a driving simulator task when compared to regular users. Non-regular users displayed significantly more collisions and slower reaction times to emergency situations after the consumption of THC.

The findings of Marks and MacAvoy (1989), Wright and Terry (2002) and Papafotiou et al. (2004c) indicate that driving-related psychomotor skills may be less impaired for regular THC users than for non-regular users, following the consumption of drugs and/or alcohol.

Chapter four: Detection of impaired driving

Detection of alcohol and other drugs: The Standardised Field Sobriety Tests (SFSTs) and the Drug Evaluation and Classification Program (DECP)

Sobriety testing involves the administration of performance tests that originated in the USA and are most commonly used for the detection of alcohol-intoxicated drivers. Historically in the USA, a number of psychophysical tests had been administered at the roadside when an officer suspected a driver to be under the influence of alcohol or drugs. The administration and results of these tests not only varied due to each officer's interpretations and preferences, but also differed between suspects, times and places. Thus, there were no standardised testing procedures for the roadside for the detection of alcohol and or drugs (Burns, 1987). Some of the typically used tests included the Finger to Nose test, Hand Slap test, recitation of the alphabet, counting backwards, as well as walking and balance tests (Burns, 1987).

During the 1960s and 1970s, many drivers produced blood alcohol concentrations (BACs) below the statutory level, even though they appeared to be extremely intoxicated. Based on the observation of the suspect's driving by the officer, sobriety test performance, manner and BAC reading, a decision was made by the officer on whether to arrest the person for driving under the influence of alcohol and/or any other drug (Page, 1995). Over the past two decades, these field sobriety tests have been undergoing a much-needed change towards standardised testing procedures and research has been performed to assess their reliability. The paragraphs below briefly describe the development of the SFST and other sobriety testing methods used predominantly in the USA.

The first study conducted on sobriety tests took place in 1977 by researchers Burns & Moskowitz. This study aimed to identify which sobriety tests out of a group of six sobriety tests (One Leg Stand, Walk and Turn, Finger-to-Nose, Finger Count, Horizontal Gaze Nystagmus and Finger Tracing), as well as four alternate tests (Romberg Balance, subtraction, counting backwards, and letter cancellation) were best related to alcohol intoxication. The report revealed that the Horizontal Gaze Nystagmus (HGN), Walk and Turn (WAT) and the One Leg Stand (OLS) correlated best with blood alcohol concentration. The HGN test was the most reliable test for alcohol consumption with a correlation coefficient of .68. The study also revealed that the use of the 6 sobriety tests (not including the alternate tests) to arrest/release participants were accurate in 76% of cases.

Tharp, Burns & Moskowitz (1981) continued their examination of the accuracy of sobriety tests by testing the reliability and validity of the three tests chosen in their earlier study (HGN, WAT and OLS). The study examined the reliability of the three tests to predict alcohol intoxication in a laboratory setting, as well as gathering roadside information and test scores obtained from drivers arrested for suspicion of drug or alcohol use (field setting). Results indicated that, in a laboratory setting and in the hands of adequately trained personnel, the three test battery is a sensitive test of BAC and impairment. The use of the tests was successful in correctly identifying 81% of individuals that had BACs above or below 0.10%. Results from the field setting study revealed a 20% increase in arrest rates involving BACs above 0.10% with the use of the three test battery. A study by Anderson et al. (1983) supports that the three test battery can be as effective in predicting BAC as a preliminary breath test. Anderson et al. (1983) also reported that the HGN was the best test of alcohol intoxication, and, in addition, the combination of scores derived from the administration of the HGN and WAT test is most accurate in predicting BAC. The three test battery used in these studies is currently referred to as the Standardised Field Sobriety Test (SFSTs).

An important issue concerning the findings of the Tharp et al. (1981) study was that, since most of the data was based on the administration of the SFST in a laboratory setting, and that administrators in the experiment were trained only prior to the commencement of the study, the results may not be representative of field situations. This concern was not unwarranted, as Compton (1985) revealed in his field study that officers who had received 16 hours of training and who were experienced in the use of the HGN test provided the most accurate judgments concerning BAC above or below 0.10%. The aim of the next study by Burns was therefore to examine the accuracy of arrest decisions, made by experienced skilled officers in a field setting based upon results from the SFSTs (Burns & Anderson, 1995). The study found that the SFSTs correctly classified 86% of drivers as having a BAC above 0.10%. More specifically, in 1977, 54% of arrest decisions (BAC above 0.10%) were correct; in 1981, 68% of arrests were correct; and in 1995, 93% of arrests were correct. Compared to previous research, the 1995 study highlights the advantage of training and experience when making decisions concerning arrests based on predicted BAC using the SFSTs.

All of these studies (Burns & Moskowitz, 1977; Tharp et al., 1981; Compton, 1985; Burns & Anderson, 1995) focus on the validity of the SFSTs to identify individuals intoxicated by BACs of 0.10%. Since some states of America later required that a driver may not have a BAC above 0.08%, the SFST validation studies conducted no longer provided sufficient support for the use of SFSTs to detect alcohol impaired drivers. Because of these changes to legal alcohol limits, one study extended the examination of the accuracy of the SFSTs to predict BAC levels between 0.04% and 0.08%. The study was conducted by Stuster and Burns (1998) and was a field study that involved the interception of drivers suspected of being impaired by alcohol. Overall, the roadside decisions to arrest on the basis of SFST performance where highly accurate. More than 91% of arrests based on 0.08% BAC estimates were correct, and 94% of estimates that BAC was between 0.04% and 0.08% were correct. The researchers concluded that the SFST battery was a valid test for the detection of drivers with a BAC level as low as 0.08%. Even though the results reported by Stuster and Burns (1998) are very impressive, it is unlikely that the report alone can provide sufficient support for the use of the SFSTs for BAC levels as low as 0.08%. It should be added that Stuster and Burns (1998) utilized a slightly different scoring procedure compared to past scoring methods of the SFSTs. For these reasons, the results of the study should be replicated.

In contrast to the results of Burns & Anderson (1995) and Stuster and Burns (1997), a study by Perrine et al. (1993) found that the tests that comprise the SFSTs are not very accurate in predicting BAC level. The study examined each of the three tests (that comprise the SFSTs) separately and the combination of the HGN and the WAT. The results revealed that the HGN test had the strongest relationship with BAC, where 81% of individuals failing this test had BAC levels between 0.10% and 0.14%. In contrast, the WAT and OLS were only slightly related to BAC, where more than half of the individuals with BAC levels of zero failed, and fewer than half with BAC levels between 0.08% and 0.10% failed. For the OLS test, 30% of individuals with BAC levels of zero failed, and 49% of individuals with BAC levels between 0.10% and 0.14% failed. In addition, the combination of the results on the HGN and WAT did not significantly improve the predictive capability of the HGN test alone. Interestingly, the study also reported that the accurate predictions of BAC level did not differ significantly between experienced and inexperienced administrators of the SFSTs. The authors acknowledged that, generally, officers administering the SFSTs in a field setting have access to additional cues when predicting the BAC level of a driver (such as driving behaviour prior to interception) compared to those available in a laboratory setting. A validation study conducted in Florida (Arend et al., 1997) supports that the WAT and OLS test are not good predictors of impairment associated with alcohol. Nevertheless, the findings of Perrine et al. (1993) encourage the further validation of the SFST battery, especially when new tests or scoring procedures are implemented, or its purpose is altered (i.e. testing for drugs other than alcohol).

The SFSTs, although designed only for the detection of alcohol-intoxicated drivers (up to 0.08%), have been implemented in some programs for the detection of drugs other than alcohol. To date, only one study exists that has evaluated the sensitivity of SFSTs to predict drug intoxication (Papafotiou et al., 2004a). This study showed that, unlike the case with alcohol where the HGN test is best related to impairment associated with alcohol, in the case of cannabis the test best related to impairment is the OLS test. This finding highlights the need for additional research into the relationship between performance on the SFSTs and drug intoxication (as opposed to alcohol). No other studies exist that validate the SFSTs (three test battery) for the detection of drug intoxicated/ impaired drivers. A very limited number of studies, however, have tested procedures that include the SFSTs in their drug impaired driver detection programs. One such program is the Drug Evaluation and Classification Program (DEC Program or DECP), a twelve-step procedure that includes the administration of the SFST battery in addition to physiological tests that are related to drug intoxication (twelve step procedure: BAC; interview; pupil size and eye tracking; eye HGN, VGN and convergence; divided attention tests; vital signs exam; darkroom exam; muscle tone exam; injection sites exam; statements and interrogation; opinion; and toxicology). The Los Angeles Police Department (LAPD) developed the DECP to detect drug impairment in drivers, after the development of the SFSTs, because of the steady incline of drug abuse and drug impaired drivers contributing to traffic accidents and deaths. LAPD officers consulted with doctors, psychologists and drug abusers about the effects of drugs. The result was the 12-step procedure that enables police officers to determine drug influence and the type of drug causing observable impairment (seven categories of drugs were developed) (Page, 1995).

The most popular studies on the efficiency of the DECP are those more commonly known as the "John Hopkins Study" (Bigelow et al., 1984) and the "173 Case Study" (Compton, 1986). The "John Hopkins Study" was a controlled clinical study conducted to test the validity and reliability of the procedure (DECP) used by Drug Recognition Experts (DREs). The study involved the analysis of data gathered from 80 participants who were administered amphetamine, cannabis, diazepam, secobarbital or placebo. The researchers claimed that the DREs were over 90% accurate in determining intoxication, and in correctly identifying the type of drug involved. A closer look at the statistics, however, indicates that in 45% of cases, where a drug was administered, the DRE opinion was 'not intoxicated'. The remaining 55% was made up of opinions of 'intoxicated' and it was here that over 90% of 'intoxicated' opinions were correct classifications of drug type (opiate, stimulant, cannabis or depressant). In addition, of those individuals that were administered cannabis (1.3% or 2.8% THC), 45% were judged as 'not intoxicated' (more often for the low THC condition compared to the high THC condition).

The "173 Case Study", unlike the "John Hopkins Study", was a field study involving drivers who were arrested for suspicion of driving under the influence of drugs. The study analysed results from 173 suspects who gave blood samples that were analysed for drugs. In many cases more than one drug other than alcohol was detected in the blood sample. Cannabis was the second most common drug detected and was commonly found in combination with alcohol and Phencyclidine (PCP). DREs decisions on 'impairment due to a drug other than alcohol' were correct in 94% of cases (the remaining percentage made up subject specimens containing alcohol only and one subject specimen containing no alcohol or drug present). In terms of the specific category of drug/s suspected, the DREs were totally correct in 49% of cases (where every drug determined by the DREs was found in the specimen) and partially correct in 38% of cases (correctly identifying one or more drug found in specimen, but also missing or incorrectly identifying an additional drug). In only 13% of cases DREs were incorrect in identifying any drug found in the specimen. These results are impressive compared to those obtained in the "John Hopkins Study". One reason that in the "173 Case Study" DREs were more successful in predicting impairment may be that the drivers investigated had consumed relatively higher amounts of a specific drug, as well as a combination of drugs, relative to the subjects tested in the "John Hopkins Study" (administered specific doses).

This would have made the identification of impairment in the "173 Case Study" easier, and supports that sobriety tests are better predictors of gross impairment associated with drugs as opposed to predictors of drug use. This hypothesis is supported by the number of times DREs were incorrect when only one drug was involved (28%), compared to when 3 or more drugs were involved (5% and 0% respectively). One major criticism of the "173 Case Study" is that it does not scientifically validate the DECP as able to distinguish between a suspect that is impaired by a drug and a suspect that is not impaired by a drug. The sample size consisted of only drivers that were suspected of drug use prior to the administration of the entire DECP. DREs were aware that these suspects were arrested for Driving Under the Influence (DUI) (and suspects would have displayed obvious symptoms of drug use) and this is likely to have influenced the interpretation of test performance. This may have also been the reason that one suspect with no drugs or alcohol in their specimen, and 10 suspects with only alcohol in their specimen, were classified as impaired by a drug other than alcohol. In addition, any suspects classified as 'not under the influence of drugs other than alcohol' were released, and no data is available to test whether the DRE was correct in releasing those drivers. These factors may have played a major role in the high correct classification rates reported in the "173 Case Study". For this reason, it is scientifically sound to test the validity and reliability of sobriety tests in a more controlled setting that includes data on non-intoxicated drivers, and this will help identify the sensitivity of SFSTs.

A later DECP validation study addressed some of the limitations of the "John Hopkins Study", by including specimens of drivers that were released after a DRE examination concluded they were 'not impaired'. Adler and Burns (1994) analysed Drug Influence Evaluation records of 500 drivers evaluated by DREs. The data included specimen results of drivers classified as impaired and drivers classified as not impaired. The results revealed that in 75.6% of cases a drug was predicted and found (hit), in 8.4% of cases a drug was predicted but not found (false positive), in 7.6% of cases a drug was not predicted but found (miss), and, finally, in 5.2% of cases a drug was not predicted and not found (correct rejection). Specifically, misses occurred most often in cases where cannabis was detected in the specimen. Ideally a study such as this requires an equal number of non-impaired drivers correctly classified as 'not impaired' (correct rejection) in order to establish that the DECP is sensitive in predicting drug intoxication. Adler and Burns (1994) acknowledged this limitation when they concluded that the DECP requires scientifically sound support from the laboratory. Nevertheless, the research lends support to the use of sobriety tests (together with additional cues or symptoms of drug use) to test for impairment caused by drugs other than alcohol.

Unlike the studies above, two studies conducted by Heishman et al. (1996; 1998) rigorously examined the DECP in a controlled laboratory setting and assessed which variables in the DECP are the best predictors of drug intake. In 1996, Heishman et al. (1996) tested eighteen participants who had been administered ethanol, cocaine, and cannabis, where in each session there was one active dose as well as a placebo. The study was double blind and randomised. It was found that the DECP was extremely sensitive (probability of dosed subject identified as dosed) and specific (non-dosed subject identified as non-dosed) in predicting drug intake. Specifically, in the cannabis condition, the DECP, when utilizing 28 variables, was efficient in accurately identifying whether a subject was dosed or not in 98.8% of cases. When only the 5 best variables were utilized, the DECP was accurate in 91.9% of cases. The results therefore suggest that there was an optimal ability to predict the use of cannabis when 28 variables were assessed. In contrast, the DECP was not as successful in identifying the specific drug causing impairment. In this case, DRE opinions on drug class were consistent with toxicology reports in only 44% of cases. It appears that DREs are extremely accurate in detecting the presence of drug intoxication, especially when utilizing a large number of variables, but not very accurate in discriminating between the class of drug consumed.

In 1998 Heishman et al. (1998) repeated their earlier study, the main difference being the class of drugs administered and the number of variables utilised. In 1998 the drugs examined were alprazolam, d-amphetamine, codeine and again cannabis. The results revealed that the DECP was accurate in predicting drug intake in 82.7% of cases, when 7 variables were utilized. The decrease in percentage compared to the 1996 study (for cannabis) was largely due to the increase in false negatives (dosed subjects identified as non-dosed). In terms of DREs identifying the specific drug causing impairment, they were accurate in only 32.1% of cases (less than in the 1996 study). The authors attribute some of the difference in percentages between both studies to the lower cannabis dose used in the 1998 study. Both studies, however, used 3.55% THC cigarettes as the highest dose. This does not explain the increase in false negatives (dosed subjects identified as non-dosed), as it is likely that the use of high THC doses would decrease the number of false negatives. The authors add that the discrepancies between laboratory studies and field evaluation studies support that in a field setting a greater number of cues, which aid in the determination of drug impairment, are available to officers. These cues can vary from erratic driving behaviour, to admission of drug use. It should be considered, however, that it is in the absence of these cues the DECP should be most accurate, as when such clues are present it is likely that an opinion of 'impaired' is formed prior to the administration of any test.

Some investigations of sobriety test programs were presented at the International Council on Alcohol, Drugs and Traffic Safety (ICADTS) conference in Sweden in 2000. Jackson et al. (2000) presented findings on a field study that examined the efficiency of a Field Impairment Test (FIT) to detect drug intake. The FIT comprised all tests of the SFST as well as the Romberg Balance test and Finger to Nose test. The results revealed that, out of 109 drivers tested, 39 failed the FIT, which led to 36 arrests. Of the 36 arrests, 24 samples were analysed of which 21 tested positive for drugs. These results indicated that the FIT was accurate in detecting drug intoxication in 87.5% of cases where a specimen was obtained. These results appear impressive, but whether FIT passes were indicative of the absence of drug intoxication was not examined, hence it is impossible to determine the accuracy of the FIT in determining drug use (present or not). Nevertheless, in terms of the specific drug class suspected by officers, opinions were correct in 64% of cases for cannabis, in 67% of cases for opiates, in 50% of cases for CNS depressants (one out of only two suspects) and in 100% of cases for CNS stimulants (5 out of 5 suspects). The investigators concluded that officers were more successful in recognising impairment rather than identifying a specific drug class. Officers commented that the OLS test appeared too sensitive for determining drug use, as the majority of suspects failed this test. The specimens of all drivers failing the OLS test were not analysed (specimens may have contained a drug), so it is possible that the OLS test may in fact be the most accurate test for drug intake. This is one, among many, issues that arise from studies that do not include a placebo condition, or do not test drivers who pass sobriety tests (classified as 'not impaired by a drug other than alcohol'). The conclusions of this study are similar to those of past research, although it should be mentioned that the sample size used in this study is extremely small compared to other studies attempting to validate the SFSTs and the DECP. The results of this study should be confirmed by studies that include specimens of drivers who pass the FIT and a larger sample size.

Finally, another study presented at the ICADTS 2000 conference determined the accuracy of DREs to predict drug intoxication and to predict the specific class of drug consumed (Shinar et al., 2000). This investigation included placebo sessions and the following drug conditions: cannabis, alprazolam, codeine, and amphetamine. The results showed that, out of 102 cases where placebo was administered, DREs decision was unimpaired in only 43.1% of cases. In 49 cases where cannabis was administered, DREs decision was unimpaired in 24.5% of cases. In terms of the specific class of drug predicted by DREs, in the cannabis condition, cannabis was correctly identified in only 40.5% of cases (cases where impairment was predicted). This study also revealed

that in many cases it was difficult for DREs to correctly identify drug class, especially in the cases of amphetamine. The results highlight the huge variation in correct classification rates of sobriety test programs, and also suggest the critical importance of including a placebo condition.

In summary, validation studies on the DECP indicate that sobriety testing procedures can be highly accurate in predicting drug intoxication in a field setting. However, the ability of sobriety testing procedures to identify the specific drug class causing impairment is not as accurate. When reviewing the research in this area, one must prioritise the reason for using such tests. When the detection of impairment, or the presence of any drug, is the most important aspect of its use, as opposed to the identification of a specific drug class, then the research generally supports the use of programs, similar to the DECP, that utilise sobriety testing procedures.

The use of the SFST battery on the other hand, for the detection of drugs other than alcohol, has only been evaluated in one study (Papafotiou et al., 2004a). This is the only study available that examines the efficiency of the SFSTs (three test battery) to detect impairment caused by drugs, and the results suggest that more research is required. All evaluations on the DECP include additional variables that test blood pressure, muscle tone, pupil reaction to light, etc. (field studies also take into consideration behaviours of a driver before any tests are performed). Since SFSTs do not take into account any physiological variables (apart from Horizontal and Vertical Gaze Nystagmus) - although driver behaviour prior to interception and other clues (mouth odour, speech) are taken into consideration (in a real-life situation) - it is important to further investigate the relationship between performance on the SFST battery and drugs (other than alcohol) administration. Research that identifies the accuracy of the SFST battery to predict drug intake is critical before it is used for that purpose.

Chapter five: The project

Method

The project consisted of two parts: cannabis together with low dose alcohol (0.03% BAC) and cannabis together with high dose alcohol (0.05% BAC). Each part was made up of six sessions and had the same experimental design and procedure.

Participants

The sample comprised 80 individuals; 31 female and 49 male. Age varied between 21 and 35 years (M=26.45, SD=5). Part one comprised 40 participants; 15 females and 25 males. Of these participants, 24 were regular cannabis users and 16 non-regular cannabis users. In part two, 40 participants included 16 females and 24 males. Of these participants, 24 were regular users, and 16 were non-regular cannabis users. All participants had smoked cannabis previously and underwent a medical examination prior to participation to ensure that they had no: history of cardiac disorders; current or past substance abuse; mental health problems; allergies to drugs; and no other medical illness (Appendix A1 and Appendix A2). Participants were assessed as either regular or non-regular users of cannabis using a Frequency of Cannabis Use questionnaire (Appendix D). All participants had a valid full drivers license (no probationary or learner drivers) to ensure that they had at least 3 years of driving experience.

All participants signed a Consent Form outlining the details of their participation and all were informed that they were free to discontinue their participation at any time (Appendix B2).

Materials

Drug conditions

The following drugs were used in the study:

Alcohol

Table 3. The major differences between each alcohol condition.

	Placebo (per glass)	**Low alcohol (per glass)**	**High alcohol (per glass)**
Alcohol content	1 ml (used to line glass)	30 ml	60 ml
Orange juice content	200ml	170 ml	140 ml

Cannabis

Table 4. The major differences between each THC condition.

	Placebo	Low dose	High dose
Cannabis type	Mississippi grown Mexican	Mississippi grown Jamaican, Special Hybrid and Mexican	Mississippi grown Jamaican, Special Hybrid and Mexican
Weight	702 +/- 40 mg	779 mg	733 mg
Moisture content	12.4%	10.8%	11.5%
Delta-9-THC content	0.003 +/- 0.00%	1.8 +/- 0.11%	3 +/- 0.18%

Alcohol was administered according to a weight-related dose. The data in Tables 5 and 6 were used to determine how many drinks according to bodyweight would be administered to the participant. The target blood alcohol concentration for participants in the low alcohol group was 0.04% BAC, and 0.06% BAC for participants in the high alcohol group. The placebo session was masked as being 0.04% BAC or 0.06% BAC when it was actually 0% BAC (nurse administered the breath alcohol test, the nurse did not administer any performance tests). By the time the driving task was performed, BAC had dropped to 0.03% and 0.05% respectively (required level for testing). The level of alcohol in blood drops approximately 0.01% every 40 minutes. The cannabis cigarettes used in the study were donated by the National Institute on Drug Abuse (NIDA) in the United States of America. Each THC cigarette was administered using a controlled smoking procedure (Papafotiou et al., 2004a). The participant was asked to inhale the cigarette for 2 seconds, hold the smoke in for 10 seconds and exhale and rest for 30 seconds. If the participant could not hold for 10 seconds they were asked to exhale when they felt they could no longer hold.

Table 5. BAC reached using 30ml vodka to 170ml of orange juice at different bodyweights, and the number of drinks required to reach this BAC.

		Bodyweight in pounds							
	Drinks needed	**100**	**120**	**140**	**160**	**180**	**200**	**220**	**240**
Males	2	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02
	4	0.08	0.06	0.05	0.05	0.04	0.04	0.03	0.03
	6	0.11	0.09	0.08	0.07	0.06	0.06	0.05	0.05
Females	2	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.02
	4	0.09	0.08	0.07	0.06	0.05	0.05	0.04	0.04
	6	0.14	0.11	0.10	0.09	0.08	0.07	0.06	0.06

Table 6. BAC reached using 60ml vodka to 140ml of orange juice at different bodyweights, and different number of drinks.

		Bodyweight in pounds							
	Drinks needed	**100**	**120**	**140**	**160**	**180**	**200**	**220**	**240**
Males	1	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02
	2	0.08	0.06	0.05	0.05	0.04	0.04	0.03	0.03
	3	0.11	0.09	0.08	0.07	0.06	0.06	0.05	0.05
	4	0.15	0.12	0.11	0.09	0.08	0.08	0.07	0.06
Females	1	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.02
	2	0.09	0.08	0.07	0.06	0.05	0.05	0.04	0.04
	3	0.14	0.11	0.10	0.09	0.08	0.07	0.06	0.06

Each drug condition (alcohol and THC) were combined to comprise 6 sessions:

Part one: Low alcohol

1. *PLACEBO SESSION:* Placebo alcohol with placebo THC
2. *LOW ALCOHOL ONLY:* 0.03% BAC with placebo THC
3. *LOW ALCOHOL AND LOW THC:* 0.03% BAC with 1.8% THC
4. *LOW ALCOHOL AND HIGH THC:* 0.03% BAC with 3% THC
5. *LOW THC ONLY:* Placebo alcohol with 1.8% THC
6. *HIGH THC ONLY:* Placebo alcohol with 3% THC

Part two: High alcohol

1. *PLACEBO ALCOHOL:* Placebo alcohol with placebo THC
2. *HIGH ALCOHOL ONLY:* 0.05% BAC with placebo THC
3. *HIGH ALCOHOL AND LOW THC:* 0.05% BAC with 1.8% THC
4. *HIGH ALCOHOL AND HIGH THC:* 0.05% BAC with 3% THC
5. *LOW THC ONLY:* Placebo alcohol with 1.8% THC
6. *HIGH THC ONLY:* Placebo alcohol with 3% THC

The study was counter-balanced, double-blind, and used a within-subject design.

Medical examinations

All participants underwent a medical examination administered by a general practitioner. Before the examination, participants completed a patient questionnaire (Appendix A1). The questionnaire was discussed in detail during the examination and other medical tests were performed (blood pressure, pulse, height, weight, etc.) (Appendix A2). The medical practitioner then decided on whether the participant was fit to participate in the study. Individuals fit to participate were asked to complete a series of questionnaires. Individuals not fit were excluded from any further participation.

Information sheet and consent forms

All individuals interested in participating in the study were provided with an information sheet that described the study in detail. Any queries were answered, and, if the individual was satisfied with the details and agreed to participate in the study, they completed and signed a consent form. See Appendix B1, B2, B3. Participants were then allocated a medical examination.

Questionnaires

Participants were asked to complete a Medical examination questionnaire, Demographics questionnaire and a Frequency of Cannabis Use questionnaire.

Medical examination questionnaire

This questionnaire consisted of several questions concerning allergies, medications, medical problems, medical operations, diet, alcohol consumption, and pregnancy for females. Medical history and health was discussed further with a medical practitioner. See Appendix A1.

Demographics questionnaire

This questionnaire consisted of 7 questions involving age, sex, education and health. See Appendix C.

Frequency of cannabis use questionnaire

This questionnaire consisted of 6 questions involving past and current frequency of cannabis use as well as method of consumption and the effects (psychological and physical) generally experienced by the individual after consuming cannabis. See Appendix D.

Driving simulator

The driving simulator was the CyberCAR LITE driver training and evaluation simulator (Thoroughbred Technologies Pty. Ltd.). The steering wheel, a 'Force Feedback', with integrated horn, indicators, headlights, ignition, automatic gears and hand brake, was affixed to a bench. The brake pedal and accelerator pedal were placed underneath the bench. Participants could adjust the pedal and seat position to suit their height. The simulator task was projected onto a 175cm x 120cm white screen (distance from steering wheel was 280cm). Participants observed a two-dimensional computer-generated driving scene, as they would through a vehicle windscreen. The simulated dashboard, which was also projected onto the white screen, included a speedometer, rear-view mirror, and side-mirrors. The tasks administered employed a simulated conventional on-road light motor vehicle with automatic transmission.

The driving simulator program consisted of two parts: the *Day-time* and *Night-time* Driving Modules: Each Driving Module (day and night) consisted of two tasks: 'freeway traffic driving' and 'city traffic driving'. Each scenario took approximately five minutes to complete. The complete driving module took approximately 20 minutes to complete. For the present study, a subset of 19 variables were analysed, each reflecting an error that can occur during the driving tasks (Papafotiou et al., 2003b). Each variable score was multiplied by that variable's "loading factor", a number that represents the severity of the error. In addition, all adjusted variable scores were summed to give an overall impairment score. Driving simulator variable scores were analysed separately for the day and night conditions. For each, a total score between 0 and 75 was classified as 'not impaired' on the driving simulator task, whereas a total score of 76 and above constituted an assessment of 'impaired' on the driving task (Papafotiou et al., 2004b).

Standardised Field Sobriety Tests (SFSTs)

The SFSTs are reported to provide reliable results only if administered by a trained person. Each test that comprises the SFSTs (HGN, WAT and OLS, described below) must be administered in the same manner to all individuals, and specific signs must be observed during each test in order for a participant to be judged as impaired (Page, 1995). A member of Victoria Police trained the researchers in the administration of the SFSTs. All three tests that comprise the SFST battery were administered, as per the administration procedures used by the Victoria Police (*Victorian Government Gazette,* 2000).

The tests that comprise the SFSTs are:

1. *Horizontal and Vertical Gaze Nystagmus (HGN and VGN) Test*

   This test involved asking the participant to follow an object moving horizontally and then vertically 12-15 inches in front of their face. The specific instructions given by the investigator were as follows:

   "I am going to check your eyes. Keep your head still and follow the tip of my pen with your eyes only. Keep focusing on the tip until I tell you to stop. Do you understand?" If the participant answered "no" the instructions were repeated and clarified; if the participant responded "yes" the investigator began the test. The pen was moved smoothly horizontally across the face, the pen was moved to the furthest left and furthest right that the eye could follow and the pen was also moved to an angle of 45 degrees from the centre of the face. The pen was then moved smoothly vertically in front of the face to the highest and lowest point in view. The investigator stopped the test if the participant was feeling dizzy or was likely to fall over and hurt him/herself.

   Scoring: The investigator observed the eyes and noted if any nystagmus was present. Nystagmus is an involuntary jerking or shaking of the eyeball. More specifically, the signs recorded were as follows (the left and right eye were scored separately):

   1. Eye does not pursuit smoothly (Left: Yes/No, Right: Yes/No)
   2. Distinct nystagmus at maximum deviation (Left: Yes/No, Right: Yes/No)
   3. Nystagmus onset before 45 degrees (Left: Yes/No, Right: Yes/No)
   4. Nystagmus at upmost position (vertical) (Left: Yes/No, Right: Yes/No)

   A sign that was observed in one eye only was recorded as only one sign, if the same sign was observed in both eyes it was recorded as two signs (the maximum number of signs for this test was therefore 8). If a total of four of more signs were observed, the participant was classified as impaired to a degree equivalent to a blood alcohol concentration (BAC) above 0.10%. An additional sign was scored - Head movement/Jerks (HMJ) - in order to determine whether HMJ increases the accuracy of the HGN test. Previous research suggests that scoring HMJ significantly increases the likelihood of correctly predicting the presence of cannabis (Papafotiou, 2000). If a head movement of jerk was observed, the participant was classified as impaired to a degree equivalent to BAC above 0.10%

2. *Walk and Turn (WAT) Test*

   This test involved asking the participant to walk a straight line marked out on the ground, taking nine steps up the line, turning around and taking another nine steps back up the line, while counting each step out aloud. The specific instructions given were as follows:

"Place your left foot on the line, and place your right foot on the line in front of your left foot, with the heel of your right against the toe of your left (correct stance demonstrated). Place your arms by your side and keep this position until I tell you to begin the test. Do you understand?" If the participant answered "no" the instructions were repeated and clarified, if the participant responded "yes" the investigator continued with the instructions.

"When I tell you to start, take nine heel to toe steps up the line like this (correct walk demonstrated), turn around taking a series of small steps like this (correct turning style demonstrated), and then take nine heel to toes steps back up the line. While you are walking, keep your arms by your side, watch your feet and count your steps out aloud. Once you start walking, do not stop until you have finished the test. Do you understand?" If the participant responded "no" the investigator asked "which part of the test don't you understand?" and the instructions were repeated and clarified. If the participant responded "yes" the investigator continued "Begin and count the first step you take as one". The investigator stopped the test if the participant was feeling dizzy or was likely to fall over and hurt him/herself.

Scoring: The investigator examined the behaviours of the participant. Specifically, the behaviours recorded were as follows:

1. Cannot keep balance while listening to the instructions of the test
2. Starts the test before the instructions are complete
3. Stops walking during the test
4. Does not touch heel to toe while walking
5. Steps off the line
6. Uses arms to maintain balance
7. Turns improperly (not as demonstrated during instructions)
8. Takes the incorrect number of steps (more or less than 9 up and/or 9 back)

Each sign observed was recorded as one sign, independent of how many times the same sign occurred or whether it occurred during both the 9 steps up and the 9 steps back (the maximum number of signs for this test therefore was 8). If two or more signs were observed, the participant was classified as impaired to a degree equivalent to a BAC above 0.10%. If the participant failed to complete the test, all 8 signs were recorded.

3. *One Leg Stand (OLS) Test*

This test involved asking the participant to stand on one leg, with the other stretched out in front of them, while counting aloud for 30 seconds starting at 1000. The specific instructions given were as follows:

"Stand with your feet together, and arms by your side, like this (position demonstrated). Do not start the test until I tell you to do so. Do you understand so far?" If the participant responded "no" the instructions were repeated and clarified; if the participant responded "yes" the investigator continued with the instructions.

"When I tell you to start, raise one leg, either leg, approximately 15 cm off the ground, toes pointed, arms by your side and keep both legs straight (position demonstrated). While holding that position, count out loud for 30 seconds in the following manner: 1001, 1002, 1003 and so on. Keep your arms by your side at all times and keep watching your raised foot. Do you understand?" If the participant responded "no" the investigator asked "which part of the test don't you understand?" and the instructions were repeated and clarified. If the participant

responded "yes" the investigator continued, "Go ahead and perform the test". If the participant counted very fast they were asked to continue and then they were stopped after 30 seconds had passed. If the participant counted too slowly they were asked to stop the test after 30 seconds had passed. The investigator stopped the test if the participant was feeling dizzy or was likely to fall over and hurt him/herself.

Scoring: The investigator examined the behaviours of the participant during performance. The specific behaviours recorded were as follows:

1. Swaying while balancing on one leg
2. Uses arms to maintain balance
3. Hopping during test to maintain balance
4. Puts raised foot down

Each sign observed was recorded as one sign, independent of how many times the same sign occurred (therefore the maximum number of signs for this test was 4). If two or more signs were observed, the participant was classified as impaired to a degree equivalent to a BAC above 0.10%. If the participant put their foot down more than 3 times and/or failed to complete the test, all 4 signs were recorded.

4. *Overall SFST performance*

Overall SFST performance involved the examination of the combined performance on the three tests used in this study that make up the SFST: the HGN test, WAT test and OLS test.

Scoring: If the participant was classified as impaired, to a degree equivalent to a BAC above 0.10%, on two or more of the tests, the participant was also classified as impaired on the SFST, to a degree equivalent to a BAC above 0.10%.

* All participants were videotaped during their performance. This video footage was used by the investigator to double-check the signs recorded, and was viewed by police officers to test for impairment using the SFSTs. The complete SFST battery took approximately 10 minutes to complete.

Blood samples

Blood samples were taken from each participant throughout all sessions, by a registered nurse. Two samples were taken over a 2.5-hour period. A medical doctor was on call throughout testing sessions. The equipment used to take blood was a 10ml syringe and 0.8 x 38mm needle. Each 10ml blood sample was transferred into a heparinised plastic tube. Blood samples were immediately placed into a – 5ºC freezer and collected each day at the end of testing. Blood samples were transported to a toxicology laboratory and were analysed immediately.

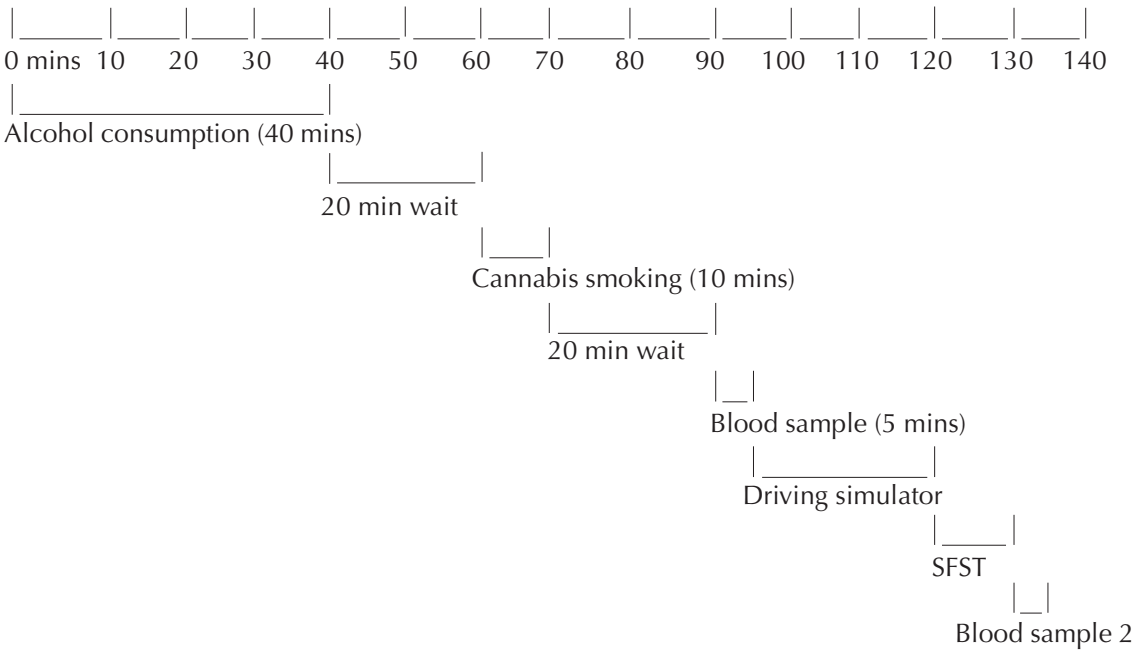
Blood samples were analysed for THC levels using the Gas Chromatograph-Mass Spectrometer (GC/MS) method. This method provides a means to confirm and quantify THC in both clinical and post-mortem specimens. GC/MS is considered to be the most accurate means of testing for the presence of drugs in blood.

Procedure

Experimental sessions

On arrival, the participant was escorted to the Pharmacology Laboratory (Centre for Neuropsychology, Swinburne University of Technology). In the first session, participants were taken to the driving simulator to practise the two driving conditions - city and freeway driving course. After a 5 minute practice session, the participant was given a beverage that contained either a quantity of vodka according to their bodyweight, mixed with the appropriate amount of orange juice or 200ml orange juice. Once the drinks were consumed, participants waited 20 minutes, and then BAC was measured using a Lion Alcometer SD 400. If the target BAC was not reached, the participant was given another drink/s to bring their BAC up to the target level. For the placebo session, the same number of drinks was given to the participant as was given in the active alcohol session; however, placebo alcohol contained only orange juice. Neither the investigator nor the participant viewed the BAC reading at any time (the nurse administered the breath alcohol test). Once target BAC was reached, the participant was handed a cannabis cigarette which contained either 0% THC, 1.8% THC or 3% THC. Ten inhalations were completed and the cigarette was soaked and disposed of in a hazard waste bin. Participants waited 20 minutes before the first 10ml blood sample was taken. Twenty minutes was used, as past research indicates that, although THC plasma levels peak immediately after smoking, behavioural impairment occurs once plasma levels have dropped (Moskowitz, 1985; Berghaus et al., 1995). Participants were then taken to the driving simulator to complete the driving module. This was followed by the SFSTs and a final blood sample.

Figure 6. Summary of one experimental session



Analysis of the original protocol and project aims determined the number of blood samples to be taken and analysed for each session. Since the aim of the project was to investigate the relationship between drug levels and performance, blood samples were taken before and after the administration of the driving simulator task and the SFSTs. A blood sample was also taken prior to the experimental session to ensure that the participant was drug-free at the time of testing (baseline). If a baseline blood sample contained drugs, data from that experimental session was

excluded from analysis. Blood samples were screened for the 7 major drug classes (opiates, amphetamines, benzodiazapines, cannabinoids, barbiturates, cocaine and methadone) and analysed for specific levels of delta-9-THC (and specific levels for any other drug if it was detected).

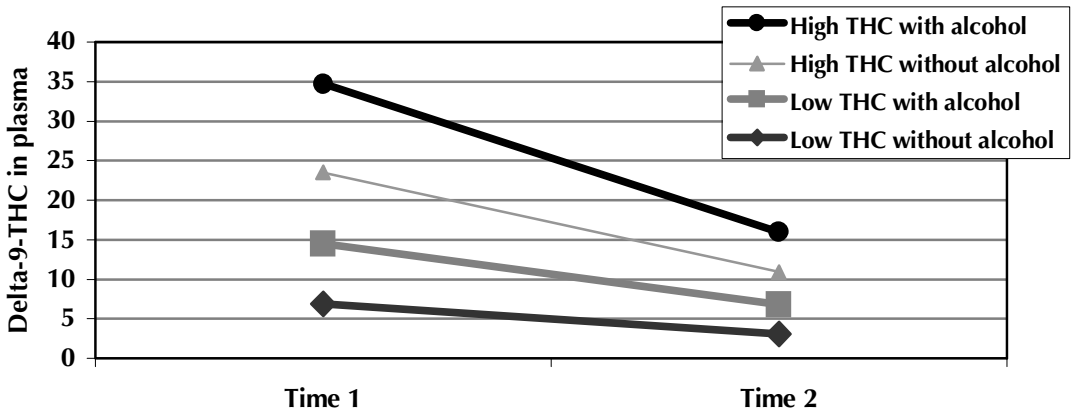
Results

Blood analysis: The level of THC in plasma

Cannabis dose and level of THC in plasma (with and without alcohol)

Blood samples were taken before the experimental sessions proceeded, to ensure that participants had no drugs in their system. Samples were analysed for the seven major drug classes (opiates, amphetamines, benzodiazapines, cannabinoids, barbiturates, cocaine and methadone). One blood sample was taken at 20 minutes after completion of cannabis smoking (Time 1; pre-performance tests) and a second sample was taken at approximately 60 mins after completion of cannabis smoking (Time 2; post-performance testing). Figure 7 displays the mean level of active delta-9-THC in plasma for the low and the high cannabis condition, with and without the administration of alcohol.

Figure 7: The level of delta-9-THC in plasma with and without alcohol



The level of THC detected in plasma decreased over a 40 minute period. In addition, the level of THC in plasma was higher after the administration of the high THC cigarette than the low THC cigarette. When alcohol was consumed prior to smoking the cannabis cigarette, the level of THC detected in plasma was higher. These results show a linear pattern between each drug condition, where the higher the THC dose consumed, the higher the level of THC in plasma, and when THC is consumed with alcohol the higher the level of THC in plasma.

Cannabis dose, the level of THC in plasma and frequency of cannabis use

The level of THC in plasma for regular cannabis users and non-regular cannabis users was examined. Figures 8 and 9 display the level of active delta-9-THC detected in plasma for each THC condition, with and without alcohol.

Figure 8: Regular cannabis users: The level of delta-9-THC in plasma with and without alcohol

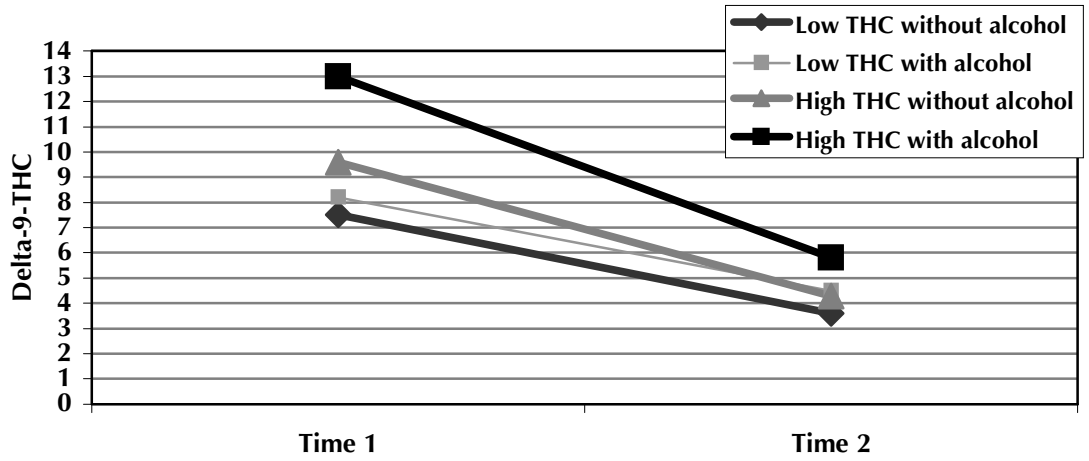
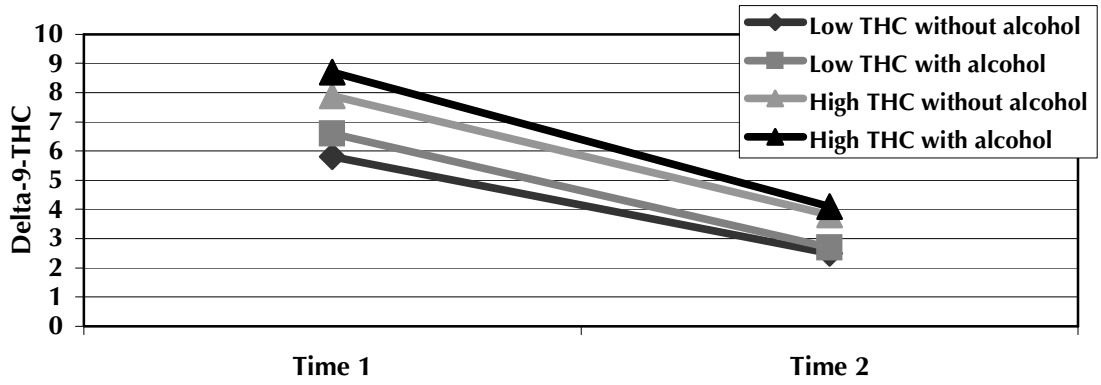


Figure 9: Non-regular cannabis users: The level of delta-9-THC in plasma with and without alcohol



The level of THC detected in plasma decreased over a 40 minute period in both regular and non-regular cannabis users. In addition, the level of THC in plasma was higher after the administration of the high THC cigarette compared to the administration of the low THC cigarette for both regular users and non-regular users. When alcohol was consumed prior to smoking the cannabis cigarette, the level of THC detected in plasma was higher. These results show a linear pattern between each drug condition, where the higher the THC dose consumed, the higher the level of THC in plasma, and when THC is consumed with alcohol the higher the level of THC in plasma. This was the case for both regular and non-regular users. In addition, at each time point and in each condition, the mean level of THC detected in plasma was higher in the regular cannabis users than non-regular users.

Driving performance

The driving data was analysed separately for the day-time and night-time driving scenarios. Performance on each driving simulator variable was analysed using a 2 x 2 x 3 mixed design Analysis of Variance (ANOVA). The between-subject factor was Alcohol Dose (low: 0.03% BAC; high: 0.05% BAC) and the within-subject variables were Alcohol (placebo; active) and THC

(placebo; low THC; high THC). A comparison of participants based on their frequency of THC use was performed by introducing the between-subjects factor User (regular THC user; non-regular THC user). The main effects were examined to determine the effect of a single variable (such as THC level) on driving behaviours, regardless of the other conditions (such as level of alcohol consumed). The interaction statistics were then explored to take into account the different effects of each variable. The results presented here are only those that were significantly different between at least two of the Alcohol, THC, Alcohol Dose or User variables.

Day-time driving conditions

Day-time: 'Dangerous action – skidded'

The mean accuracy and standard deviations for the driving variable 'dangerous action – skidded' for the low and high dose alcohol groups are displayed in Table 7.

Table 7: Means and standard deviations for the driving variable 'dangerous action – skidded' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	0.18	0.55	0.39	1.16	0.28	0.90
Placebo	Low	0.20	0.52	0.21	0.47	0.20	0.49
Placebo	High	0.18	0.55	0.13	0.41	0.15	0.48
Active	Placebo	0.60	1.22	0.56	2.43	0.58	1.90
Active	Low	0.33	1.05	0.44	1.35	0.38	1.20
Active	High	0.20	0.52	0.62	1.82	0.41	1.34

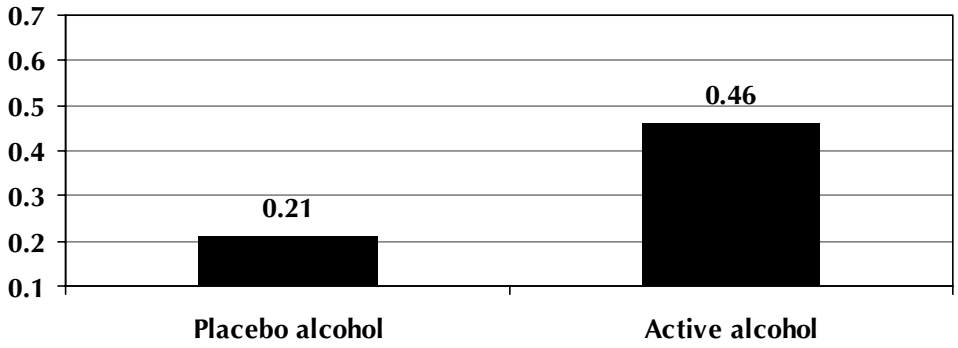
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 8.

Table 8: Results from the mixed design ANOVA for driving variable 'dangerous action – skidded'

Day-time: Dangerous action – skidded	Mean Square	F	df	p
Alcohol Dose	1.43	0.31	1,77	0.58
Alcohol	7.14	3.99	1,77	0.04
Alcohol x Alcohol Dose	0.34	0.19	1,77	0.66
THC	1.12	1.84	2,154	0.16
THC x Alcohol Dose	0.17	0.28	2,154	0.75
Alcohol x THC	0.16	0.60	2,154	0.55
Alcohol x THC x Alcohol Dose	1.24	4.74	2,154	0.01

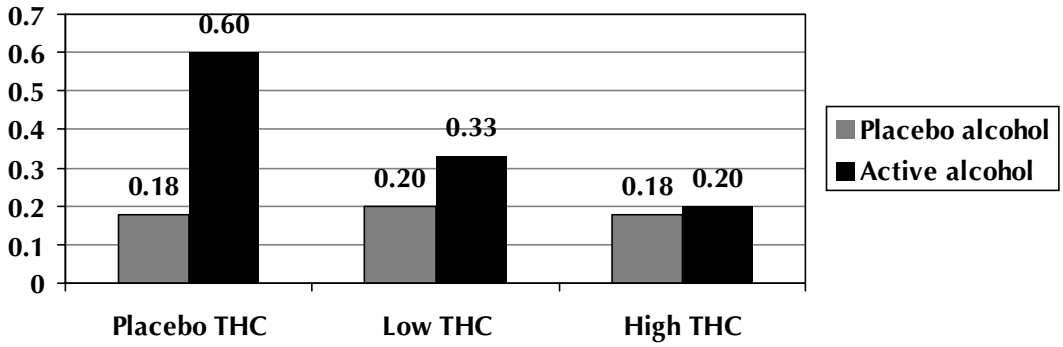
There was a significant main effect of Alcohol. In the alcohol condition there was significantly more skidding than in the placebo condition (Figure 10).

Figure 10: Mean number of errors for the driving variable 'dangerous action – skidded' for the two alcohol conditions



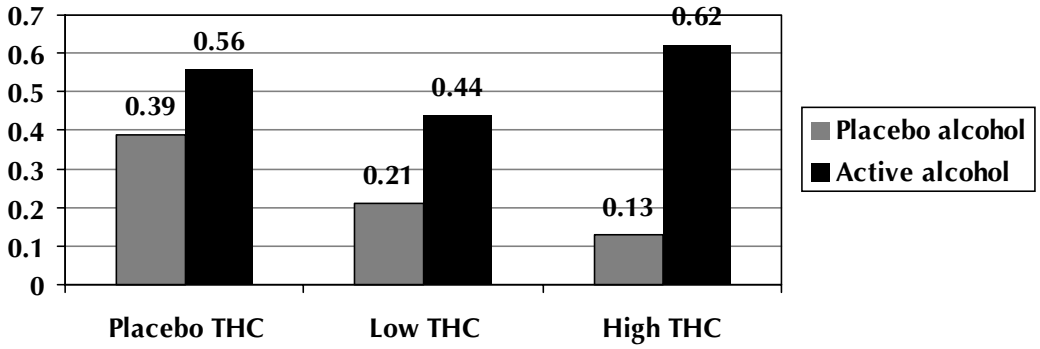
There was also a significant interaction between Alcohol, THC and Dose. In the low alcohol group (0.03% BAC), there were significantly more skidding errors when active alcohol was combined with placebo THC, than when placebo alcohol was combined with placebo THC ($p < 0.01$) (Figure 11).

Figure 11: Mean number of errors for the driving variable 'dangerous action – skidded' for the two alcohol conditions across the THC conditions in the low alcohol group



However, in the high alcohol group (0.05% BAC), there was significantly more skidding when active alcohol was combined with high THC than when high THC was consumed alone ($p < 0.01$) (Figure 12).

Figure 12: Mean number of errors on the driving variable 'dangerous action – skidded' for the two alcohol conditions across the THC conditions in the high alcohol group



Day-time: 'Speed control – fast'

The mean and standard deviations for errors on the driving variable 'speed control – fast' (driving too fast for the conditions) for the low and high dose alcohol groups are displayed in Table 9.

Table 9: Means and standard deviations for the driving variable 'speed control – fast' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	0.88	2.23	0.64	2.05	0.76	2.13
Placebo	Low	2.38	4.38	0.90	3.42	1.65	3.98
Placebo	High	1.13	2.65	1.28	2.97	1.20	2.80
Active	Placebo	2.50	5.66	1.54	4.00	2.03	4.90
Active	Low	1.13	2.11	0.90	2.53	1.01	2.32
Active	High	1.25	3.54	1.92	4.53	1.58	4.05

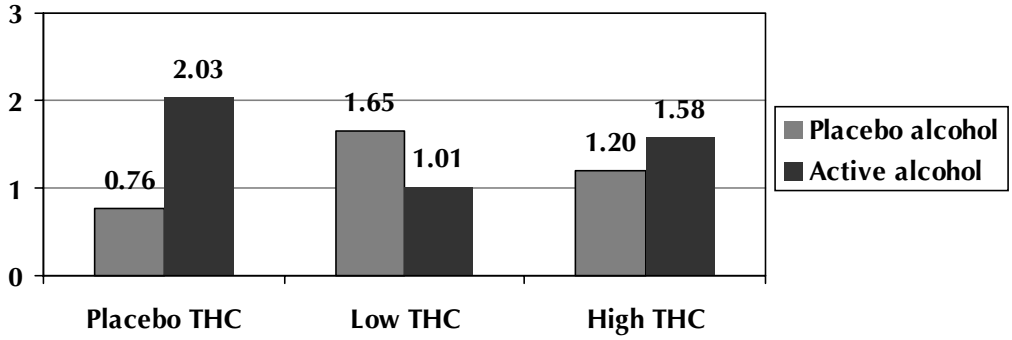
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 10.

Table 10: Results from the mixed design ANOVA for driving variable 'speed control – fast'.

Day-time: Speed control – fast	Mean Square	F	df	p
Alcohol Dose	14.11	0.59	1,77	0.44
Alcohol	13.68	1.92	1,77	0.17
Alcohol x Alcohol Dose	3.55	0.50	1,77	0.48
THC	0.25	0.02	2,154	0.98
THC x Alcohol Dose	17.76	1.73	2,154	0.18
Alcohol x THC	35.18	3.11	2,154	0.04
Alcohol x THC x Alcohol Dose	9.87	0.87	2,154	0.42

There was a significant interaction between Alcohol and THC. In the placebo THC condition, participants drove too fast for the conditions significantly more often when they had consumed active alcohol, compared to when they had consumed placebo alcohol. In the low and high THC conditions, there was no significant difference between the numbers of errors made when THC was combined with active alcohol compared to when THC was combined with placebo alcohol (Figure 13).

Figure 13: Mean number of errors for the driving variable 'speed control – fast' for placebo and active alcohol in the three THC conditions



Day-time: 'Speed control – following distance'

The mean accuracy and standard deviations for the driving variable 'following distance' (number of times driver did not keep a safe following distance) for the low and high dose alcohol groups are displayed in Table 11.

Table 11: Means and standard deviations for the driving variable 'speed control – following distance' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	25.75	15.00	24.62	15.10	25.19	14.97
Placebo	Low	24.38	16.61	21.67	15.15	23.04	15.86
Placebo	High	25.50	17.28	27.05	16.37	26.27	16.75
Active	Placebo	26.00	25.20	24.49	14.99	25.25	20.68
Active	Low	28.38	21.64	28.85	16.12	28.61	19.00
Active	High	27.38	18.91	29.87	16.52	28.61	17.70

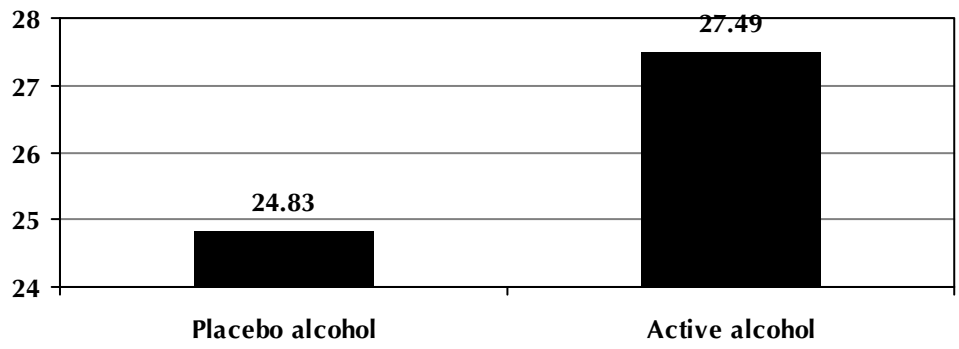
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 12.

Table 12: Results from the mixed design ANOVA for driving variable 'speed control – following distance'.

Day-time: Speed control – following distance	Mean Square	F	df	p
Alcohol Dose	2.30	0.00	1,77	0.96
Alcohol	842.20	4.03	1,77	0.04
Alcohol x Alcohol Dose	46.20	0.22	1,77	0.64
THC	211.50	1.24	2,154	0.29
THC x Alcohol Dose	139.10	0.81	2,154	0.45
Alcohol x THC	304.80	1.58	2,154	0.21
Alcohol x THC x Alcohol Dose	31.90	0.17	2,154	0.85

There was a significant main effect of Alcohol. A safe following distance was kept more often in the placebo alcohol conditions than in the active alcohol conditions (Figure 14).

Figure 14: Mean number of errors for the driving variable 'speed control – following distance' for the two alcohol conditions



Day-time: 'Violation traffic law – speed limit'

Mean accuracy and standard deviations for the driving variable 'speed limit' for the low and high dose alcohol groups are displayed in Table 13.

Table 13: Means and standard deviations for the driving variable 'speed limit' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	6.30	6.40	5.44	5.23	5.87	5.83
Placebo	Low	5.95	6.33	4.10	4.35	5.04	5.49
Placebo	High	4.85	6.04	4.67	4.93	4.76	5.48
Active	Placebo	6.95	7.39	6.26	7.44	6.61	7.38
Active	Low	6.05	6.35	5.59	6.29	5.82	6.29
Active	High	5.50	6.07	6.46	5.83	5.98	5.94

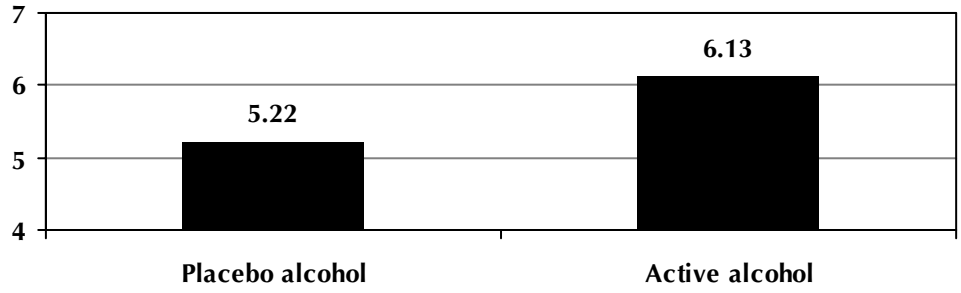
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 14.

Table 14: Results from the mixed design ANOVA for driving variable 'speed limit'.

Day-time: Violation traffic law – speed limit	Mean Square	F	df	p
Alcohol Dose	31.37	0.21	1,77	0.65
Alcohol	99.65	6.36	1,77	0.01
Alcohol x Alcohol Dose	24.04	1.54	1,77	0.22
THC	37.20	2.64	2,154	0.07
THC x Alcohol Dose	25.57	1.81	2,154	0.17
Alcohol x THC	2.80	0.18	2,154	0.84
Alcohol x THC x Alcohol Dose	4.09	0.26	2,154	0.77

There was a significant main effect of Alcohol. There were significantly more violations of the speed limit in the active alcohol condition compared to the placebo alcohol condition (Figure 15).

Figure 15: Mean number of errors for the driving variable 'speed limit' for the two alcohol conditions



Day-time: 'Initial speed on freeway'

The mean and standard deviations of the driving variable 'initial speed on freeway' for the low and high dose alcohol groups are displayed in Table 15.

Table 15: Means and standard deviations for the driving variable 'initial speed on freeway' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	96.10	34.28	98.27	25.79	97.18	30.21
Placebo	Low	84.37	40.94	84.13	37.97	84.25	39.25
Placebo	High	91.01	37.56	82.71	40.52	86.91	39.02
Active	Placebo	93.26	37.43	97.48	30.92	95.35	34.22
Active	Low	84.25	40.74	87.37	39.09	85.79	39.71
Active	High	93.97	37.91	82.12	43.49	88.12	40.94

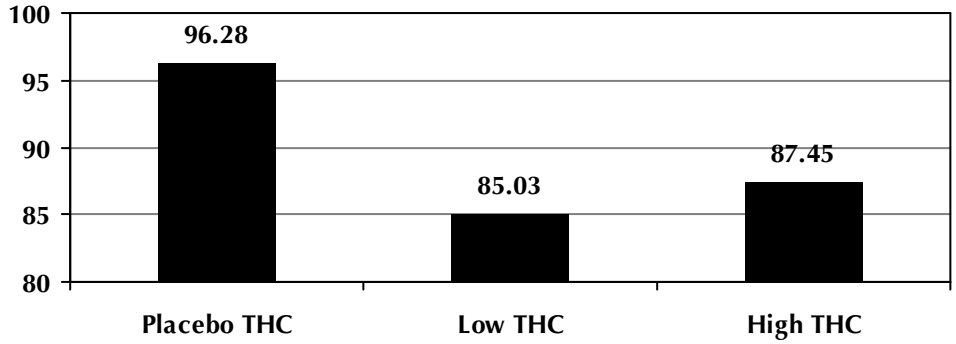
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 16.

Table 16: Results from the mixed design ANOVA for driving variable 'initial speed on freeway'.

Day-time: Initial speed on freeway	Mean Square	F	Df	p
Alcohol Dose	391	0.17	1,77	0.68
Alcohol	12	0.01	1,77	0.91
Alcohol x Alcohol Dose	11	0.01	1,77	0.91
THC	5537	4.24	2,154	0.02
THC x Alcohol Dose	2050	1.57	2,154	0.21
Alcohol x THC	135	0.10	2,154	0.91
Alcohol x THC x Alcohol Dose	134	0.10	2,154	0.91

The main effect of THC was significant. Participants had a significantly slower initial speed on the freeway in both the low ($p < 0.01$) and high ($p < 0.05$) THC conditions than in the placebo THC condition (Figure 16).

Figure 16: Mean speed (km/h) for the driving variable 'initial speed on freeway' for the three THC conditions



Night-time driving conditions.

Night-time: 'Collisions'

The mean and standard deviations for the driving variable 'collisions' in the low and high alcohol groups are displayed in Table 17.

Table 17: Means and standard deviations for the driving variable 'collisions' in the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	2.75	5.06	4.62	6.82	3.68	6.03
Placebo	Low	4.75	7.16	4.62	7.20	4.68	7.13
Placebo	High	3.75	7.05	7.44	9.93	5.57	8.73
Active	Placebo	5.00	5.55	5.13	7.21	5.06	6.38
Active	Low	6.75	8.29	7.44	8.50	7.09	8.34
Active	High	5.50	7.83	6.92	6.94	6.21	7.39

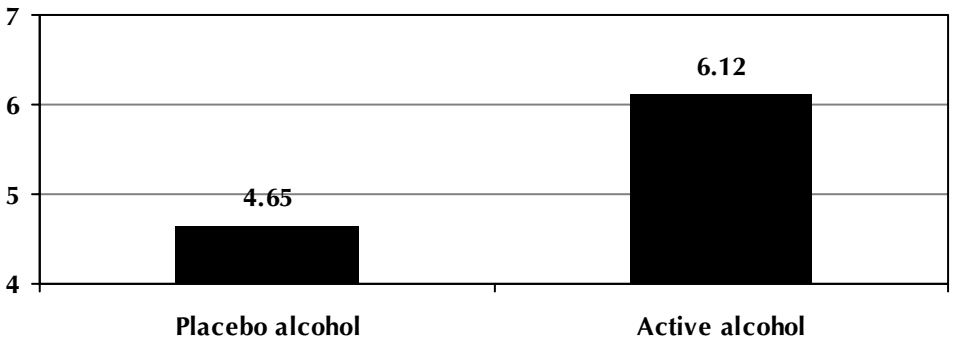
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 18.

Table 18: Results from the mixed design ANOVA for driving variable 'collisions'.

Night-time: Collisions	Mean Square	F	df	P
Alcohol Dose	192.80	2.82	1,77	0.097
Alcohol	256.06	5.34	1,77	0.023
Alcohol x Alcohol Dose	33.27	0.69	1,77	0.407
THC	121.93	2.50	2,154	0.086
THC x Alcohol Dose	53.58	1.10	2,154	0.336
Alcohol x THC	31.93	0.56	2,154	0.571
Alcohol x THC x Alcohol Dose	26.86	0.47	2,154	0.624

There was a significant main effect of Alcohol. There were significantly more collisions in the active alcohol condition than in the placebo alcohol condition (Figure 17).

Figure 17: Mean number of errors on the driving variable 'collisions' for placebo alcohol conditions and active alcohol conditions



Night-time: 'Dangerous action – skidded'

The mean number of errors and standard deviations for the driving variable 'skidded' for the low and high dose alcohol groups are displayed in Table 19.

Table 19: Means and standard deviations for the driving variable 'skidded' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	0.25	0.59	0.26	0.55	0.25	0.57
Placebo	Low	0.30	0.91	0.15	0.43	0.23	0.72
Placebo	High	0.10	0.44	0.08	0.27	0.09	0.36
Active	Placebo	0.23	0.62	0.41	0.99	0.32	0.82
Active	Low	0.40	1.06	0.26	1.02	0.33	1.03
Active	High	0.28	0.64	0.46	0.97	0.37	0.82

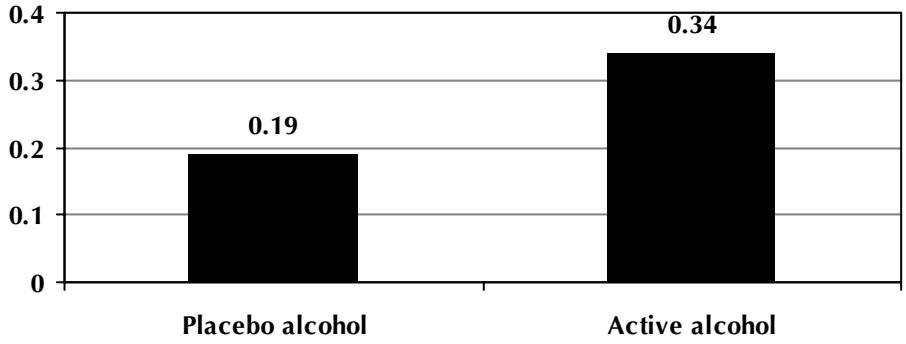
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 20.

Table 20: Results from the mixed design ANOVA for driving variable 'skidded'.

Night-time: Dangerous action – skidded	Mean Square	F	df	p
Alcohol Dose	0.01	0.01	1,77	0.925
Alcohol	2.61	4.50	1,77	0.037
Alcohol x Alcohol Dose	0.50	0.87	1,77	0.355
THC	0.15	0.48	2,154	0.622
THC x Alcohol Dose	0.72	2.27	2,154	0.107
Alcohol x THC	0.52	1.78	2,154	0.172
Alcohol x THC x Alcohol Dose	0.12	0.42	2,154	0.659

There was a significant main effect of Alcohol. Dangerous skidding was significantly more frequent in the active alcohol condition than in the placebo alcohol condition (Figure 18).

Figure 18: Mean number of errors for the driving variable 'skidded' for the two alcohol conditions



Night-time: 'Speed control – fast'

The mean accuracy and standard deviations for the driving variable 'speed control – fast' for the low and high dose alcohol groups are displayed in Table 21.

Table 21: Means and standard deviations for the driving variable 'speed control – fast' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	0.38	1.33	1.92	4.68	1.34	3.49
Placebo	Low	3.25	5.13	0.90	2.53	2.09	4.21
Placebo	High	0.88	2.50	0.38	1.35	0.63	2.02
Active	Placebo	1.13	3.84	0.26	1.12	0.70	2.86
Active	Low	1.25	2.72	1.41	2.80	1.33	2.74
Active	High	2.50	4.53	2.31	4.27	2.41	4.38

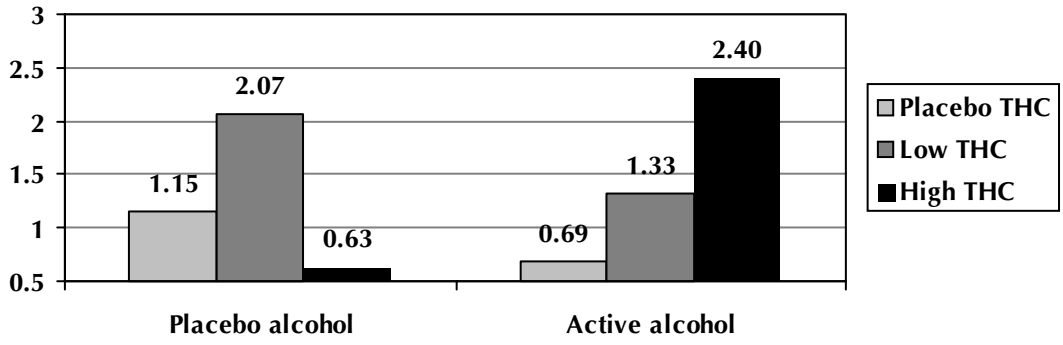
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 22.

Table 22: Results from the mixed design ANOVA for driving variable 'speed control – fast'.

Night-time: Speed control - Fast	Mean Square	F	df	p
Alcohol Dose	15.86	1.23	1,77	0.270
Alcohol	4.31	0.46	1,77	0.501
Alcohol x Alcohol Dose	0.51	0.05	1,77	0.816
THC	26.39	2.28	2,154	0.105
THC x Alcohol Dose	20.37	1.76	2,154	0.175
Alcohol x THC	75.06	6.85	2,154	0.001
Alcohol x THC x Alcohol Dose	60.19	5.49	2,154	0.005

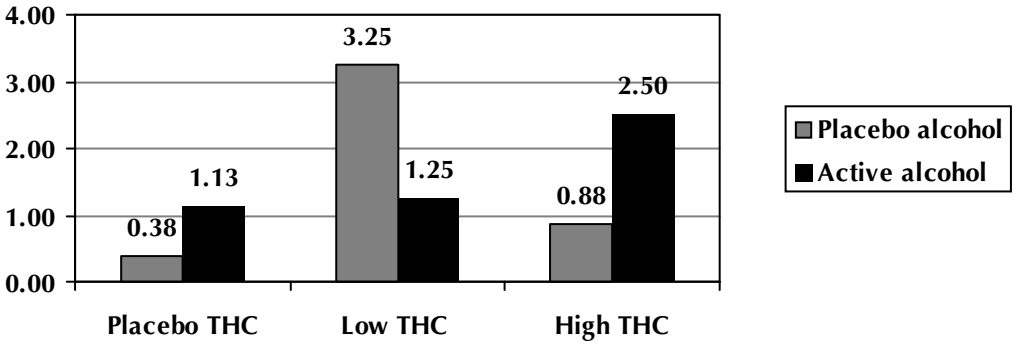
There was a significant interaction between Alcohol and THC. Driving too fast for the conditions occurred significantly more often when high THC was combined with alcohol than when high THC was consumed alone ($p < 0.01$) (Figure 19).

Figure 19: Mean number of errors for the driving variable 'speed control – fast' for the three THC conditions across the two alcohol conditions



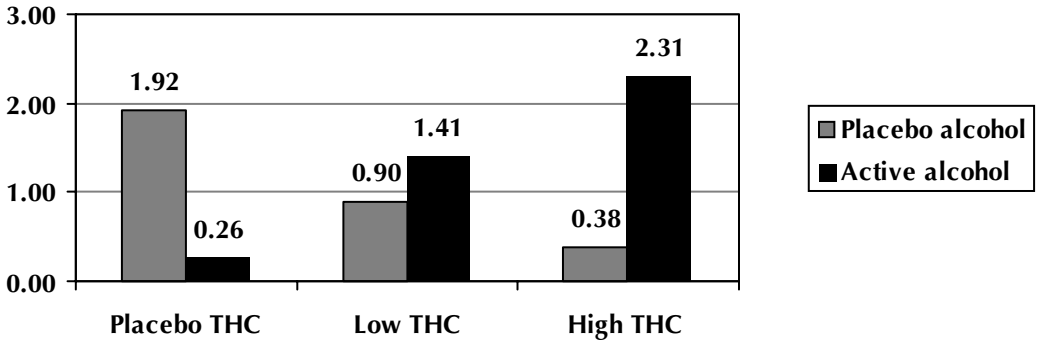
There was also a significant interaction between Alcohol, THC and Dose. In the low alcohol group, participants performed more errors in the low THC condition than the high THC ($p < 0.01$) and placebo THC ($p < 0.001$) conditions when THC was consumed without active alcohol. In addition, participants performed more errors when low THC was consumed alone, compared to when low THC was combined with active alcohol ($p < 0.01$) (Figure 20).

Figure 20: Mean number of errors for driving variable 'speed control – fast' for the low dose alcohol group for the placebo and active alcohol conditions across the three THC conditions



In the high alcohol group, participants performed more errors in the active alcohol condition when it was combined with high THC, than when active alcohol was combined with placebo THC ($p < 0.05$). In addition, participants also drove too fast for the conditions significantly more often when placebo THC was combined with active alcohol than when it was combined with no alcohol ($p < 0.05$) (Figure 21).

Figure 21: Mean number of errors for driving variable 'speed control – fast' for the high alcohol group in the placebo and active alcohol conditions across the three THC conditions



Night-time: 'Speed control – following distance'

The mean accuracy and standard deviations for the driving variable 'speed control – following distance' for the low and high dose alcohol groups are displayed in Table 23.

Table 23: Means and standard deviations for the driving variable 'speed control – following distance' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	26.75	16.11	30.13	17.75	28.42	16.92
Placebo	Low	26.35	17.33	25.90	19.16	25.62	18.14
Placebo	High	26.88	17.35	28.59	17.88	27.72	17.52
Active	Placebo	30.38	23.02	32.05	19.08	21.20	21.05
Active	Low	30.00	17.47	30.90	21.58	30.44	19.48
Active	High	28.75	22.95	34.74	19.63	31.71	21.45

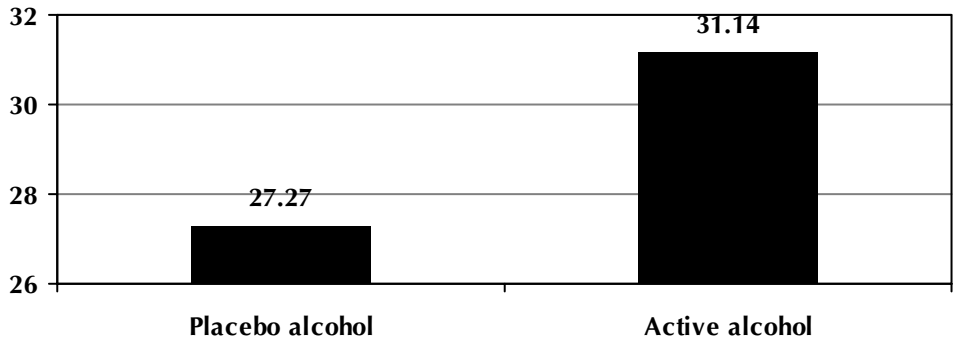
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 24.

Table 24: Results from the mixed design ANOVA for driving variable 'speed control – following distance'.

Night-time: Speed control – following distance	Mean Square	F	Df	p
Alcohol Dose	664.34	0.55	1,77	0.462
Alcohol	1775.54	8.23	1,77	0.005
Alcohol x Alcohol Dose	28.19	0.13	1,77	0.719
THC	160.94	0.93	2,154	0.396
THC x Alcohol Dose	97.59	0.56	2,154	0.570
Alcohol x THC	42.14	0.19	2,154	0.826
Alcohol x THC x Alcohol Dose	91.19	0.41	2,154	0.662

There was a significant main effect of Alcohol. In the active alcohol condition, participants made significantly more following distance errors than in the placebo alcohol condition (Figure 22).

Figure 22: Mean number of errors for the driving variable 'speed control – following distance' for the two alcohol conditions



Night-time: 'Speed control – slow'

The mean accuracy and standard deviations for the driving variable 'speed control – slow' for the low and high dose alcohol groups are displayed in Table 25.

Table 25: Means and standard deviations for the driving variable 'speed control – slow' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	1.80	1.02	1.72	1.02	1.76	1.02
Placebo	Low	1.58	0.96	1.49	1.00	1.53	0.97
Placebo	High	1.28	0.96	1.23	0.93	1.25	0.94
Active	Placebo	1.50	0.93	1.90	1.23	1.70	1.10
Active	Low	1.53	1.78	1.67	1.11	1.59	1.34
Active	High	1.48	0.96	1.51	0.88	1.49	0.92

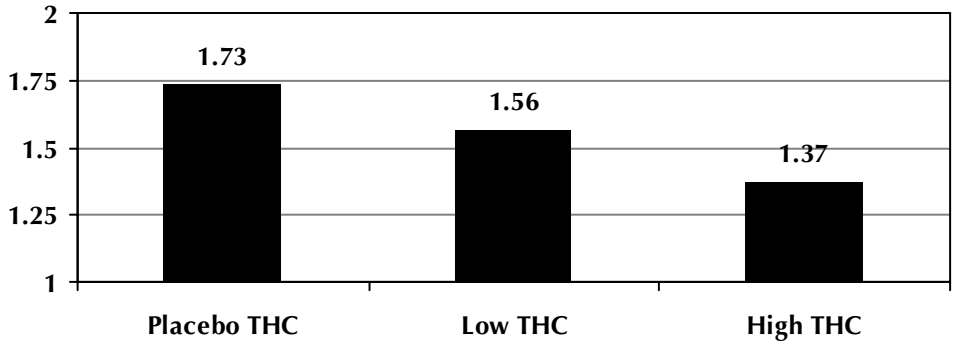
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 26.

Table 26: Results from the mixed design ANOVA for driving variable 'speed control – slow'.

Night-time: Speed control – slow	Mean Square	F	df	p
Alcohol Dose	0.43	0.26	1,77	0.615
Alcohol	0.79	0.71	1,77	0.403
Alcohol x Alcohol Dose	2.06	1.84	1,77	0.179
THC	5.00	5.47	2,154	0.005
THC x Alcohol Dose	0.29	0.32	2,154	0.730
Alcohol x THC	0.91	1.14	2,154	0.324
Alcohol x THC x Alcohol Dose	0.40	0.50	2,154	0.607

The main effect of THC was significant. Participants drove too slowly for the conditions significantly more often in the placebo THC condition than in the high THC condition (Figure 23).

Figure 23: Mean number of errors for the driving variable 'speed control – slow' for the three THC conditions across the two alcohol conditions



Night-time: 'Steering – straddle barrier line'

The mean accuracy and standard deviations for the low and high dose alcohol groups for the driving variable 'straddle barrier line' are displayed in Table 27.

Table 27: Means and standard deviations for the driving variable 'straddle barrier line' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	0.45	0.96	0.87	1.82	0.66	1.46
Placebo	Low	0.95	2.02	1.13	2.59	1.04	2.31
Placebo	High	1.40	1.93	1.54	2.40	1.47	2.17
Active	Placebo	0.75	1.55	1.08	2.04	0.91	1.81
Active	Low	1.25	1.68	2.56	3.86	1.90	3.02
Active	High	1.05	1.75	2.21	3.37	1.63	2.72

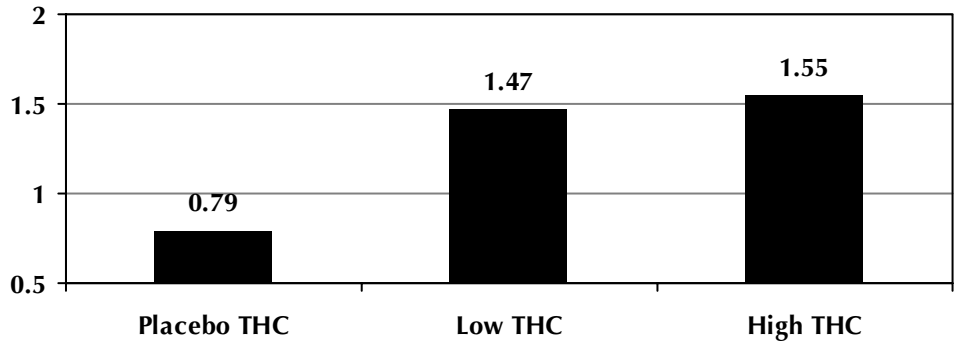
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 28.

Table 28. Results from the mixed design ANOVA for driving variable 'straddle barrier line'.

Night-time: Steering – straddle	Mean Square	F	Df	p
Alcohol Dose	41.118	3.215	1,77	0.077
Alcohol	21.530	6.257	1,77	0.014
Alcohol x Alcohol Dose	13.935	4.050	1,77	0.048
THC	27.793	9.377	2,154	0.000
THC x Alcohol Dose	1.463	0.494	2,154	0.611
Alcohol x THC	5.866	1.263	2,154	0.286
Alcohol x THC x Alcohol Dose	4.549	0.979	2,154	0.378

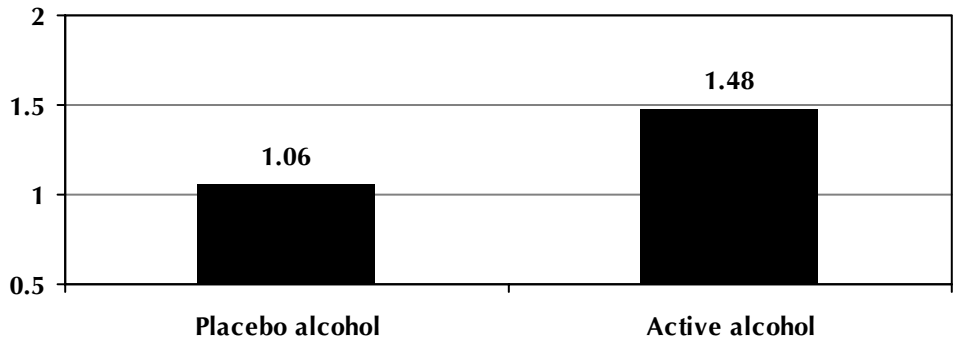
The main effect of THC was significant. There was significantly more straddling of the barrier lines in the low THC ($p < 0.001$) and high THC ($p < 0.001$) conditions than in the placebo THC condition (Figure 24).

Figure 24: Mean number of errors for the driving variable 'straddle barrier line' for the three THC conditions



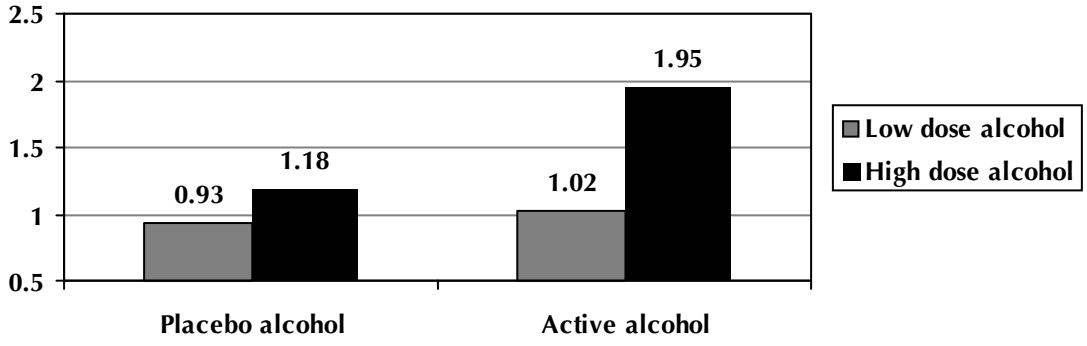
The main effect of Alcohol was also significant. Straddling the barrier line occurred significantly more often in the active alcohol condition, than in the placebo alcohol condition (Figure 25).

Figure 25: Means for driving variable 'straddle barrier line' for the two alcohol conditions



The interaction between Alcohol and Dose was significant. In the active alcohol condition, participants in the high dose alcohol group performed significantly more straddling errors than participants in the low dose group ($p < 0.05$) (Figure 26).

Figure 26: Mean number of errors for the driving variable 'straddle barrier line' for the different doses of alcohol across the placebo and active alcohol conditions



Night-time: 'Steering – wandering'

The mean accuracy and standard deviations for the driving variable 'steering – wandering' for the low and high dose alcohol groups are displayed in Table 29.

Table 29: Means and standard deviations for the driving variable 'steering – wandering' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	2.80	3.99	3.49	4.15	3.14	4.06
Placebo	Low	2.85	3.50	2.82	3.46	2.84	3.46
Placebo	High	3.15	3.36	2.77	3.03	2.96	3.18
Active	Placebo	3.40	3.79	2.77	3.72	3.09	3.75
Active	Low	3.30	3.41	4.51	4.15	3.90	3.81
Active	High	3.95	4.31	4.15	3.88	4.05	4.08

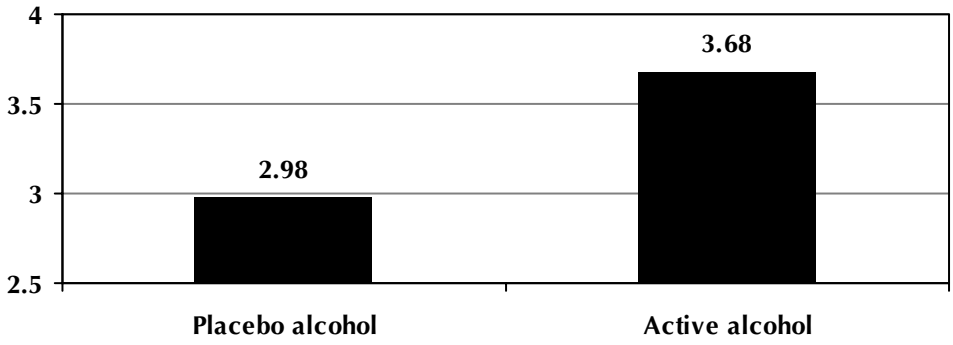
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 30.

Table 30: Results from the mixed design ANOVA for driving variable 'steering – wandering'.

Night-time: Steering - wandering	Mean Square	F	Df	p
Alcohol Dose	3.718	0.102	1,77	0.750
Alcohol	58.304	7.844	1,77	0.006
Alcohol x Alcohol Dose	0.853	0.115	1,77	0.736
THC	6.254	0.533	2,154	0.588
THC x Alcohol Dose	5.224	0.445	2,154	0.641
Alcohol x THC	17.134	2.026	2,154	0.135
Alcohol x THC x Alcohol Dose	17.455	2.064	2,154	0.130

The main effect of Alcohol was significant. In the active alcohol condition there were significantly more vehicle wandering errors than in the placebo alcohol conditions (Figure 27).

Figure 27: Mean number of errors for the driving variable 'steering – wandering' for the two alcohol conditions



Night-time: 'Stopping – clear space'

The mean accuracy and standard deviations for the driving variable 'stopping – clear space' for the low and high dose alcohol groups are displayed in Table 31.

Table 31: Means and standard deviations for the driving variable 'stopping – clear space' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	0.25	0.67	0.31	0.73	0.28	0.70
Placebo	Low	0.15	0.53	0.21	0.61	0.18	0.57
Placebo	High	0.40	0.93	0.31	0.73	0.35	0.83
Active	Placebo	0.25	0.67	0.51	1.10	0.38	0.91
Active	Low	0.50	0.99	0.46	0.97	0.48	0.97
Active	High	0.55	1.43	0.97	1.44	0.76	1.44

Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 32.

Table 32: Results from the mixed design ANOVA for driving variable 'stopping – clear space'.

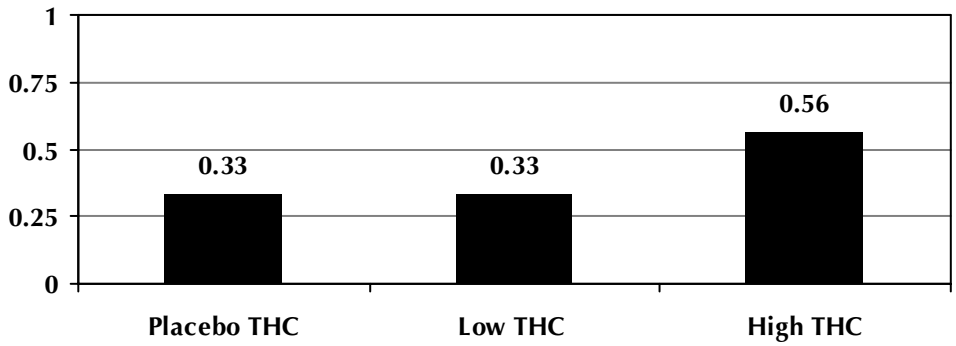
Night-time: Stopping – clear space	Mean Square	F	Df	p
Alcohol Dose	1.474	1.019	1,77	0.316
Alcohol	8.725	12.742	1,77	0.001
Alcohol x Alcohol Dose	1.299	1.897	1,77	0.172
THC	2.746	3.432	2,154	0.035
THC x Alcohol Dose	0.316	0.395	2,154	0.675
Alcohol x THC	0.953	1.169	2,154	0.314
Alcohol x THC x Alcohol Dose	0.919	1.127	2,154	0.327

The main effect of Alcohol was significant. In the active alcohol condition there were significantly more errors of not keeping a clear space around the vehicle when stopping than in the placebo alcohol conditions (Figure 28).

Figure 28: Mean number of errors for the driving variable 'stopping – clear space' for the two alcohol conditions

The main effect of THC was also significant. There were significantly more errors of not keeping clear space around the vehicle when stopping in the high THC condition, than in the placebo THC condition ($p < 0.05$) and the low THC condition ($p < 0.05$) (Figure 29).

Figure 29: Mean number of errors for the driving variable 'stopping – clear space' for the three THC conditions



Night-time: 'Stopping unnecessarily'

The mean accuracy and standard deviations for the driving variable 'stopping unnecessarily' for the low and high dose alcohol groups are displayed in Table 33.

Table 33: Means and standard deviations for the driving variable 'stopping unnecessarily' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	1.00	0.91	0.56	0.64	0.78	0.81
Placebo	Low	0.90	1.08	0.85	1.04	0.87	1.05
Placebo	High	0.75	0.87	0.56	0.79	0.66	0.83
Active	Placebo	0.95	0.93	0.92	1.06	0.94	0.99
Active	Low	0.85	0.86	1.03	1.33	0.94	1.11
Active	High	0.80	0.94	1.03	0.93	0.91	0.94

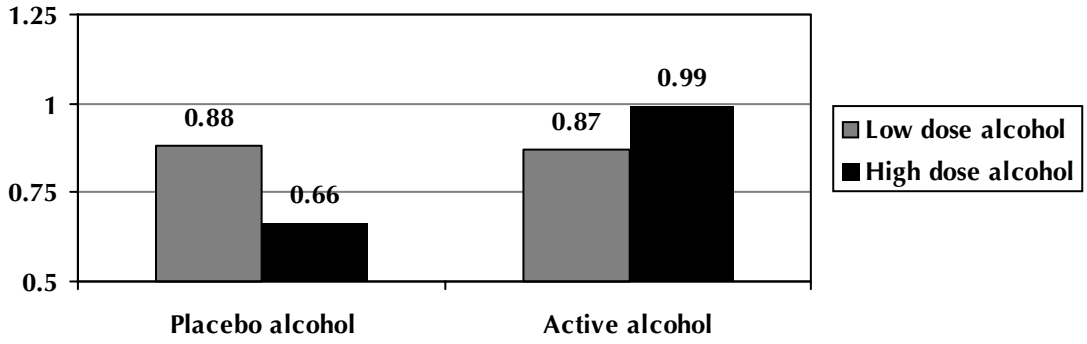
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 34.

Table 34: Results from the mixed design ANOVA for 'stopping unnecessarily'.

Night-time: Stopping unnecessarily	Mean Square	F	Df	p
Alcohol Dose	0.299	0.162	1,77	0.688
Alcohol	2.970	3.750	1,77	0.056
Alcohol x Alcohol Dose	3.628	4.581	1,77	0.035
THC	0.584	0.799	2,154	0.451
THC x Alcohol Dose	0.989	1.354	2,154	0.261
Alcohol x THC	0.361	0.496	2,154	0.610
Alcohol x THC x Alcohol Dose	0.108	0.148	2,154	0.863

There was a significant interaction between Alcohol and Dose. In the high alcohol group, there were significantly more stopping unnecessarily errors in the active alcohol condition than in the placebo alcohol condition ($p < 0.01$) (Figure 30).

Figure 30: Mean number of errors for the driving variable 'stopping unnecessarily' for the two alcohol conditions



Night-time: 'Violation traffic law – straddle solid line'

The mean accuracy and standard deviations for the driving variable 'straddle solid line' for the low and high dose alcohol groups are displayed in Table 35.

Table 35: Means and standard deviations for the driving variable 'straddle solid line' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	0.45	1.06	0.67	1.47	0.56	1.28
Placebo	Low	0.65	1.46	0.72	1.26	0.68	1.35
Placebo	High	0.80	1.49	0.77	1.27	0.78	1.37
Active	Placebo	0.20	0.76	0.56	1.12	0.38	0.96
Active	Low	0.65	1.39	0.77	1.69	0.71	1.54
Active	High	0.75	1.79	1.49	1.99	1.12	1.91

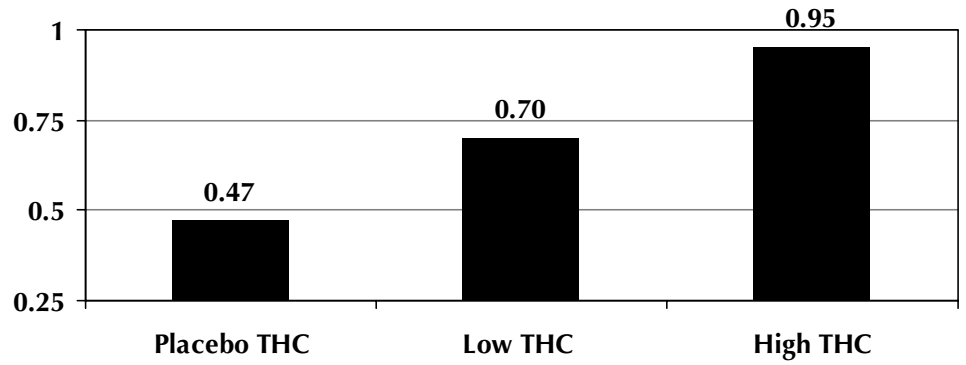
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 36.

Table 36: Results from the mixed design ANOVA for driving variable 'straddle solid line'.

Night-time: Violation traffic law – straddle solid line	Mean Square	F	Df	p
Alcohol Dose	7.154	1.467	1,77	0.230
Alcohol	0.442	0.181	1,77	0.671
Alcohol x Alcohol Dose	3.075	1.261	1,77	0.265
THC	9.163	8.387	2,154	0.000
THC x Alcohol Dose	0.725	0.663	2,154	0.517
Alcohol x THC	2.608	1.872	2,154	0.157
Alcohol x THC x Alcohol Dose	1.494	1.072	2,154	0.345

There was a significant main effect of THC. Participants straddled the solid line significantly more often in the high THC condition than in the placebo THC ($p<0.001$) and low THC ($p<0.05$) conditions (Figure 31).

Figure 31: Mean number of errors for the driving variable 'straddle solid line' for the three THC conditions



Night-time: 'Initial speed on freeway'

The mean accuracy and standard deviations for the driving variable 'initial speed on freeway' for the low and high dose alcohol groups are displayed in Table 37.

Table 37: Means and standard deviations for the driving variable 'initial speed on freeway' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	97.88	25.41	88.90	37.38	93.45	32.00
Placebo	Low	88.61	33.11	85.75	35.70	87.18	34.22
Placebo	High	76.71	46.85	79.20	39.84	77.94	41.67
Active	Placebo	94.26	30.16	88.25	36.01	91.29	33.10
Active	Low	84.10	40.68	85.61	38.67	84.85	39.45
Active	High	82.78	40.78	90.12	34.01	86.40	37.53

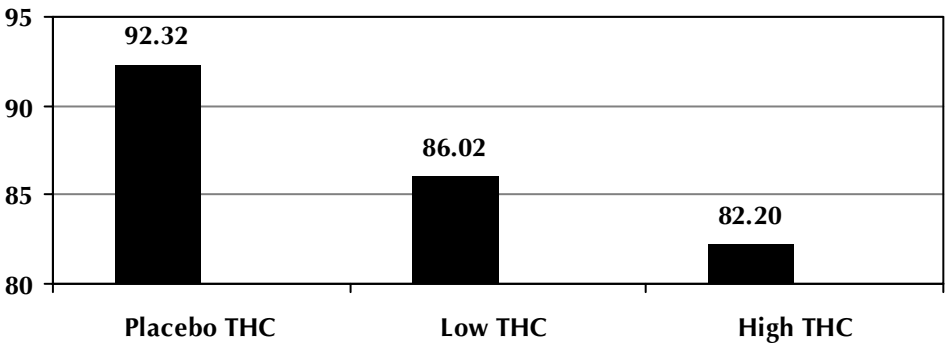
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 38.

Table 38: Results from the mixed design ANOVA for driving variable 'initial speed on freeway'.

Night-time: Initial speed on freeway	Mean Square	F	Df	p
Alcohol Dose	139.123	0.080	1,77	0.778
Alcohol	213.981	0.137	1,77	0.713
Alcohol x Alcohol Dose	488.765	0.312	1,77	0.578
THC	4127.082	3.954	2,154	0.021
THC x Alcohol Dose	1525.875	1.462	2,154	0.235
Alcohol x THC	1514.559	1.137	2,154	0.323
Alcohol x THC x Alcohol Dose	9.196	0.007	2,154	0.993

The main effect of THC was significant. Initial speed on the freeway was significantly slower in the high THC condition than the placebo THC condition (Figure 32).

Figure 32: Mean number of errors for the driving variable 'initial speed on freeway' for the three THC conditions



Night-time: 'Inappropriate signalling'

The mean accuracy and standard deviations for the driving variable 'inappropriate signalling' for the low and high dose alcohol groups are displayed in Table 39.

Table 39: Means and standard deviations for the driving variable 'inappropriate signalling' for the low and high dose alcohol groups.

Condition		Low Dose Alcohol N = 40		High Dose Alcohol N = 39		Overall N = 79	
Alcohol	**THC**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Placebo	Placebo	63.43	23.70	76.26	34.63	69.76	30.11
Placebo	Low	66.45	34.58	67.49	26.64	66.96	30.72
Placebo	High	70.88	33.61	72.03	32.03	71.44	62.63
Active	Placebo	67.05	28.20	74.15	33.79	70.56	31.09
Active	Low	71.65	25.13	89.82	50.90	80.62	40.76
Active	High	69.60	26.19	79.49	34.80	74.48	30.95

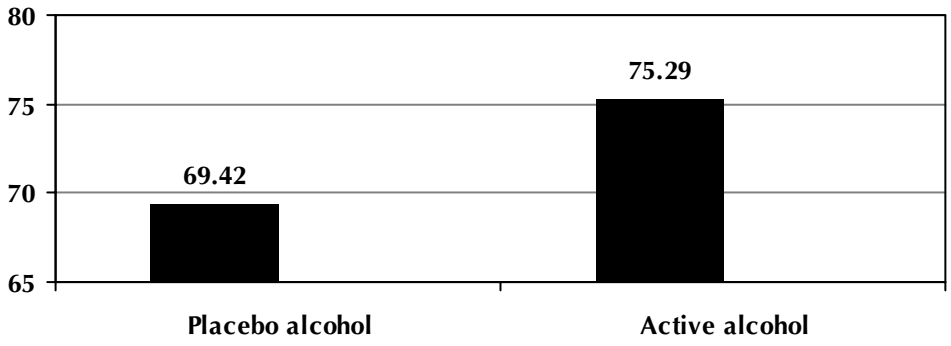
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 40.

Table 40: Results from the mixed design ANOVA for driving variable 'inappropriate signalling'.

Night-time: Inappropriate signalling	Mean Square	F	Df	p
Alcohol Dose	8287.449	2.777	1,77	0.100
Alcohol	4087.662	4.701	1,77	0.033
Alcohol x Alcohol Dose	1335.257	1.536	1,77	0.219
THC	569.143	0.838	2,154	0.434
THC x Alcohol Dose	240.978	0.355	2,154	0.702
Alcohol x THC	1898.998	3.142	2,154	0.046
Alcohol x THC x Alcohol Dose	1320.301	2.184	2,154	0.116

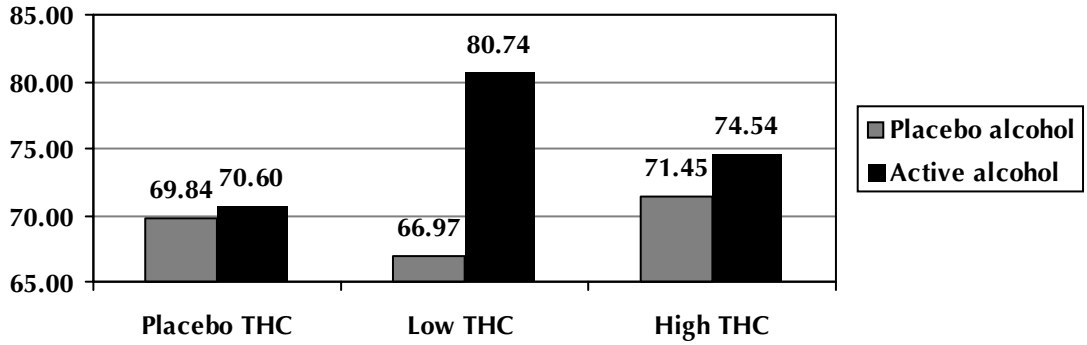
There was a significant main effect of Alcohol. There were significantly more signalling errors in the active alcohol condition than in the placebo alcohol condition (Figure 33).

Figure 33: Mean number of errors for the driving variable 'inappropriate signalling' for the two alcohol conditions



There was also a significant interaction between Alcohol and THC. There were significantly more signalling errors when alcohol was combined with low THC, than when alcohol was combined with placebo THC. There were also significantly more signalling errors when low THC was combined with active alcohol compared to when low THC was combined with placebo alcohol ($p < 0.001$) (Figure 34).

Figure 34: Mean number of errors for the driving variable 'inappropriate signalling' for the two alcohol conditions across the three THC conditions



Day-time driving conditions, non-regular and regular THC users.

Day-time, regular, non-regular users: 'Collisions'

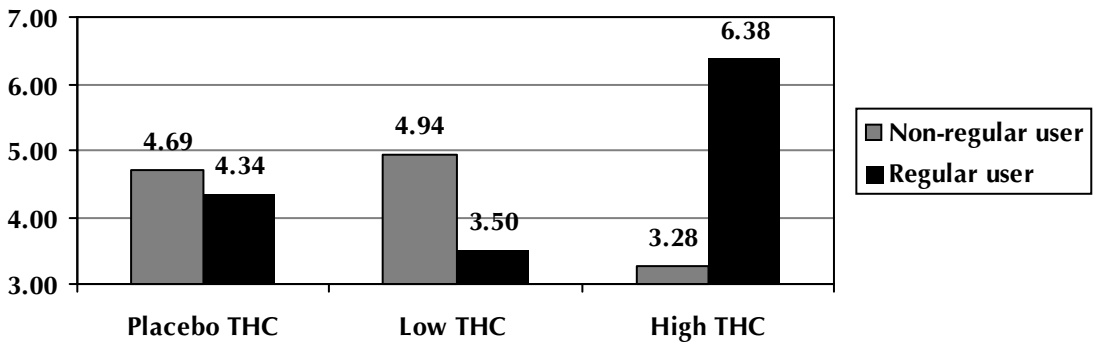
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 41.

Table 41: Results from the mixed design ANOVA for driving variable 'collisions'.

Day-time: Collisions	Mean Square	F	Df	p
User (regular vs. non-regular)	23.247	0.391	1,74	0.534
Alcohol Dose x User	122.148	2.056	1,74	0.156
Alcohol x User	2.067	0.034	1,74	0.854
Alcohol x Alcohol Dose x User	8.830	0.145	1,74	0.704
THC x User	217.962	3.726	2,148	0.026
THC x Alcohol Dose x User	44.494	0.761	2,148	0.469
Alcohol x THC x User	81.248	1.526	2,148	0.221
Alcohol x THC x Alcohol Dose x User	105.984	1.991	2,148	0.140

There was a significant interaction between THC and User. In the high THC condition, regular users had significantly more collisions than the non-regular users ($p < 0.05$). There were no significant differences in collision errors between regular and non-regular users in the low THC or the placebo THC conditions (Figure 35).

Figure 35: Mean number of errors for the driving variable 'collisions' for the two user groups across the three THC conditions



Day-time, regular, non-regular users: 'Speed control – Following distance'

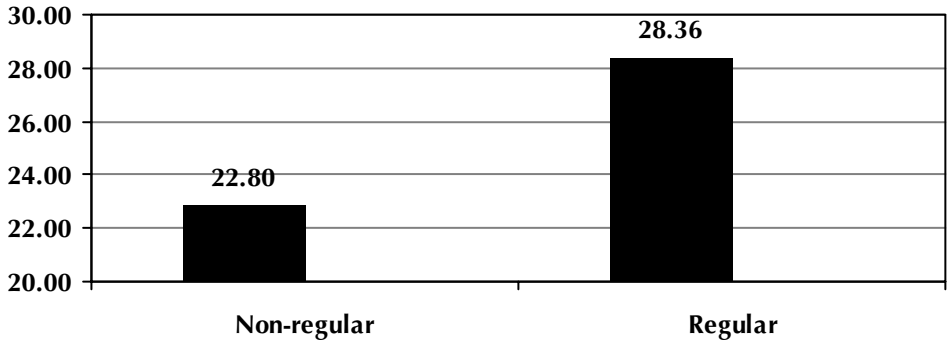
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 42.

Table 42: Results from the mixed design ANOVA for driving variable 'speed control – following distance'.

Day-time: Speed control – following distance	Mean Square	F	Df	p
User (regular vs. non-regular)	3464.92	4.04	1,74	0.048
Alcohol Dose x User	5186.83	6.04	1,74	0.016
Alcohol x User	40.44	0.19	1,74	0.661
Alcohol x Alcohol Dose x User	58.94	0.28	1,74	0.597
THC x User	776.86	4.78	2,148	0.010
THC x Alcohol Dose x User	264.78	1.63	2,148	0.200
Alcohol x THC x User	103.68	0.52	2,148	0.594
Alcohol x THC x Alcohol Dose x User	65.63	0.33	2,148	0.719

There was a significant main effect of User. Regular users made more following distance errors than the non-regular users (Figure 36).

Figure 36: Mean number of errors for the driving variable 'speed control – following distance' for the two user groups, non-regular and regular

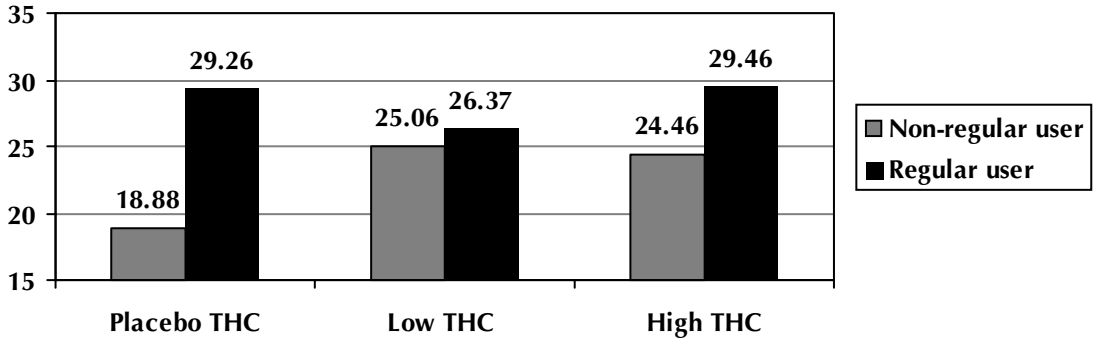


The interaction between Dose and User was also significant. In the low alcohol group, regular users made significantly more following distance errors than the non-regular users ($p < 0.01$). In the high alcohol group, there were no differences in following distance errors between the regular and non-regular users (Figure 37).

Figure 37: Mean number of errors for the driving variable 'speed control – following distance' for the two user groups across the two alcohol groups

There was also a significant interaction between THC and User. In the placebo THC condition, regular users made significantly more following distance errors than the non-regular users ($p < 0.05$). There were no significant differences between the regular and non-regular users in the low THC and high THC conditions, (Figure 38).

Figure 38: Means for driving variable 'speed control – following distance' for the two user groups across the three THC conditions



Day-time, regular, non-regular THC users: 'Traffic law violation – speed limit'

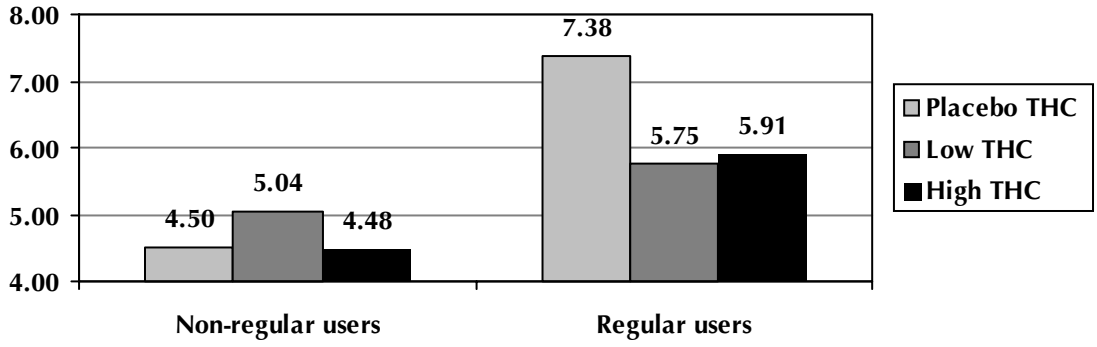
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 43.

Table 43: Results from the mixed design ANOVA for driving variable 'speed limit'.

Day-time: Exceeded speed limit	Mean Square	F	Df	p
User (regular vs. non-regular)	313.773	2.117	1,74	0.150
Alcohol Dose x User	183.958	1.241	1,74	0.269
Alcohol x User	0.042	0.003	1,74	0.959
Alcohol x Alcohol Dose x User	3.880	0.239	1,74	0.626
THC x User	45.870	3.316	2,148	0.039
THC x Alcohol Dose x User	5.026	0.363	2,148	0.696
Alcohol x THC x User	34.405	2.188	2,148	0.116
Alcohol x THC x Alcohol Dose x User	14.441	0.918	2,148	0.401

There was a significant interaction between THC and User. Regular users exceeded the speed limit significantly more often in the placebo THC condition than in the low THC ($p < 0.01$) and high THC ($p < 0.01$) conditions. There was no difference in performance across the THC conditions for the non-regular users (Figure 39).

Figure 39: Mean number of errors for the driving variable 'speed limit' for the three THC conditions across the two user groups



Day-time, regular, non-regular THC users: 'Initial speed on freeway'

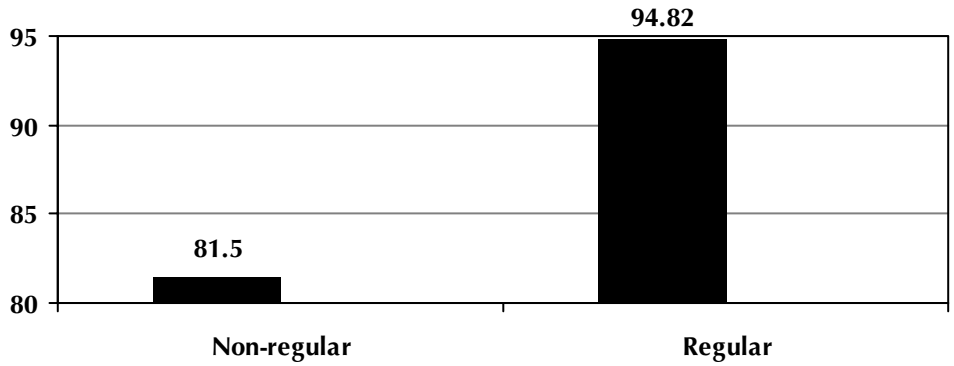
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 44.

Table 44: Results from the mixed design ANOVA for driving variable 'initial speed on freeway'.

Day-time: Initial speed on freeway	Mean Square	F	df	p
User (regular vs. non-regular)	19865.04	9.33	1,74	0.003
Alcohol Dose x User	727.50	0.34	1,74	0.561
Alcohol x User	206.20	0.25	1,74	0.619
Alcohol x Alcohol Dose x User	1333.07	1.61	1,74	0.208
THC x User	5036.56	3.94	2,148	0.021
THC x Alcohol Dose x User	720.78	0.56	2,148	0.570
Alcohol x THC x User	2776.88	2.08	2,148	0.129
Alcohol x THC x Alcohol Dose x User	2255.13	1.69	2,148	0.189

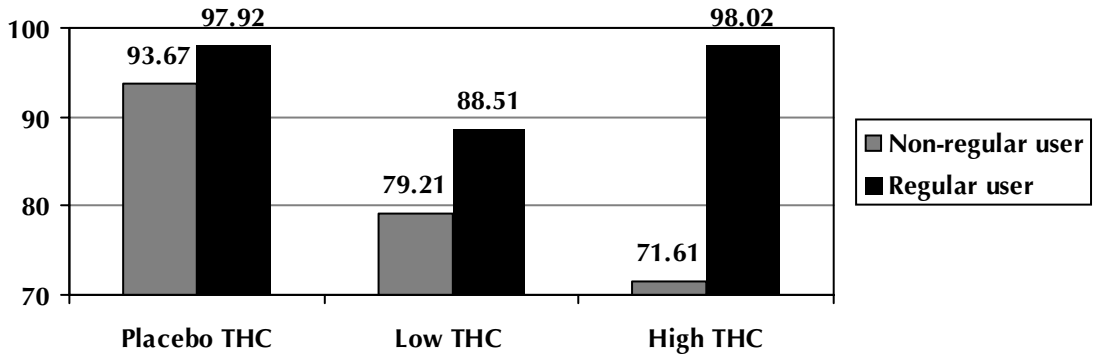
There was a significant main effect of User. Regular users had significantly faster initial speed on the freeway than the non-regular users (Figure 40).

Figure 40: Mean number of errors for the driving variable 'initial speed on freeway' for the two user groups, non-regular and regular



The interaction between THC and User was also significant. In the high THC condition, regular users had a significantly higher faster initial speed on the freeway compared to non-regular users ($p < 0.001$) (Figure 41). In the placebo and low THC condition, there were no differences in performance between the regular and non-regular users.

Figure 41: Mean number of errors for driving variable 'initial speed on freeway' for the two user groups across the three THC conditions



Day-time, regular, non-regular THC users: 'Reaction time in an advanced situation'

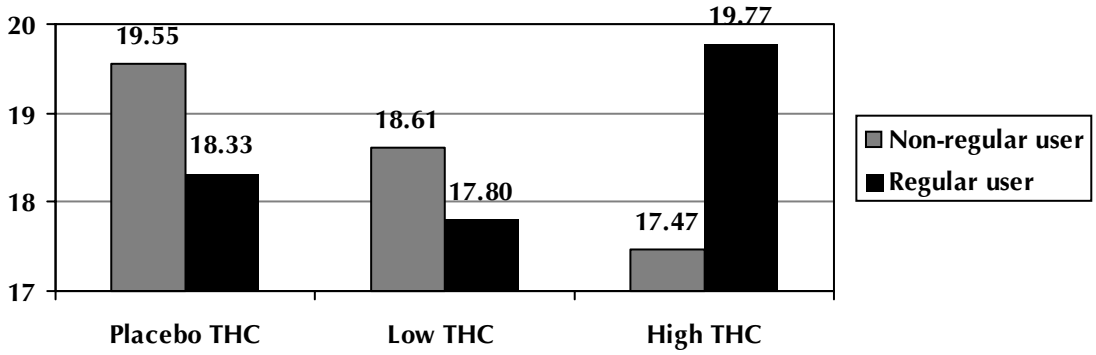
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 45.

Table 45: Results from the mixed design ANOVA for driving variable 'reaction time in advanced situation'.

Day-time: Reaction time in advanced situation	Mean Square	F	Df	p
User (regular vs. non-regular)	0.785	0.026	1,67	0.872
Alcohol Dose x User	31.025	1.031	1,67	0.314
Alcohol x User	19.925	0.632	1,67	0.429
Alcohol x Alcohol Dose x User	161.912	5.138	1,67	0.027
THC x User	127.006	3.637	2,134	0.029
THC x Alcohol Dose x User	16.020	0.459	2,134	0.633
Alcohol x THC x User	194.568	5.473	2,134	0.005
Alcohol x THC x Alcohol Dose x User	1.520	0.043	2,134	0.958

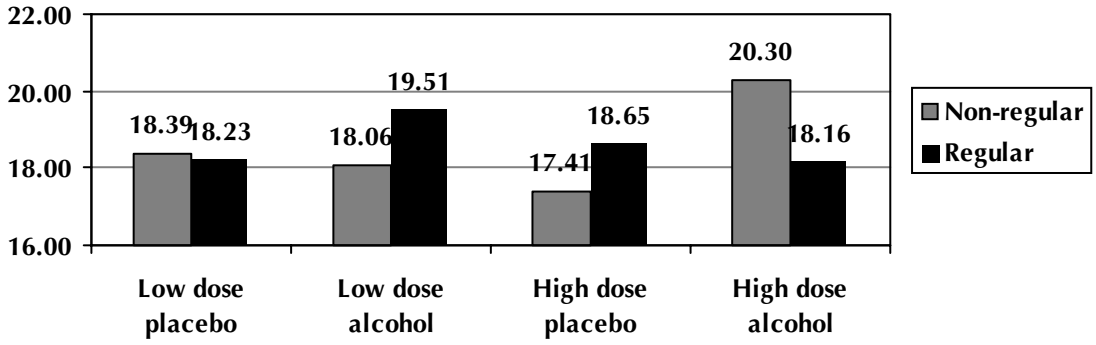
The interaction between THC and User was significant. In the high THC condition, regular users had significantly slower reaction times than non-regular users ($p < 0.05$). There was no difference in reaction times between the regular and non-regular users in the placebo THC and low THC conditions (Figure 42).

Figure 42: Mean reaction time (x 0.1 = in seconds) for the driving variable 'reaction time in advanced situation' for the two user groups across the three THC conditions



There was also a significant interaction between Alcohol, Dose and User. In the high alcohol group only, the non-regular users had significantly longer reaction times in an unexpected event after consuming alcohol, compared to the regular users ($p < 0.05$) (Figure 43).

Figure 43: Mean reaction time (x 0.1 = in seconds) for the driving variable 'reaction time in advanced situation' for the two user groups across the placebo and active alcohol conditions for the low and high dose alcohol groups



The interaction between Alcohol, THC and User was also significant. When no alcohol was consumed, regular users had significantly slower reaction times in the high THC condition, than in the placebo THC ($p < 0.05$) and the low THC conditions ($p < 0.01$) (Figure 44). However, when alcohol was consumed, there were no differences in reaction time between regular and non-regular users across the three THC conditions (Figure 45).

Figure 44: Mean reaction time (x 0.1 = in seconds) for the driving variable 'reaction time in advanced situation' for the two user groups in the placebo alcohol condition across the three THC conditions

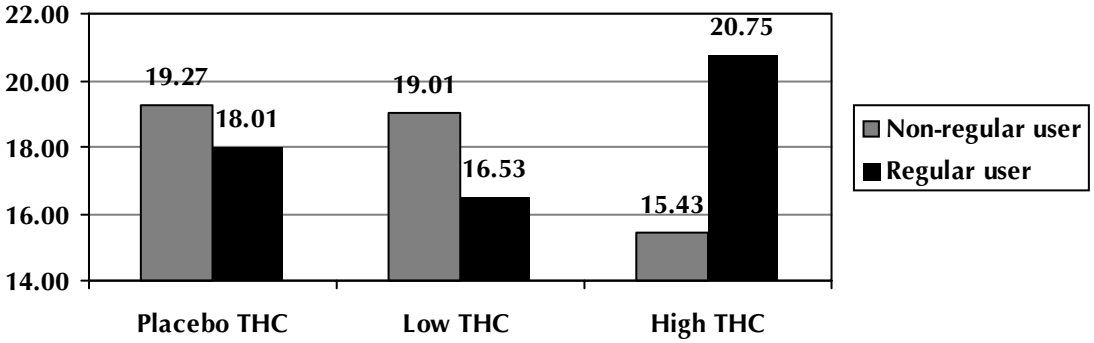
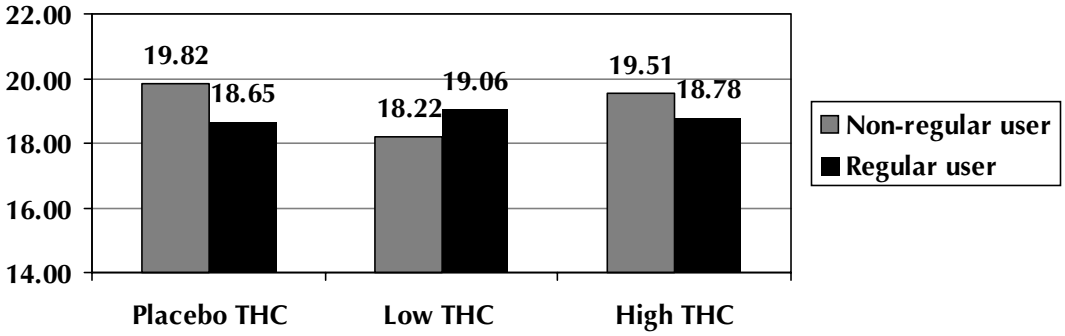


Figure 45: Mean reaction time (x 0.1 = in seconds) for the driving variable 'reaction time in advanced situation' for the two user groups in the active alcohol condition across the three THC conditions



Day-time, regular, non-regular users: 'Inappropriate signalling'

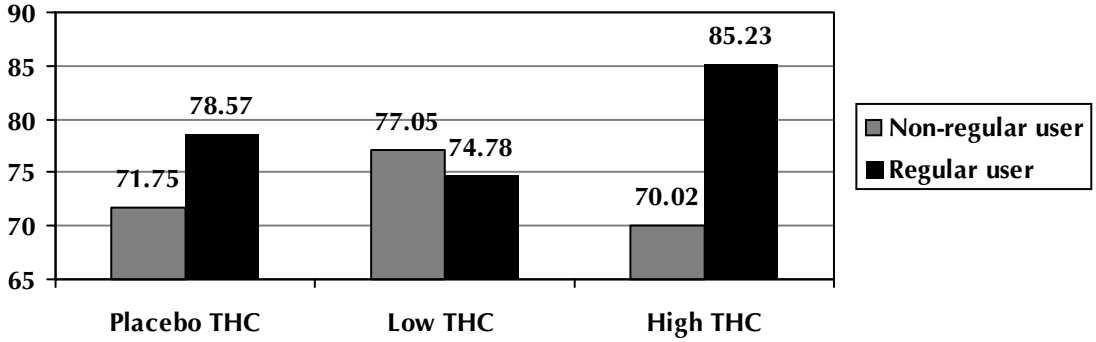
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 46.

Table 46: Results from the mixed design ANOVA for driving variable 'inappropriate signalling'.

Day-time: Inappropriate signalling	Mean Square	F	Df	p
User (regular vs. non-regular)	4853.102	1.558	1,74	0.216
Alcohol Dose x User	4663.346	1.497	1,74	0.225
Alcohol x User	136.051	0.136	1,74	0.713
Alcohol x Alcohol Dose x User	0.593	0.001	1,74	0.981
THC x User	2854.351	3.163	2,148	0.045
THC x Alcohol Dose x User	1858.420	2.059	2,148	0.131
Alcohol x THC x User	3130.162	3.913	2,148	0.022
Alcohol x THC x Alcohol Dose x User	1965.762	2.458	2,148	0.089

The interaction between THC and User was significant. Regular users performed significantly more signalling errors in the high THC condition than in the low THC condition. There were no significant differences in signalling errors in the low and high THC condition for the non-regular users ($p < 0.05$) (Figure 46).

Figure 46: Mean number of errors for the driving variable 'inappropriate signalling' for the two user groups across the three THC conditions



The interaction between Alcohol, THC and User was significant. When no alcohol was consumed, regular users performed more signalling errors in the high THC condition, than the low THC condition ($p < 0.001$) (Figure 47). These differences were not observed for the non-regular users (Figure 48).

Figure 47: Mean number of errors for the driving variable 'inappropriate signalling' for the regular user group, displaying the two alcohol conditions across the three THC conditions

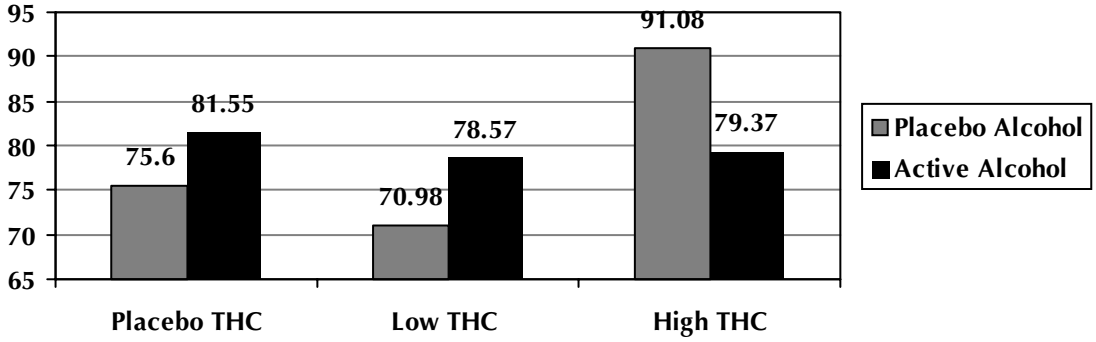
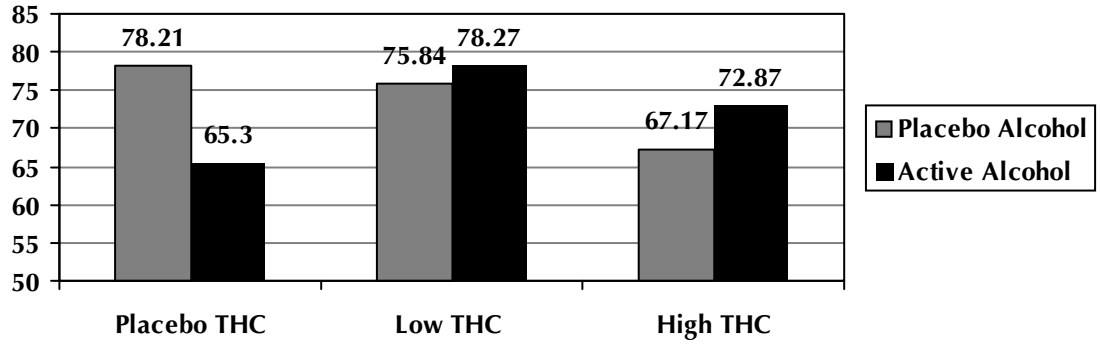


Figure 48: Mean number of errors for the driving variable 'inappropriate signalling' for the non-regular user group, displaying the two alcohol conditions across the three THC conditions



Night-time driving conditions, non-regular and regular THC users.

Night-time, regular, non-regular users: 'Collisions'

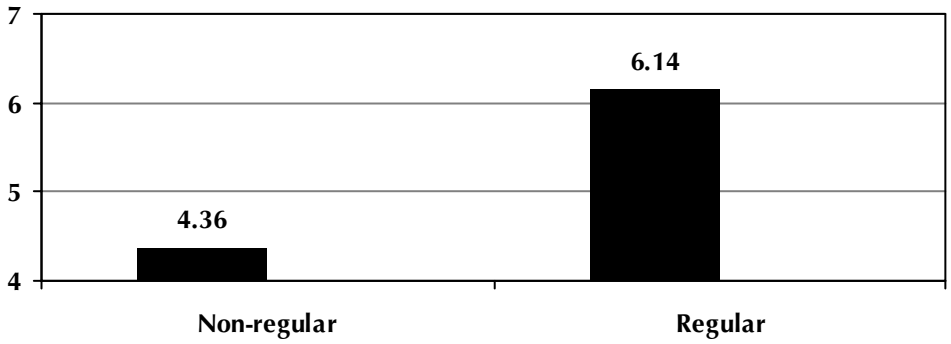
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 47.

Table 47: Results from the mixed design ANOVA for driving variable 'collisions'.

Night-time: Collisions	Mean Square	F	Df	p
User (regular vs. non-regular)	352.491	5.730	1,74	0.019
Alcohol Dose x User	234.824	3.817	1,74	0.055
Alcohol x User	61.731	1.269	1,74	0.264
Alcohol x Alcohol Dose x User	25.777	0.530	1,74	0.469
THC x User	189.762	3.996	2,148	0.020
THC x Alcohol Dose x User	51.533	1.085	2,148	0.341
Alcohol x THC x User	38.024	0.651	2,148	0.523
Alcohol x THC x Alcohol Dose x User	16.145	0.276	2,148	0.759

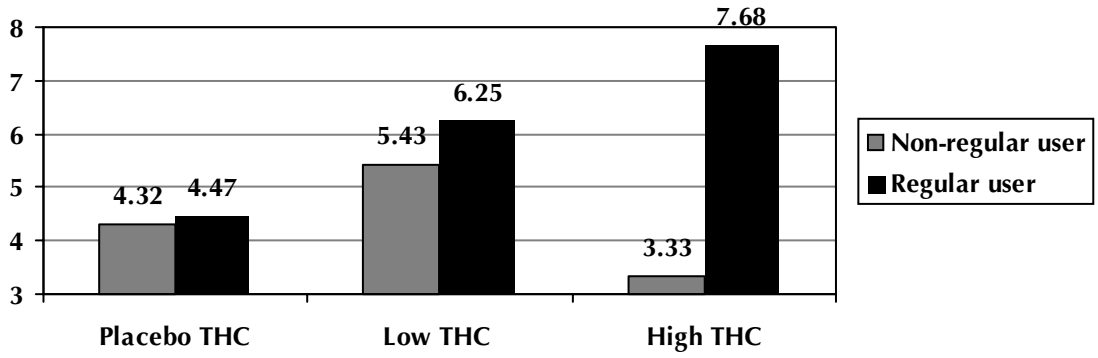
There was a significant main effect of User. The regular users were involved in collisions significantly more often than the non-regular users (Figure 49).

Figure 49: Mean number of errors for the driving variable 'collisions' for the two user groups, non-regular and regular



The interaction between THC and User was also significant. There was a significant difference between regular users and non-regular users in the high THC condition ($p < 0.01$). The regular users had significantly more collisions than the non-regular users in the high THC condition (Figure 50). In the placebo THC and low THC condition there were no significant differences in performance between the regular and non-regular users.

Figure 50: Mean number of errors for the driving variable 'collisions' for the two user groups across the three THC conditions



Night-time, regular, non-regular users: 'inappropriate braking'

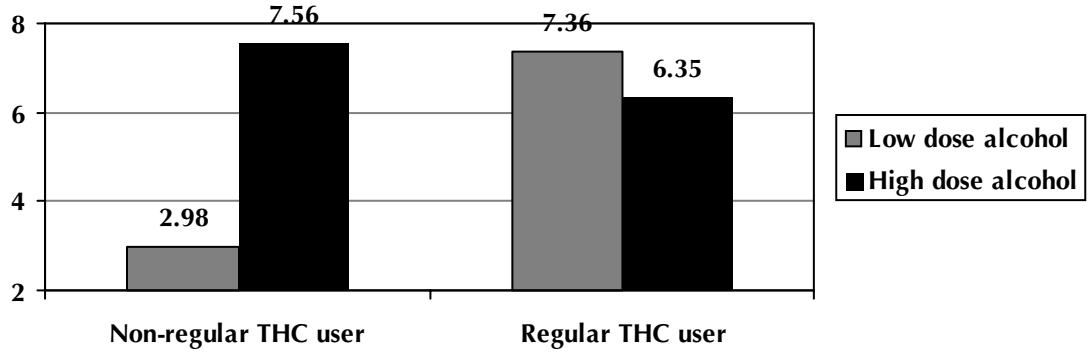
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 48.

Table 48: Results from the mixed design ANOVA for driving variable 'inappropriate braking'.

Night-time: Inappropriate braking	Mean Square	F	Df	p
User (regular vs. non-regular)	281.097	1.458	1,74	0.231
Alcohol Dose x User	877.349	4.551	1,74	0.036
Alcohol x User	0.793	0.030	1,74	0.863
Alcohol x Alcohol Dose x User	20.305	0.762	1,74	0.385
THC x User	67.230	4.255	2,148	0.016
THC x Alcohol Dose x User	2.744	0.174	2,148	0.841
Alcohol x THC x User	13.591	0.859	2,148	0.426
Alcohol x THC x Alcohol Dose x User	1.220	0.077	2,148	0.926

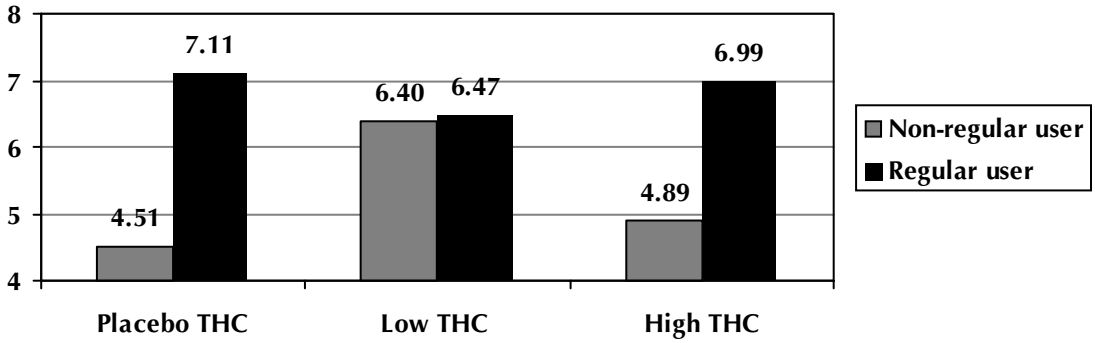
There was a significant interaction between Dose and User. Non-regular users in the high alcohol group were more impaired by alcohol than non-regular users in the low alcohol group ($p < 0.05$). There were no differences in performance between the regular users in the high alcohol group and the low alcohol group (Figure 51).

Figure 51: Mean number of errors for the driving variable 'inappropriate braking' for regular and non-regular users



The interaction between THC and User was significant. Non-regular users made more errors in the low THC condition, than in the placebo THC ($p < 0.01$) and high THC ($p < 0.05$) condition. There were no differences in performance for the regular users across the three THC conditions (Figure 52).

Figure 52: Mean number of errors for the driving variable 'inappropriate braking' for the two user groups across the three THC conditions



Night-time, regular, non-regular users: 'Following distance'

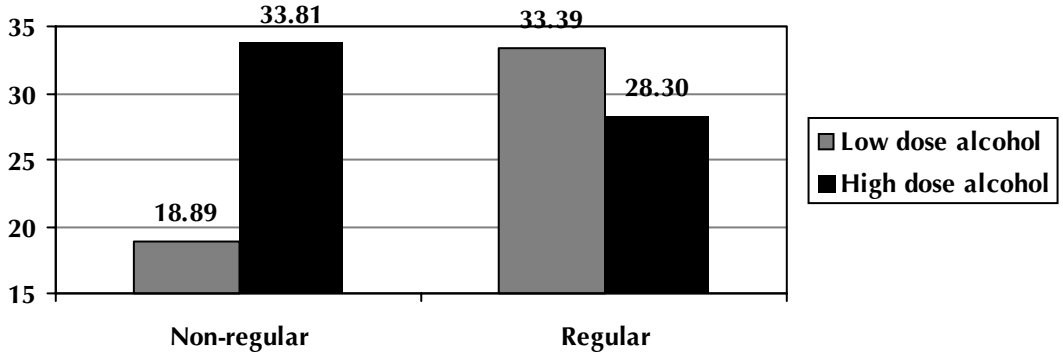
Results from the 2 x 2 x 3 mixed design ANOVA are displayed in Table 49.

Table 49: Results from the mixed design ANOVA for driving variable 'following distance'.

Night-time: Following distance	Mean Square	F	Df	p
User (regular vs. non-regular)	2708.198	2.509	1,74	0.117
Alcohol Dose x User	11212.007	10.385	1,74	0.002
Alcohol x User	211.794	0.971	1,74	0.328
Alcohol x Alcohol Dose x User	66.501	0.305	1,74	0.582
THC x User	679.458	4.023	2,148	0.020
THC x Alcohol Dose x User	72.568	0.430	2,148	0.652
Alcohol x THC x User	64.653	0.289	2,148	0.750
Alcohol x THC x Alcohol Dose x User	243.753	1.088	2,148	0.339

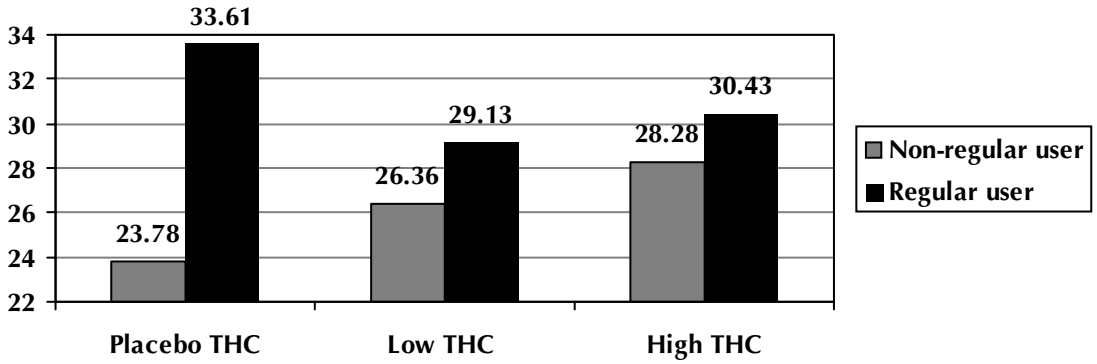
There was a significant interaction between Dose and User. The non-regular users in the high dose alcohol group performed more following distance errors than the non-regular users in the low dose alcohol group ($p < 0.01$). There were no differences in performance between the low and high alcohol group for the regular users (Figure 53).

Figure 53: Mean number of errors for the driving variable 'following distance' for the low and high dose alcohol in the two user groups



There was a significant interaction between THC and User. Regular users made more errors in the placebo THC compared to the low THC condition ($p < 0.05$). There was no difference in performance across these THC conditions for the non-regular users (Figure 54).

Figure 54: Mean number of errors for the driving variable 'following distance' for the two user groups across the three THC conditions



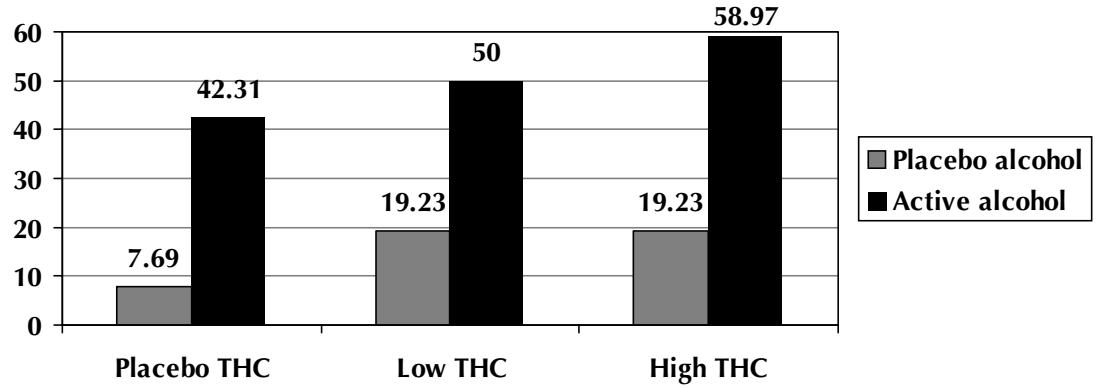
The Standardised Field Sobriety Tests (SFSTs)

The following section examined performance on SFSTs across the six drug conditions (THC - placebo, low, high; and alcohol - placebo, active). In order to determine the frequency of errors in each cannabis condition (with and without alcohol), the low alcohol condition (0.03% BAC) and the high alcohol condition (0.05% BAC) were combined. Each alcohol condition was also analysed separately and this analysis is included in Appendix E. The Cochrane Q statistic was calculated to determine whether a significantly different percentage of participants displayed a particular error between each drug condition. Only the errors that were displayed in a significantly different percentage across the drug conditions are reported.

Horizontal Gaze Nystagmus: Lack of Smooth Pursuit (LSP)

There was a significant difference in the percentage of participants who displayed the sign LSP across the six drug conditions (Cochran Q = 84.33, df = 5, $p < 0.001$). The LSP sign was observed more often in the active alcohol conditions than in the placebo alcohol conditions. Furthermore, the Horizontal Gaze Nystagmus LSP sign was observed more frequently in the low THC condition and the high THC condition than in the placebo condition (Figure 55).

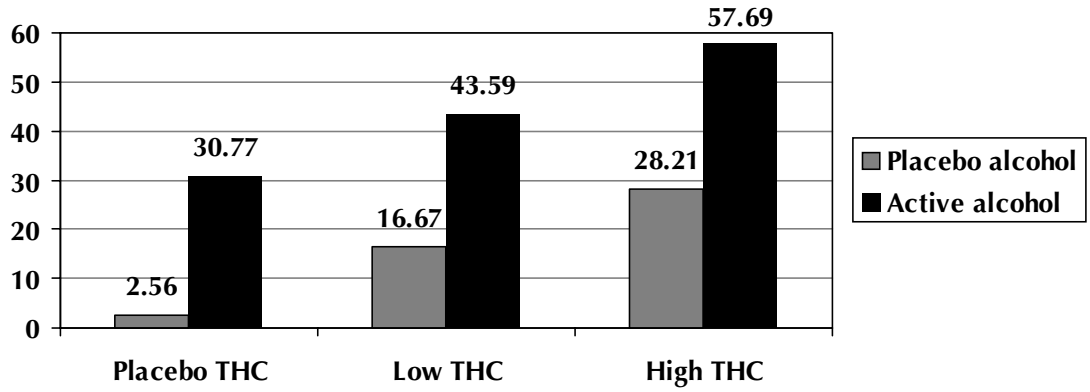
Figure 55: Percentage of participants in each of the six drug conditions that displayed LSP during the SFSTs



Horizontal Gaze Nystagmus: Nystagmus at Maximum Deviation (NMax)

There was a significant difference in the percentage of participants that displayed the sign NMax across the six drug conditions (Cochran Q = 82.74, df = 5, $p < 0.001$). The NMax sign was observed more often in the alcohol conditions than in the placebo conditions. Furthermore, NMax was present more frequently in the low THC condition and high THC conditions than in the placebo THC condition (Figure 56).

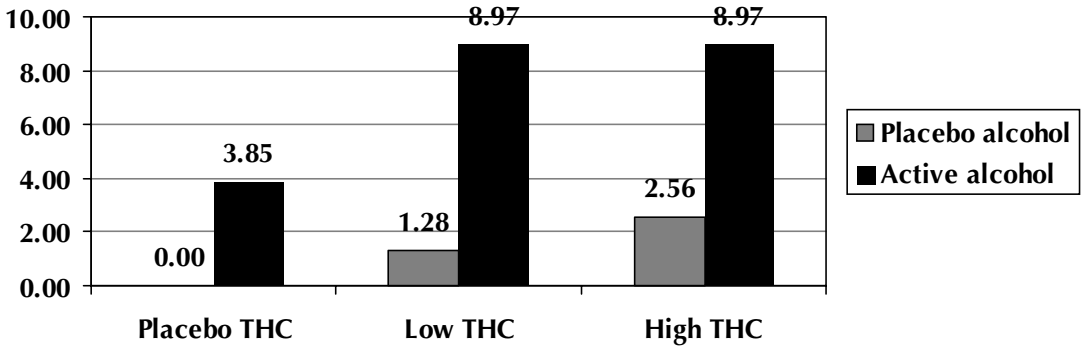
Figure 56: Percentage of participants in each of the six drug conditions that displayed NMax during the SFSTs



Horizontal Gaze Nystagmus: Nystagmus at 45 degrees (N45)

There was a significant difference in the percentage of participants that displayed the N45 sign across the six drug conditions (Cochran Q =15.45, df = 5, $p < 0.01$).

Figure 57: Percentage of participants in each of the six drug conditions displayed N45 during the SFSTs

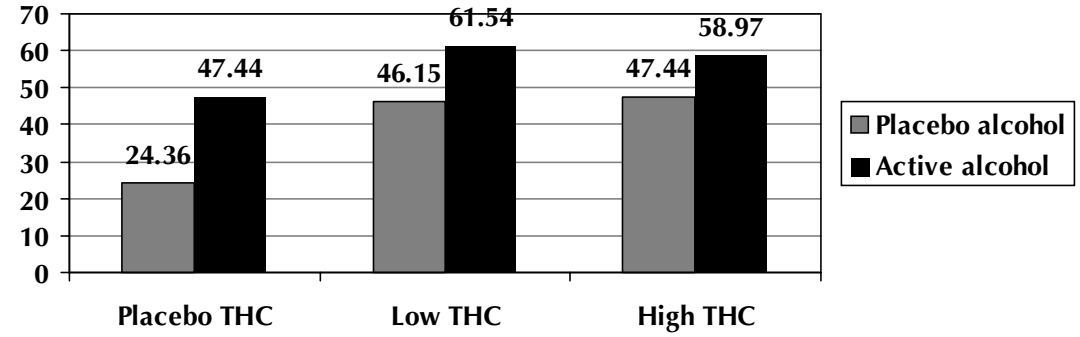


The sign N45 was present more often in the alcohol conditions than in the placebo conditions. Furthermore, N45 was observed more frequently in the low THC condition and the high THC condition than in the placebo condition (Figure 57).

Horizontal Gaze Nystagmus: Head Movements/Jerks (HMJ)

There was a significant difference in the percentage of participants that displayed the error HMJ across the six drug conditions (Cochran Q = 35.68, df = 5, $p < 0.001$).

Figure 58: Percentage of participants in each of the six drug conditions that displayed HMJ during the SFSTs



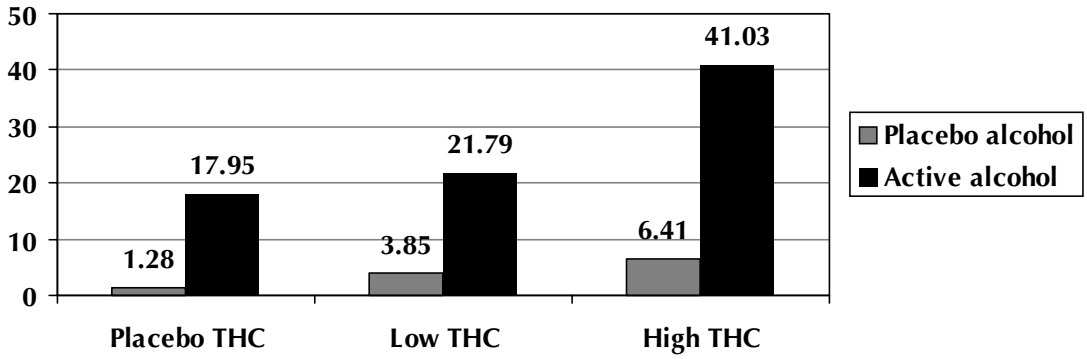
The error HMJ was observed more often in the alcohol condition than in the placebo condition. Furthermore, HMJ was observed more frequently in the low THC condition and the high THC condition than in the placebo condition (Figure 58).

Overall Horizontal Gaze Nystagmus (Overall HGN)

There was a significant difference in the percentage of participants that displayed impairment during the administration of the HGN test (taking into consideration the presence of all errors observed during the HGN test) across the six drug conditions (Cochran Q = 73.91, df = 5, $p < 0.001$).

Impairment on the HGN test was observed more often in the alcohol conditions than in the placebo conditions. Furthermore, impairment on the HGN test was observed more frequently in the low THC condition and the high THC condition than in the placebo condition (Figure 59).

Figure 59: Percentage of participants in each of the six drug conditions that displayed impairment overall during the Horizontal Gaze Nystagmus test

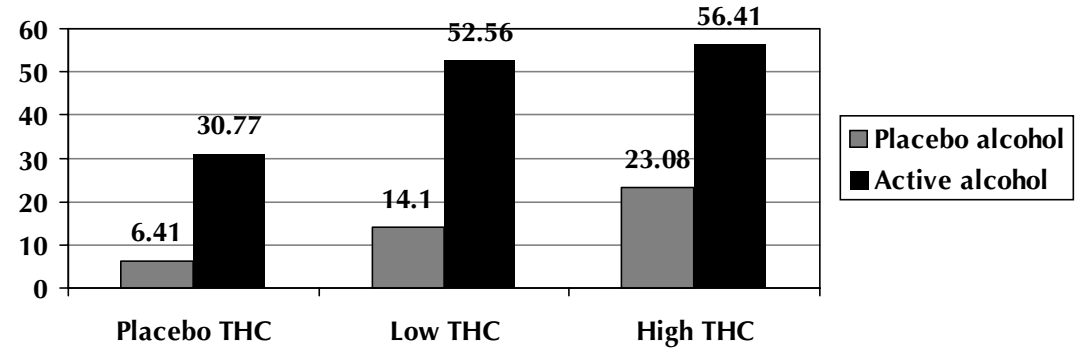


Overall HGN including HMJ (Overall HGNHMJ)

There was a significant difference in the percentage of participants that displayed impairment during the HGN test (when the HMJ scores were included) across the six drug conditions (Cochran $Q = 85.75$, $df = 5$, $p < 0.001$).

Impairment on the HGN test including HMJ was observed more often in the alcohol condition than in the placebo condition. Furthermore, impairment on the HGN test including HMJ was observed more frequently in the low THC condition and the high THC condition than in the placebo condition (Figure 60).

Figure 60: Percentage of participants in each of the six drug conditions that displayed impairment overall during the Horizontal Gaze Nystagmus test when HMJ was included

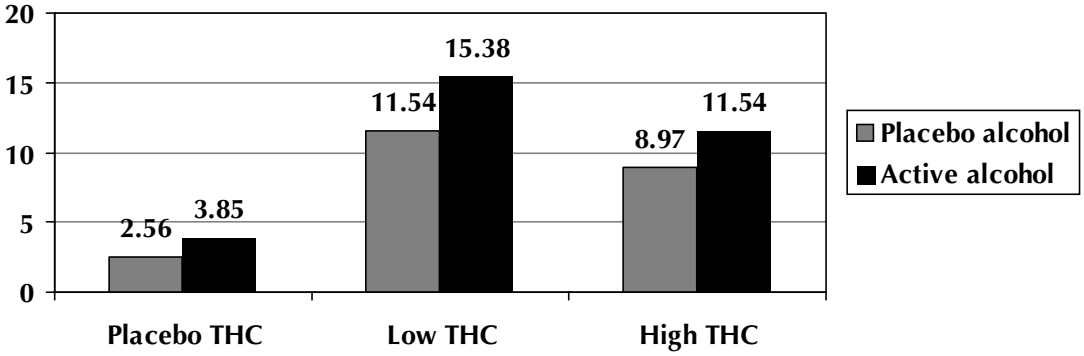


Walk and Turn Test: Steps Off Line (SOL)

There was a significant difference in the percentage of participants that SOL during the WAT test across the six drug conditions (Cochran $Q = 12.61$, $df = 5$, $p < 0.05$).

The sign SOL was observed more often in the alcohol condition than in the placebo condition. Furthermore, SOL was observed more frequently in the low THC condition and the high THC condition than in the placebo condition (Figure 61).

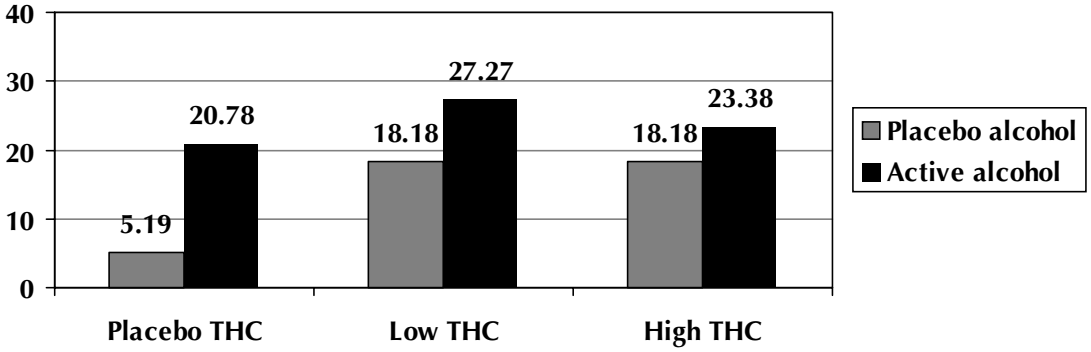
Figure 61: Percentage of participants in each of the six drug conditions that displayed SOL during the SFSTs



Overall Walk and Turn test (Overall WAT)

There was a significant difference in the percentage of participants that displayed impairment during the WAT test (taking into consideration the presence of all errors observed during the WAT test) across the six drug conditions (Cochran Q = 17.63, df = 5, p < 0.01).

Figure 62: Percentage of participants in each of the six drug conditions who displayed impairment overall during the Walk and Turn test

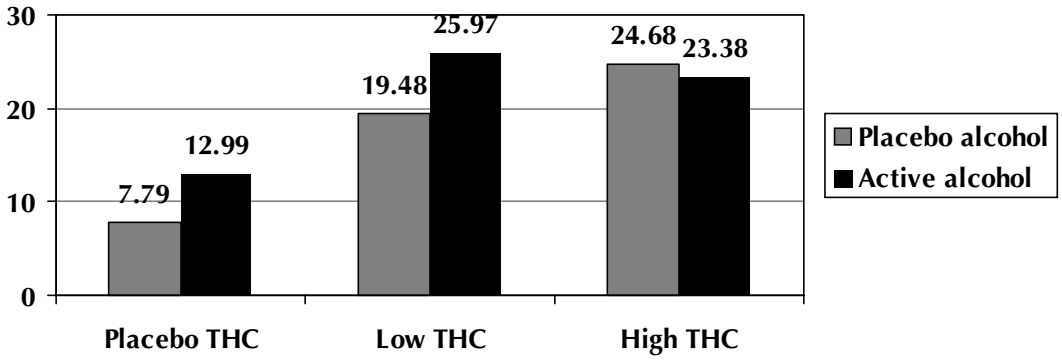


Impairment during the WAT test was observed more often in the active alcohol conditions than in the placebo alcohol conditions. Furthermore, impairment during the WAT test was observed more frequently in the low and high THC conditions than in the placebo THC conditions (Figure 62).

One Leg Stand: Swaying (S)

There was a significant difference in the percentage of participants that displayed the error S during the administration of the OLS test across the six drug conditions (Cochran Q =19.42, df = 5, p < 0.01).

Figure 63: Percentage of participants in each of the six drug conditions that displayed S during the SFSTs

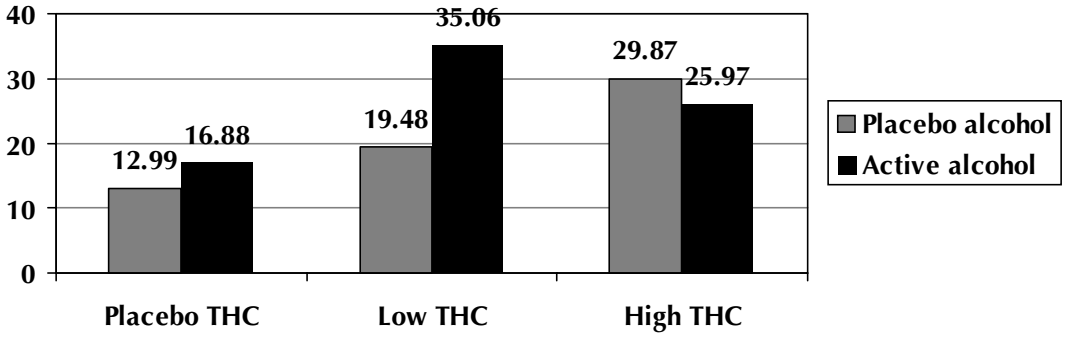


The error S was observed more often in the active alcohol conditions than in the placebo alcohol conditions, except when combined with high THC. Furthermore, S was observed more frequently in the low and high THC conditions than in the placebo THC conditions (Figure 63).

One Leg Stand: Arms used to Balance (AB)

There was a significant difference in the percentage of participants that used their arms to balance across the six drug conditions (Cochran Q =21.08, df = 5, $p < 0.001$).

Figure 64: Percentage of participants in each of the six drug conditions that displayed AB during the SFSTs

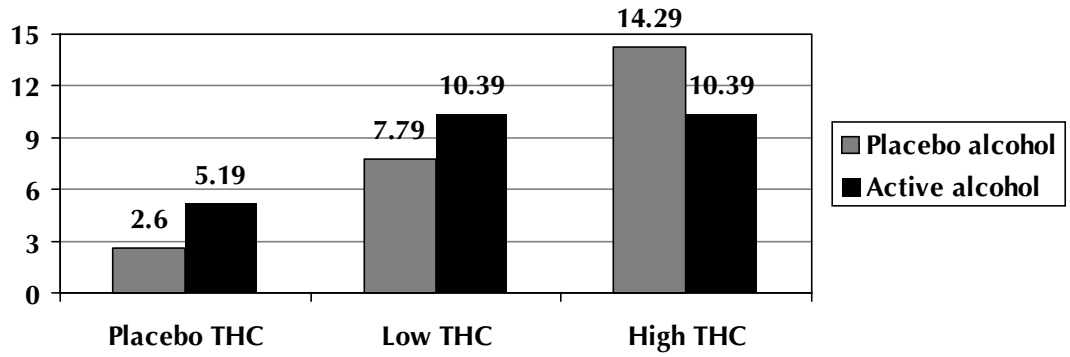


Participants displayed the sign AB more often in the active alcohol conditions than in the placebo alcohol conditions when alcohol was combined with placebo THC and low THC. Furthermore, AB was observed more frequently in the low and high THC conditions than in the placebo THC conditions (Figure 64).

One Leg Stand: Hopping (H)

There was a significant difference in the percentage of participants displaying H during the administration of the OLS test across the six drug conditions (Cochran Q =11.12, df = 5, $p < 0.05$).

Figure 65: Percentage of participants in each of the six drug conditions that displayed H during the SFSTs

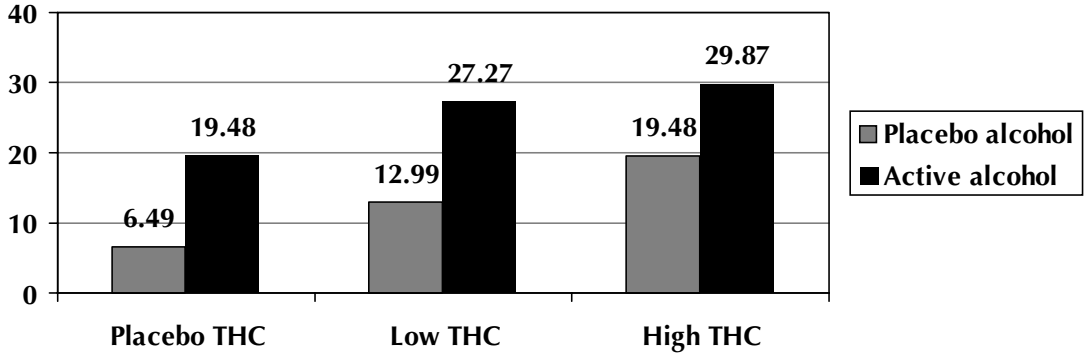


The error H was observed more often in the active alcohol conditions than the placebo alcohol conditions across both the placebo THC and low THC conditions. Furthermore, H was observed more in the low THC and high THC conditions than the placebo THC conditions (Figure 65).

One Leg Stand: Foot Down (FD)

There was a significant difference in the percentage of participants that displayed the error FD across the six drug conditions (Cochran Q = 24.18, df = 5, $p < 0.001$).

Figure 66: Percentage of participants in each of the six drug conditions that displayed FD during the SFSTs

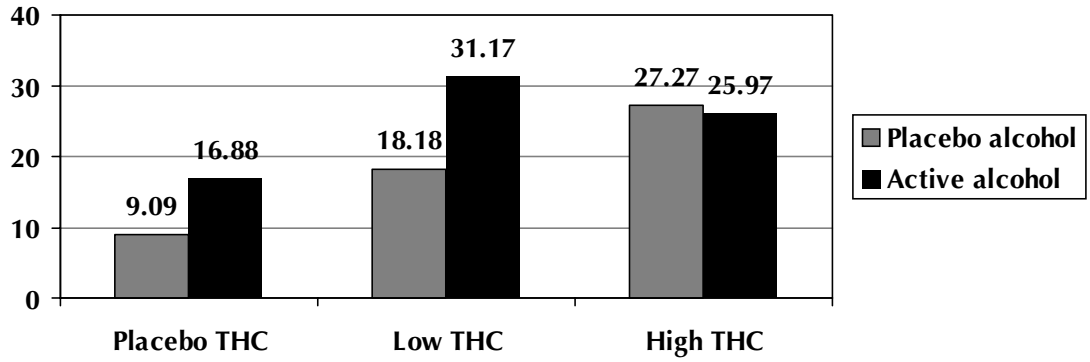


The error FD was observed more often in the active alcohol conditions than in the placebo alcohol conditions. Furthermore, FD was observed more frequently in the low THC conditions and the high THC conditions than in the placebo conditions (Figure 66).

Overall One Leg Stand (Overall OLS)

There was a significant difference in the percentage of participants who displayed impairment during the OLS test (taking into consideration the presence of all errors observed during the OLS test) across the six drug conditions (Cochran Q = 22.19, df = 5, $p < 0.001$).

Figure 67: Percentage of participants in each of the six drug conditions that displayed impairment overall during the One Leg Stand test

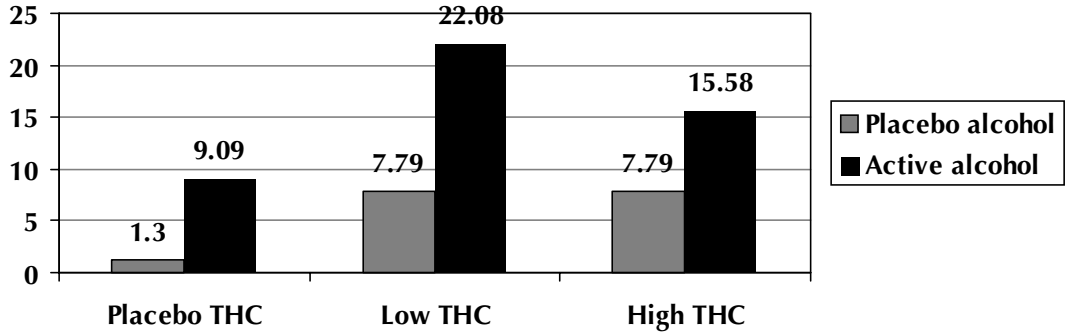


Performance on the OLS test was impaired more often in the active alcohol conditions than in the placebo alcohol conditions when combined with the placebo THC and low THC conditions. Furthermore, performance on the OLS test was impaired more frequently in the low THC condition and the high THC condition than in the placebo condition (Figure 67).

Overall Standardised Field Sobriety Test: Overall SFST

There was a significant difference in the percentage of participants that were impaired during the administration of the SFST battery (taking into consideration the presence of all errors observed during the HGN, WAT and OLS test) across the six drug conditions (Cochran Q = 24.32, df = 5, $p < 0.001$).

Figure 68: Percentage of participants in each of the six drug conditions that displayed impairment overall during the SFSTs

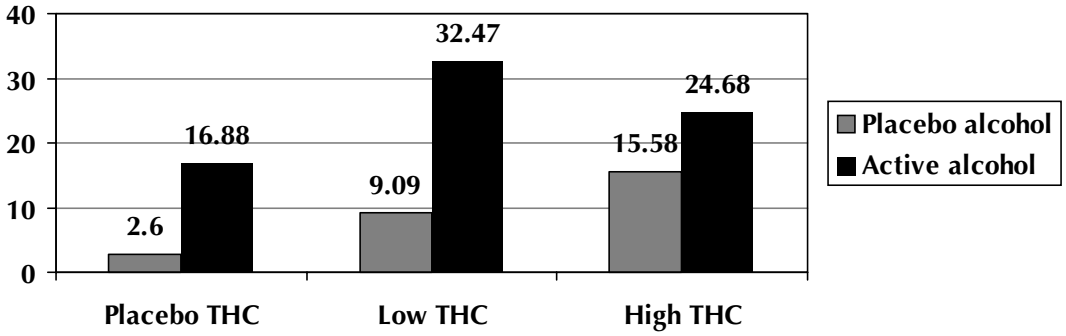


Performance was impaired during the administration of the SFST battery more often in the active alcohol conditions than in the placebo alcohol conditions. Furthermore, performance on the SFSTs was impaired more frequently in the low THC conditions and the high THC conditions than in the placebo THC conditions (Figure 68).

Overall SFST including Head Movements/Jerks: Overall SFST HMJ

There was a significant difference in the percentage of participants that displayed impairment during the administration of the SFSTs when including the HMJ scores across the six drug conditions (Cochran Q = 38.41, df = 5, $p < 0.001$).

Figure 69: Percentage of participants in each of the six drug conditions that displayed impairment overall during the SFSTs when HMJ was included



Performance on the SFSTs including HMJ was more often impaired in the active alcohol conditions than in the placebo alcohol conditions. Furthermore, performance on the SFSTs including HMJ was impaired more frequently in the low THC conditions and the high THC conditions than in the placebo condition (Figure 69).

Efficiency of the Standardised Field Sobriety Tests to predict driving as impaired or not impaired

A Discriminant Function Analysis (DFA) was applied to the data to determine the predictive capacity of SFSTs to test for driving impairment. Driving performance was scored as either impaired or not impaired for each participant in each drug condition. This classification was a replication of previous research that also used the CyberCar LITE in its testing procedures (Papafotiou, 2004b). Each drug condition was analysed separately which resulted in six DFAs being computed. DFAs with a Wilks' Lambda significance value of less than 0.05 are reported. A Wilks' Lambda significance value of less than 0.05 indicates that, in that drug condition, SFSTs predict driving as impaired or not impaired significantly better than chance. For the drug conditions (low THC only; high THC with low alcohol (0.03% BAC); and high THC with high alcohol (0.05% BAC) SFSTs were able to correctly classify driving performance as impaired or not impaired significantly better than chance. The sobriety test that contributed most to the correct classification rate is also reported.

Low THC only

The use of sobriety tests correctly classified participants as either impaired or not impaired on the driving task in 73.9% of cases. Specifically, of those participants who were impaired on the driving task, 33.3% were correctly classified as impaired. Of those participants who were not impaired on the driving task, 88.2% were correctly classified as not impaired. The best single predictor of driving impairment was the score obtained on the OLS test. The OLS test was the test that had the greatest discriminatory ability in classifying a participant as impaired or not impaired on the driving task. In addition, scores obtained on the OLS test contributed most to the correct classification rate of the SFST battery. Including HMJ in the scoring procedure of the HGN test did not change the predictive power of using the SFSTs.

Table 50: Wilks' Lambda for SFSTs to generate a driving classification in the low THC and placebo alcohol drug conditions.

Wilks' Lambda	Chi-Square	df	Sig.
0.873	4.551	1	0.03

Table 51: Structure Matrix displaying the discriminatory power of each sobriety test to test for driving impairment.

Sobriety test	Function 1
OV OLS	1.000
OV SFST	0.518
OV SFST HMJ	0.518
OV WAT	0.335
OV HGN	-0.080

High THC with low dose alcohol (0.03% BAC)

The use of sobriety tests correctly classified participants as either impaired or not impaired on the driving task in 69.4% of cases. Specifically, of those participants who were impaired on the driving task, 38.5% were correctly classified as impaired. Of those participants who were not impaired on the driving task, 87% were correctly classified as not impaired. The best single predictor of driving impairment was the score obtained on the OLS test. The OLS test was the test that had the greatest discriminatory ability in classifying a participant as impaired or not impaired on the driving task. In addition, scores obtained during the OLS test contributed the most to the correct classification rate of the SFST battery. Including HMJ in the scoring procedure of the HGN slightly improved the predictive power of the SFSTs.

Table 52: Wilks' Lambda for SFSTs to generate a driving classification in the high THC and low alcohol (0.03% BAC) drug conditions.

Wilks' Lambda	Chi-Square	df	Sig.
0.895	3.594	1	0.05

Table 53: Structure Matrix displaying the discriminatory power of each sobriety test to test for driving impairment.

Sobriety test	Function 1
OV OLS	1.000
OV SFST HMJ	0.455
OV SFST	0.434
OV HGN	-0.201
OV WAT	-0.093

High THC with high dose alcohol (0.05% BAC)

The use of sobriety tests correctly classified participants as either impaired or not impaired on the driving task in 69.4% of cases. Specifically, of those participants who were impaired on the driving task, 46.7% were correctly classified as impaired. Of those participants who were not impaired on the driving task, 85.7% were correctly classified as not impaired. Performance on the WAT test was the best single predictor of driving impairment. The WAT test was the test that had the greatest discriminatory ability in classifying a participant as impaired or not impaired on the driving task. In addition, scores obtained during the WAT test contributed the most to the correct classification rate of the SFST battery. Including HMJ in the scoring procedure of the HGN slightly improved the predictive power of the SFSTs.

Table 54: Wilks' Lambda for SFSTs to generate a driving classification in the high THC and high alcohol (0.05% BAC) drug conditions.

Wilks' Lambda	Chi-Square	df	Sig.
0.873	4.551	1	0.03

Table 55: Structure Matrix displaying the discriminatory power of each sobriety test to test for driving impairment.

Sobriety test	Function 1
OV WAT	1.000
OV SFST HMJ	0.583
OV SFST	0.571
OV OLS	0.211
OV HGN	0.078

In summary, performance during the administration of the OLS test was the best test of driving impairment associated with the consumption of cannabis alone and cannabis combined with alcohol. In addition, including HMJ in the scoring procedure of the HGN test slightly improved the predictive power of the SFST battery. Performance on the SFSTs successfully predicts driving impairment as impaired or not impaired at best in 73.9% of cases.

Inter-rater reliability: Testing the rate of agreement between police officer and researcher reports on impairment using the Standardised Field Sobriety Tests (SFSTs).

Inter-rater reliability of the SFSTs was assessed to determine whether the observation of errors by police officers (Victoria Police) and researchers (Swinburne University) was similar. SFSTs were administered by the researchers in 480 sessions (i.e. 80 participants x 6 test conditions). The researchers administered the SFSTs to participants and scored performance on the day of testing. Performance on the SFSTs was video taped and passed onto police officers to be scored. Not all participants gave consent for a member of the Victoria Police to view the video footage of their performance on the SFSTs. Seventy-three percent of participants did provide consent, therefore the inter-rater reliability statistical analysis included 350 performances on the SFSTs (viewed and scored by both researcher raters and police officer raters).

A Pearsonian Chi-squared test provided a test of whether inter-rater reliability was statistically significant (i.e. the frequency that the police officer rater and the researcher rater agreed that a sign was present or not present). Table 56 displays the Pearsonian Chi-squared significance results for each of the twenty-three SFST errors recorded.

Table 56: Chi-squared significance results indicating whether there was significant inter-rater agreement (between Victorian Police and Swinburne researcher ratings) that a SFST sign was present.

SFST sign	(Df)	χ^2	P-value
Horizontal Gaze Nystagmus (HGN)			
Lack of Smooth Pursuit	1	0.56	0.456
Nystagmus at Max. Deviation	1	3.59	0.058
Nystagmus at 45 degrees	1	0.63	0.429
Vertical Gaze Nystagmus	1	Nil	Nil
Head Movement Jerks (HMJ)	1	19.45	0.000
Overall HGN	1	3.13	0.077
Overall HMJ	1	7.08	0.008
Walk and Turn Test			
Not balance	1	16.92	0.000
Start too soon	1	66.78	0.000
Stops walking	1	0.53	0.467
Misses heel to toe	1	0.12	0.730
Steps off line	1	4.70	0.030
Raises arms	1	49.73	0.000
Improper turn	1	36.64	0.000
Actual steps taken	1	16.16	0.000
Overall walk and turn	1	16.95	0.000
One Leg Stand			
Sway	1	21.21	0.000
Arms to balance	1	33.93	0.000
Hopping	1	20.66	0.000
Puts foot down	1	77.03	0.000
Overall One Leg Stand	1	46.24	0.000
Overall SFST	1	27.41	0.000
OV SFST HMJ	1	25.48	0.000

Df = degrees of freedom; χ^2 = chi-squared value; p-value = probability value that this result has occurred by chance (under 0.05 equates to 95% confidence that this result is accurate)

These results support a high level of agreement between the police officer ratings and the researcher ratings on impairment using the SFSTs. There was statistically significant agreement between raters on 17 out of the 23 SFST signs recorded. There was also a strong trend towards a statistically significant agreement between raters on the presence of the error 'Nystagmus at 45 degrees' (N45) and overall impairment on the Horizontal Gaze Nystagmus (HGN) test.

There was a significant lack of agreement between the police officer raters and researcher raters on the presence of four errors scored during the administration of the SFSTs. The observation of the sign 'Lack of Smooth Pursuit' (LSP) was significantly different for the police officers and the researchers. Police officers and researchers agreed that, in the 350 performances during the HGN test, the error LSP was present in 169 cases (48%) and was not present in 33 cases (10%). However, there was a lack of agreement in 147 cases (42%) in which in the majority of these cases (102 cases or 29%) the researchers observed the error LSP and the police officers did not.

There was also a statistically significant lack of agreement between the police officers and the researchers on the presence of the error N45. Of the 350 performances scored, both raters agreed that the error N45 was not present in 320 cases (91%); however, there was a lack of agreement in 30 cases (9%). Surprisingly, there was not a single incidence of agreement, between raters, that the error N45 sign was present. The absence of even a single incidence of agreement between the police officers and the researchers on the presence of the error N45 suggests that the error N45 may not be a reliable indicator of impairment.

There was no statistically significant agreement between the police officer raters and the researcher raters on the observation of the error 'Stop Walking' (SW) during the Walk and Turn test (WAT). The police officers and the researchers disagreed on whether this error was present during performance on the WAT test in 47 cases (13%). While both raters agreed this sign was not present in 301 cases (86%), in only one case (<1%) both raters agreed that the error SW was present. There was also no significant inter-rater agreement between both raters for the presence of the error 'Misses Heel to Toe' (MHT). In 337 performances both the police officers and the researchers did not observe the error MHT (96%). In 13 cases there was non-agreement on the presence of the error MHT (4%).

Discussion

Blood analysis

The results of the present study are consistent with past research showing that the level of THC detected in the blood is higher after the consumption of THC in combination with alcohol, than THC without alcohol (Lukas & Oronzco, 2001). Regular users showed higher levels of THC in plasma than non-regular users which is also consistent with past research (Papafotiou, et al., 2004c). The higher the dose of THC administered, the higher the level of THC detected in plasma.

Driving performance

Analysis of the data obtained from the driving simulator suggests that cannabis impairs driving performance. More driving errors were observed in the THC conditions when compared to the placebo THC conditions. The results also highlighted the effect of alcohol consumption on behaviour. Several variables were impaired in the active alcohol condition (irrespective of THC consumption) when compared to the placebo alcohol condition. Participants also displayed more driving errors during the high alcohol condition (0.05% BAC) than in the low alcohol condition (0.03% BAC).

During the driving simulator task, the mean number of times the errors of 'straddling the solid line', 'straddling the barrier line', 'insufficient stopping clear space' and 'slower initial speed on the freeway' occurred was higher when THC was consumed than when placebo THC was consumed (with or without alcohol). This suggests that there is an increased likelihood that individuals who have consumed cannabis drive with two or more wheels of the vehicle moving over lines marked out for traffic moving in the same direction, or lines marked out for traffic moving in the opposite direction. In addition, there is an increased likelihood that individuals who have smoked cannabis will drive with insufficient clear space between their own vehicle and the vehicle in front of them (driving too close to the vehicle in front). Although the consumption of THC was also associated with slower initial speed when entering the freeway, this does not appear to be related to safer driving. The observation of an increase in straddling barrier and solid lines and insufficient stopping clear space during the THC condition indicates that driving slowly (at one point or another) is associated with deficiencies in abilities essential to safely drive a motor vehicle. The results also highlight that, when under the influence of THC, many driving errors are observed whether alcohol is also consumed or not.

The findings of the present study are almost identical to those reported in a previous project by our research team utilising the same driving simulator (Papafotiou et al., 2004b). Papafotiou et al. (2004b) reported that, compared to placebo, the consumption of THC was associated with an increase in 'straddling the solid line' and 'straddling the barrier line'. These findings are consistent with previous research reporting that THC impairs car control (Moskowitz, 1985), increases the number of obstacles hit on a driving course (Hansteen et al., 1976; Smiley et al., 1981), increases the standard deviation of the lateral position of a vehicle (Smiley et al., 1981; Ramaekers et al., 2000), impairs tracking ability (Ramaekers et al., 2000) and increases the number of sideway movements of a vehicle and percentage of time spent out of a lane (Robbe & O'Hanlon, 1993; Ramaekers et al., 2000). Previous research on driving performance, therefore, suggests that, during sobriety test performance, individuals should have difficulty maintaining focus and in keeping balance. This was demonstrated in performance during the Walk and Turn test and One Leg Stand test (discussed in 5.3.4).

In the present study the driving variables 'straddling the barrier line' and 'insufficient stopping clear space' were impaired by the consumption of THC. These errors were also observed significantly more often in conditions that included the administration of alcohol compared to placebo. In addition, the error 'straddling the barrier line' occurred significantly more often in the 0.05% BAC condition than in the 0.03% BAC condition.

With respect to impairment associated with the administration of alcohol (with and without THC), a number of driving variables were impaired. 'Dangerous skidding', 'unsafe stopping distance', 'violation of the speed limit', 'collisions', 'straddling the barrier lines' 'wandering', and 'insufficient clear space' occurred significantly more frequently in the active alcohol condition than in the placebo alcohol condition. The errors 'straddling the barrier lines' and 'unnecessary stopping' occurred significantly more often in the 0.05% BAC condition compared to the 0.03% BAC condition. The results highlight that many driving errors are observed while under the influence of alcohol whether it is consumed with THC or not. The results are consistent with previous research that has reported that alcohol increases the number of errors in variables that measure acceleration, braking, responding to traffic signs and speeding (Crancer et al., 1969; Kreuger & Vollrath, 2000; Stein et al., 1983). In addition, the present results support that even levels of alcohol below legal alcohol limits (0.03% BAC) can have impairing effects on driving performance. The data also supports that more errors are likely to occur when under the influence of 0.05% BAC when compared to legal alcohol limits (0.03% BAC).

For a statistical interaction to be observed, impairment after the consumption of alcohol together with THC needs to be greater than the combination of the effects of alcohol only and THC only. The absence of an interaction would suggest that, when both drugs are consumed together, impairment is not significantly greater than when each drug is consumed separately. There were three significant interactions between the THC condition and the alcohol condition. In other words, the results showed that when THC was consumed together with alcohol, performance was more impaired than when THC or alcohol is consumed in separate conditions. Specifically, while there were significantly more 'dangerous skidding' errors in the alcohol condition compared to the placebo condition, the greatest number of errors occurred when alcohol was combined with THC. In addition, while there were significantly more 'inappropriate signalling' errors in the alcohol condition compared to the placebo condition, the greatest number of errors occurred when alcohol was combined with THC. The results indicate that each drug alone has deleterious effects on driving performance; however, the consumption of both drugs together can produce an even greater impairment.

Driving performance: Differences between regular cannabis users and non-regular cannabis users

Data from the driving simulator reported many significant differences in performance between regular cannabis users and non-regular cannabis users. Irrespective of the drug administered, regular users were involved in more collisions, had an unsafe following distance more often, and had a faster initial speed on the freeway when compared to non-regular users. Furthermore, the greatest number of errors performed by regular users involved 'collisions', 'violation of the speed limit', 'fast initial speed on the freeway', 'inappropriate signalling' and 'slow reaction time to emergency situation' during the THC condition (with and without alcohol). These results are not consistent with previous research that suggests regular users perform better than non-regular users (Marks & MacAvoy, 1989; Wright & Terry, 2002). Since regular users are more experienced with the psychological and physiological effects of THC, it has been suggested that these users are better able to compensate for the impairing effects of the drug. In the present study, the addition of alcohol may have influenced driving behaviour differently in both groups. For instance, in the THC condition, regular users performed significantly worse than non-regular users with and without alcohol. In the present study, the consumption of alcohol – which has previously been associated with over-confident driving behaviour, decreased inhibitions and greater risk taking – may have led regular users to underestimate the effects of consuming THC with alcohol. This is evident particularly in the risky driving behaviours observed in regular users, such as speeding, dangerous skidding and collisions. The conflicting findings suggest that research in this area remains equivocal and further investigation is required.

The Standardised Field Sobriety Test (SFSTs)

Performance on the Standardised Field Sobriety Tests (SFSTs) after the administration of THC with alcohol has not been previously reported. Therefore, the results of the present study cannot be directly compared to previous research. However, there have been studies that have examined the effects of these two drugs, alone and in combination, on sobriety test procedures that comprise the Drug Evaluation and Classification Program (DEC Program), although these studies did not report individual test scores or the prevalence of individual test errors/signs.

By comparing performance after the administration of THC and after the administration of THC and alcohol, significant differences in SFST performance were identified. In the Horizontal Gaze Nystagmus (HGN) test, the percentage of participants exhibiting errors in the HGN test was higher in the low THC and high THC condition than in the placebo condition. When THC and alcohol were administered, the percentage of participants exhibiting errors in the HGN test increased. In all three THC conditions, when THC was administered together with alcohol, the number of

participants exhibiting the sign Lack of Smooth Pursuit (LSP), Nystagmus at Maximum Deviation (NMax) and Nystagmus at 45 degrees (N45) more than doubled compared to when THC was administered without alcohol. When the dose of alcohol administered with THC was 0.05% BAC, the number of participants displaying LSP and NMax tripled. These results are consistent with studies that report that alcohol induces nystagmus, although previous research has reported that nystagmus is observed after the administration of alcohol up to 0.08% BAC. Perhaps the current study observed nystagmus at lower BACs because of an interaction between the physiological effects of THC and alcohol. In addition, the number of participants who were scored as impaired on overall HGN was higher when THC was consumed together with alcohol, than in the THC only condition.

Another obvious effect of THC and alcohol was that neither THC, nor THC together with alcohol, resulted in the presence of Vertical Gaze Nystagmus (VGN). It appears that this error is not related to the consumption of THC, or the consumption of alcohol.

Our research team has previously reported that the error Head Movements/Jerks (HMJ) is observed in a high percentage of individuals who have consumed THC (Papafotiou, 2004a). The present study re-examined the relationship between the error HMJ and the administration of THC and THC with alcohol. The data showed that the sign HMJ was observed in a higher percentage of individuals when compared to traditionally scored errors during the HGN test. Furthermore, when scoring performance on the SFSTs including HMJ, the highest percentage of participants was classified as impaired in the high THC with alcohol condition. In the placebo condition, scoring HMJ did not substantially change the percentage of individuals classified as impaired. These results suggest that scoring HMJ increases the likelihood of identifying an individual who has consumed THC only and THC together with alcohol.

Unlike the results from the HGN test, only one sign of the Walk and Turn (WAT) test – Steps off the Line (SOL) – was related to drug condition. For the remaining WAT signs, there were an equal number of participants who displayed the error across all drug conditions (including placebo). While there were no statistically significant differences for these WAT signs, Swaying (S), Misses Heel to Toe (MHT) and Improper Turn (IT) were observed in a higher percentage in the THC only condition compared to the THC with alcohol condition. It was expected that the addition of alcohol would produce greater impairment because the SFST battery was designed to test for the presence of alcohol. However, the results are consistent with our previous research reports in which some individual WAT signs were not accurate indicators of the recent consumption of THC or driving impairment associated with THC (Papafotiou et al., 2004a). Papafotiou et al. (2004a) reported that the error Improper Turn was observed more often in placebo conditions and therefore this error is not related to drug consumption. This information is important because these errors may be observed during the administration of the WAT test even when no drug has been consumed. Overall WAT impairment (where all errors are taken into consideration) was observed significantly more often in the THC condition than in the placebo condition. A greater number of participants failed the WAT test when THC was consumed with alcohol.

Results from the One Leg Stand (OLS) test suggest there was a significant relationship between the presence of all the signs scored during the OLS test and the THC only condition and the THC with alcohol condition. More errors were observed as the dose of THC consumed increased. OLS test scores did not appear to have any relationship with the presence of alcohol. This finding is consistent with previous research that suggests that the OLS test score is the best predictor of the consumption of THC (compared to the HGN test and the WAT test). In addition, the results suggest that the OLS test score is the most reliable indicator of impairment associated with the consumption of THC.

Finally, performance on the entire SFST battery (addition of HGN, WAT and OLS test scores) was significantly impaired in the THC only condition and THC together with alcohol condition. When THC was consumed together with alcohol, the percentage of individuals classified as impaired more than doubled compared to when THC was consumed alone. These results highlight the sensitivity of SFSTs to test for the presence of alcohol. When scoring SFSTs and including HMJ, the percentage of individuals classified as impaired increased. This finding is consistent with our previous research that suggests that including HMJ in the scoring procedure increases the likelihood of classifying an individual who has consumed THC as impaired (Papafotiou, 2004a). Administrators of the SFST battery should, therefore, consider scoring, or at least recording, the presence of HMJ as it is a good indicator of drug consumption, especially in the case of THC and alcohol.

Efficiency of the Standardised Field Sobriety Tests (SFSTs) to predict driving performance

When driving performance was impaired, a large number of errors were observed during the administration of the SFSTs. Data from the driving simulator revealed that driving was significantly impaired when THC was consumed and when THC was consumed together with alcohol (0.05% BAC and below). Results from the SFSTs revealed that a high percentage of individuals displayed errors during performance on the SFSTs when THC was administered, and this percentage increased when THC was administered together with alcohol (0.05% and below).

The driving variables that were impaired after the consumption of THC only and THC together with alcohol were: "Straddling the solid line"; "straddling the barrier line"; and "stopping distance between vehicles". These results suggest that the consumption of THC and alcohol is associated with impairment in maintaining a steady position of the vehicle in traffic. The OLS test primarily assesses balance, and the sign HMJ measures the ability to keep the head in a steady position while following a stimulus moving across the visual field. The OLS test score and the sign HMJ were significantly related to drug dose. It appears that a test that assesses balance and steadiness accurately identifies impairment associated with THC (with and without alcohol).

It is acknowledged that SFSTs are not typically administered to drivers to test for 'driving impairment', but rather to test for the presence of a drug that is known to impair driving ability (Burns, 1987). The assumption that if a drug has been consumed then driving is impaired is not always true. It is, therefore, important to distinguish between the presence of a drug and the presence of impairment. The sobriety tests used by Victoria Police officers are administered to drivers suspected of being impaired who may pose a danger on the road. In this context, SFSTs should assess driving impairment, irrespective of drug use.

In order to statistically examine whether sobriety test scores predict driving impairment, a Discriminant Function Analysis (DFA) was performed. Whether a participant is a regular or non-regular cannabis user is irrelevant, as SFST scores should assess the presence of impairment irrespective of participant characteristics and the level of THC in the plasma. Overall, SFST scores and scores from each test that comprise the SFSTs were examined. The results of the present study indicate that sobriety test scores obtained after the administration of low THC only, high THC together with low alcohol (0.03% BAC), and high THC together with high alcohol (0.05% BAC), significantly predicted driving as either impaired or not impaired. Using the SFSTs, driving was correctly classified in 73.9% of cases as either impaired or not impaired after the administration of low THC. The best test of impairment associated with low THC was the OLS test. This finding is consistent with past research that has highlighted that the OLS test is the best test of impairment associated with the administration of cannabis. When high dose THC was consumed together with low dose alcohol (0.03% BAC), SFST scores correctly classified driving as impaired or not impaired in up to 69.4% of cases. Once again, the OLS test score was the best predictor of driving

impairment. Finally, after the consumption of high dose THC together with high dose alcohol (0.05% BAC), SFST scores correctly predicted driving impairment in 69.4% of cases. When this occurred the WAT test score was the best predictor of driving impairment. When high dose THC was consumed (with or without alcohol) the SFST scores that included the error HMJ were slightly better predictors of driving impairment than when HMJ was not included.

This finding supports previous recommendations, reported in police sobriety test manuals and research by the investigators (Papafotiou, et al., 2004a), that assessing whether an individual is able to keep their head still during the HGN test improves the efficiency of the SFSTs to test for impairment associated with THC. Previous research reports that the HGN test is best related to impairment associated with the consumption of alcohol (up to 0.08% BAC). However, the present findings highlight that when THC is consumed (with and without alcohol), the test best related to impairment is the OLS test. These results suggest that the consumption of THC impairs both balance and attention, and tests that assess these abilities are the best predictors of driving impairment associated with the consumption of THC.

In summary, departments or organisations using or considering the use of sobriety tests can be confident that the SFSTs assess impairment in driving associated with the consumption of THC (with and without 0.05% BAC and below) considerably better than chance. However, administrators should consider the inclusion of the sign HMJ in the scoring of the HGN, as HMJ has been associated with impairment.

The Level of THC in plasma and performance

The level of THC detected in plasma 20 minutes after the consumption of a 1.8% THC (low dose) cannabis cigarette was 6.9 ng/ml. The level of THC detected in plasma 20 minutes after the consumption of a 3% THC (high dose) cigarette was 9 ng/ml. The levels of THC in plasma were higher when each cannabis cigarette was consumed with alcohol (7.6 ng/ml and 11.2 ng/ml respectively). This finding is consistent with previous research (Lukas & Orozco, 2001). The level of THC in plasma dropped by approximately half in all THC conditions, over a 40 minute period (administration of the driving simulator and SFSTs). Regular users and non-regular cannabis users recorded different levels of THC in plasma at all time points. The level of THC detected in plasma for regular users, 20 minutes after the consumption of the low THC cigarette, was 9.5 ng/ml; and 20 minutes after the consumption of the high THC cigarette was 9.6 ng/ml. Non-regular users recorded lower levels in plasma, with 5.8 ng/ml of THC detected after the consumption of the low THC cigarette and 7.9 ng/ml after the consumption of the high THC cigarette. For both regular and non-regular cannabis users, the level of THC in plasma was higher when THC was consumed with alcohol. These results are consistent with previous research that reports that the level of THC in the plasma drops to below 20 ng/ml 20 minutes after smoking cannabis, and will remain relatively low for up to 2 hours after smoking (Cone & Huestis, 1993; Papafotiou, 2004). The difference in the level of THC detected in regular users and non-regular users can be attributed to regular users having greater experience in smoking cannabis. Although the smoking procedure was identical for both groups, it appears that regular users were more successful in inhaling THC smoke for two seconds and holding THC smoke in their lungs for 10 seconds, as requested. This would result in a larger amount of THC being absorbed by the lungs and distributed into the blood stream (Chesher, 1997).

When driving was impaired, the level of THC in plasma was between 3.1 ng/ml and 11.2 ng/ml. This finding is consistent with previous research that has reported that driving performance is maximally impaired by cannabis when THC plasma levels drop to 13 ng/ml and below (Berghaus et al., 1995; Cone & Huestis, 1993). In the present study, the variables 'straddling the barrier line', 'straddling the solid line' and 'insufficient clear space' were impaired when the level of THC in plasma was between 3.1 and 11.2 ng/ml. This finding suggests that tracking, attention, and balance

(maintaining a balanced/steady position of the steering wheel/vehicle) are impaired by low levels of THC in plasma. Berghaus et al. (1995) reported that tracking is impaired by plasma THC levels of 6 ng/ml, attention is impaired by 9 ng/ml, and visual functioning is impaired by 12 ng/ml. The results of Berghaus et al's (1995) study indicate that driving-related skills are severely affected when the level of THC in plasma drops to below 13 ng/ml (approximately 1 hour after the beginning of smoking; elimination phase in the actions of THC), consistent with the findings of the present study.

Regular users displayed significantly more driving errors than non-regular users. When this occurred, the level of THC detected in plasma in regular users was between 3.6 ng/ml and 13 ng/ml. Although previous research has reported impairment at these plasma levels, it is inconsistent that regular users were more impaired than non-regular users. Previous research has suggested that regular users have a higher tolerance to the psychological and physiological effects of cannabis, and are able to compensate for impairment (Robbe & O'Hanlon, 1993). It is possible that, since alcohol reduces inhibitions and increases risk-taking behaviours, when THC was consumed together with alcohol, regular users may have underestimated the impairing effects of THC together with alcohol. For regular users, alcohol may have hindered compensatory/inhibitory mechanisms, in which their ability to over-compensate was impaired or a decision was made that compensation was not required.

Inter-rater reliability of the Standardised Field Sobriety Tests (SFSTs)

Results from the present study support a high level of agreement between police officer ratings and researcher ratings on impairment using the SFSTs. There was statistically significant agreement between raters for 17 out of 26 SFSTs signs recorded. The individual errors in the SFSTs that resulted in a lack of agreement between police raters and researcher raters were those scored during the administration of the HGN test. The errors that involve eye signs, such as Lack of Smooth Pursuit (LSP), and Nystagmus at 45 degrees (N45), were reported to be present more often by the researchers than by the police. These results are not surprising, as police officers were required to record the presence of HGN errors using video footage, not while in the presence of the participant on the day of testing (no face-to-face observation). Subtle eye signs may not have been obvious in the video footage viewed by police. The researchers had the advantage of being able to observe greater eye detail, and, in addition, the researchers were able to view the participant at various angles, if required, during the administration of the HGN test. This information is also relevant to the disagreement in the presence of the error Misses Heel to Toe (MHT) (WAT test error). The visual angle that police officers had available through the video footage may have hindered their ability to determine the distance between each heel to toe steps. The task of having to distinguish a difference between a 2 cm and 3 cm gap between a heel to toe step through video footage is likely to have been difficult (if the gap between heel and toe is greater than 2.5cm an MHT error is recorded). Considering that the police raters were required to score performance on the SFSTs using video footage, the level of agreement on the presence of errors between police raters and researcher raters is high. With respect to identifying overall impairment on each individual test (HGN, WAT and OLS) and overall impairment on the SFST battery as whole, there was statistically significant agreement between police raters and the researcher raters in all cases. This indicates that, when administered correctly, and by a rater trained to administer SFSTs, the SFSTs are reliable tests of impairment. Overall, the results suggest that the SFSTs involve a reliable scoring procedure and that scores on the SFSTs are accurate and replicable.

Summary of findings

The main finding of the project was that smoking cannabis containing either 1.8% THC or 3% THC (with or without alcohol) significantly impaired driving performance and sobriety test performance. When alcohol was consumed, impairment in driving was also observed, and significantly more errors were made when the level of alcohol was 0.05% BAC rather than 0.03% BAC. When driving was impaired, the level of THC in plasma varied between 3 and 11 ng/ml. Driving variables were also impaired when BACs ranged from 0.03% to 0.05%. In addition, scores obtained using the SFSTs predicted driving performance associated with cannabis and alcohol considerably better than chance (at best in 76.3% of cases). The SFST battery is improved when HMJ (Head Movements/Jerks) is scored in the HGN test. Finally, the consumption of cannabis cigarettes containing either 1.8% or 3% THC, together with 0.05% BAC or below, impaired performance in regular cannabis users more severely than in non-regular cannabis users. When this occurred, the level of THC in plasma was higher in regular users than in non-regular users.

In conclusion, the SFSTs provide relevant information concerning drug consumption and driver fitness particularly associated with the consumption of THC.

Chapter six: Implications and future research

Implications of the present study

The findings of the present study demonstrate that the consumption of cannabis, with and without alcohol, significantly impairs driving behaviour. The research also highlights that the Standardised Field Sobriety Tests (SFSTs) are appropriate measures for the detection of cannabis and alcohol consumption, and driving impairment associated with the consumption of cannabis and alcohol. The current project is the first to study the effects of cannabis in combination with legal levels of alcohol (0.05% BAC and below) on SFST battery performance together with driving performance, and has highlighted the beneficial applications of such a combination of measures. For instance, the examination of SFSTs together with a driving task has demonstrated that performance on the SFSTs, after the consumption of cannabis with and without alcohol, is significantly related to driving ability. The SFST battery was able to successfully predict driving impairment significantly better than chance in up to 73.9% of cases. The results suggest that SFSTs can be used as a means of testing for driving impairment caused by cannabis and alcohol. In cases where simple roadside specimen tests are unavailable, the SFST battery provides essential information on a person's ability to perform tasks such as driving. Furthermore, in cases where a driver specimen is available, and drugs are detected in the specimen, performance on the SFSTs can provide information to support that the drug was causing impairment, and therefore likely to increase crash risk.

The present study provides essential information on how accurately the SFSTs assess driving impairment caused by cannabis and alcohol. Many law enforcement agencies currently using the SFSTs, or considering the use of the SFSTs to test for drug impairment, can use this information to make informative decisions on the best ways to implement the SFSTs and the best ways to utilise SFST battery data. The current project provides detailed information on which signs within each test are best related to drug intoxication. This information can be used to support both impaired and not impaired classifications of drivers. For instance, an "impaired classification" based on the presence of two or more signs in the OLS is therefore likely to be correct, as the present study supports that the OLS test is often the best predictor of impairment caused by cannabis and alcohol. In addition, in the WAT test, the presence of two or more signs (errors) also constitutes a classification of "impaired" on this test. However, the errors IT (Improper Turn), MHT (Misses Heel to Toe), and Swaying (S) sign of the WAT test were not significantly related to drug dose. Therefore if either IT, MHT and S are the only signs observed during WAT performance, a classification of "impaired" is likely to be inaccurate. It is this type of information that can be used to support decisions concerning the prosecution of drivers for 'driving while impaired', especially in cases where the observed signs are shown to be related to cannabis and alcohol dose and driving impairment.

In addition, the present study re-examined a new sign to be scored in the HGN test of the SFSTs. This sign is named HMJ (Head Movements/Jerks). The scoring of this sign increased the number of participants classified as impaired after the administration of cannabis and alcohol, and was the sign that was observed most often compared to traditional HGN test errors. This result outlines the advantages of introducing the sign HMJ into the scoring procedure of the HGN test of the SFSTs. Law enforcement agencies currently using the SFSTs, or considering the use of the SFSTs, to test for drug impairment can use this information to increase the effectiveness of the SFSTs. The more accurate the test being used by law enforcement agencies, the more drivers will be correctly classified as impaired and prosecuted.

Finally, the research also demonstrated that, when THC levels drop to between 3.1 ng/ml and 11.2 ng/ml, driving is impaired. In cases where only blood samples are available, low THC levels may not raise serious concern about the possibility that the driver may be impaired. Data on SFST battery performance together with blood sample data can provide essential information on whether the level of THC found in a sample should raise concern regarding a driver's degree of impairment. This information can also provide support for decisions on the prosecution of drivers for 'driving while impaired', particularly in cases where the level of THC in blood is very low. This information also supports that it is essential to test for the presence of drugs other than alcohol in cases where a BAC reading reports alcohol levels below the legal limit. The findings highlight that, even at legal BACs, driving is impaired, in particular when cannabis is also consumed.

Future research

Research utilising the same methodology should examine the effects of other illicit drugs. The most obvious next step would be to investigate the effects of the second most commonly used drug other than alcohol. Reports show that the prevalence of amphetamine use is increasing. In particular the consumption of methamphetamine ('speed') by truck drivers and the consumption of methylenedioxymethamphetamine (MDMA: 'Ecstasy') recreationally is increasing. Research into how these drugs specifically impair performance is vital. The investigation of the level of the drug in blood associated with impairment will help identify at what drug levels driving is impaired.

Research should also extend to the investigation of the level of a drug in saliva, as saliva drug detection devices are currently being developed for implementation on the roadside. The identification of the level of a drug in saliva that is associated with driving impairment will provide information on possible cut-off levels to be implemented, in the same way that legal alcohol limits have been implemented into drink driving legislation.

Future research would provide invaluable information on the best ways to administer and interpret SFST battery data, as well as identify impairing levels of a drug in blood and saliva. This information will be relevant to law enforcement agencies currently using or considering the use of the SFSTs and saliva drug detection devices, to detect drug impaired drivers.

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Appendix A1

Patient Questionnaire: Medical History

Trial Name and Number:_____

Participant Name:_____Number_____

D.O.B: _____ Sex: _____ Date:_____

Background and concurrent disease:

Medications:

	Yes	No	If yes, give details below:
Allergic History	☐	☐	_____
Cardiovascular	☐	☐	_____
Ophthalmologic	☐	☐	_____
Respiratory	☐	☐	_____
Gastrointestinal	☐	☐	_____
Hepatobiliary	☐	☐	_____
Renal/Genitourinary	☐	☐	_____
Metabolic/Endocrine	☐	☐	_____
Neurologic	☐	☐	_____
Musculoskeletal	☐	☐	_____
Dermatological	☐	☐	_____
Hematological	☐	☐	_____
Neoplastic	☐	☐	_____
Other (specify)	☐	☐	_____

Signature: _____

Appendix A2

Medical Examination: Physical Examination

Trial Name and Number:_____

Participant Name:_____ Number_____

D.O.B: _____ Sex: _____ Date:_____

	Normal	Abnormal	Comments:
Chest	☐	☐	_____
Heart	☐	☐	_____
Abdomen	☐	☐	_____
Nervous System	☐	☐	_____
Lymph Nodes	☐	☐	_____
ENT and Eyes	☐	☐	_____
Extremities	☐	☐	_____
Skin	☐	☐	_____
Other (specify)	☐	☐	_____

Baseline Obs: BP standing _____ BP sitting _____

Pulse _____ T° _____

Height _____ Weight _____

Urinalysis _____

Comments: _____

_____

_____

_____

Signature:_____

Appendix B1

SWINBURNE UNIVERSITY OF TECHNOLOGY

INFORMATION SHEET

AN EVALUATION OF THE EFFICIENCY OF SOBRIETY TESTING IN DETECTING THE COMBINATION OF ALCOHOL AND THC.

This is a joint project between Swinburne University and Victoria Police

Prof. Con Stough

Dr Katherine Papafotiou

Dr Pradeep Nathan

Swinburne Centre for Neuropsychopharmacology
Swinburne University of Technology

PARTICIPANT'S NAME:

SUBJECT CODE: ***CODE*** _____

We are conducting research to examine the relationship between different levels of THC and low levels of alcohol (0.03% and 0.05% BAC) and performance on the Standard Field Sobriety Test (SFST). This project is being undertaken to provide more information on the effects of THC combined with alcohol on performance and assess the efficiency of sobriety tests in detecting THC and alcohol in drivers. The study will provide essential data concerning the introduction of roadside sobriety testing in Victoria. The research from this project is part of an ongoing investigation into the evaluation of sobriety tests by K. Tzambazis as part of a funded protocol by the National Drug Law Enforcement Research Fund (NDLERF), as well as collaboration between Swinburne University of Technology and Victoria Police.

The study involves two experiments:

Experiment One: Marijuana and 0.03% Alcohol (six randomised sessions)

Experiment Two: Marijuana and 0.05% Alcohol (six experimental sessions)

You will be allocated to one of the two experiments, where neither you nor the investigator will know which. If you agree to participate in this study you will take part in six sessions. Firstly, you will be asked to complete a Basic Medical Examination and then a Frequency of Cannabis Use questionnaire. This should take approximately 20 mins. The six sessions will be experimental where you will be administered alcohol that will bring your blood alcohol concentration (BAC) to either 0.04% or 0.06% depending on which experiment you are allocated (the blood alcohol levels will drop to 0.03% or 0.05%, respectively by the time you are required to perform any tasks). After your appropriate BAC is reached you will be asked to smoke a cannabis cigarette containing one of three different doses of THC, the active ingredient in marijuana (placebo: No THC, 2.02% of THC

or 3.13% of THC). You will then be asked to perform a Standard Field Sobriety Test (SFST). The SFST involves three tests that involve balance and motor coordination including the Horizontal Gaze Nystagmus, the Walk and Turn test and the One Leg Stand test. These tests will take approximately 10 minutes to complete. Finally you will complete a computerised driving simulator task that will take approximately 20 minutes to complete. One blood sample will be taken before you begin any alcohol or marijuana consumption to be used as a baseline. And a final blood sample will be taken after you complete the SFST (before driving task). Only two blood samples in total will be taken in each session.

The administration of alcohol will be carried out using vodka and orange. Each glass of alcohol will contain 40ml vodka and 200ml orange juice. Placebo alcohol (no alcohol) will contain 240ml of orange juice.

The administration of THC will be carried out using cigarettes containing either 0%, 2.02% or 3.13% of THC.

Neither you or the experimenters will know the alcohol content or THC content to be administered to you at any particular session. On the sessions that you will receive alcohol and THC we advise you that the likely effects include: Drowsiness, euphoria, heightened sensory awareness, altered time perception, reddened conjunctiva (eyes), dry mouth and increased heart rate.

Each experimental (alcohol and THC administration) session will take approximately 2 hours to complete.

You must agree not to consume alcohol for at least 24 hours before each session and no other drugs for at least 7 days before each session. Cannabis combined with alcohol is known to influence driving ability, so taxi vouchers will be provided for those who cannot make alternative transport arrangements home from each session. In addition, you must agree not to drive or ride, operate any machinery, nor consume any alcohol or medication, for at least 24 hours after each experimental session.

You are welcome to discontinue participation in the experiment at any time. If you do decide to discontinue participation, you are still required to abide by the safety restrictions advising that you not drive for at least 24 hours after the administration of alcohol and THC, and that you do not consume additional alcohol, marijuana or any other medications for at least 24 hours after each session.

You will also be video taped while performing the SFST. This footage is likely be used in training sessions for the SFST to police officers and/or other professionals, only if you provide your consent (see attached SFST Footage Consent Form).

Results from this study will appear in publications. However, personal details will remain confidential at all times and individual participants will not be identified.

Any questions regarding the project *An evaluation of the Efficiency of Sobriety Testing in Detecting the Combination of Alcohol and THC* can be directed to Prof. Con Stough, Swinburne Centre for Neuropsychopharmacology, Swinburne University of Technology (ph: 9214 8167 email: cstough@swin.edu.au).

In the event of any complaint about the way you have been treated during the study, or a query that Prof. Stough has not been able to satisfy, please contact:

The Chair
Human Experimental Ethics Committee
Swinburne University of Technology
P.O. Box 218
HAWTHORN VIC 3122

Appendix B2

SWINBURNE UNIVERSITY OF TECHNOLOGY

INFORMED CONSENT FORM

AN EVALUATION OF THE EFFICIENCY OF SOBRIETY TESTING IN DETECTING THE COMBINATION OF ALCOHOL AND THC.

This is a joint project between Swinburne University and Victoria Police

Prof. Con Stough

Dr Katherine Papafotiou

Dr Pradeep Nathan

Swinburne Centre for Neuropsychopharmacology
Swinburne University of Technology

PARTICIPANT'S NAME:

SUBJECT CODE: ***CODE*** _____

I (the participant) have read and understood the information above. Any questions I have asked have been answered to my satisfaction.

I agree that in the experimental sessions I may be administered alcohol to which my blood alcohol concentration may reach either; 0.0%, 0.04% or 0.06% combined with the administration of a marijuana cigarette containing THC that may contain either; no THC, 2.02% of THC or 3.13% of THC.

I agree that for the sessions in which I may possibly be administered alcohol and/or THC, I will not drive or ride to or from the session. I agree that I will utilise the transport home provided for me by the researchers.

I agree that I should not consume alcohol for at least 24 hours or any medications or other drugs for at least 7 days before my sessions.

THC combined with alcohol is known to influence driving ability, therefore I agree to utilise the transport/taxi vouchers organised to go home.

I agree that I should not drive or ride, operate any machinery, nor consume alcohol or any medication for at least 24 hours after my sessions.

I agree that I will organise suitable transport or utilise the transport home provided for me by the researchers.

I agree to participate in this activity, realising that I can withdraw from the experiment at any time.

I agree that research data collected for the study may be published or provided to other researchers on the condition that my name is not used.

NAME OF PARTICIPANT _____

SIGNATURE _____DATE_____

NAME OF PRINCIPAL INVESTIGATOR/S _____

_____

SIGNATURE _____DATE_____

SIGNATURE_____DATE_____

Appendix B3

SWINBURNE UNIVERSITY OF TECHNOLOGY

SFST INFORMED CONSENT FORM

AN EVALUATION OF THE EFFICIENCY OF SOBRIETY TESTING IN DETECTING THE COMBINATION OF ALCOHOL AND THC.

This is a joint project between Swinburne University and Victoria Police

Prof. Con Stough

Dr Katherine Papafotiou

Dr Pradeep Nathan

Swinburne Centre for Neuropsychopharmacology
Swinburne University of Technology

PARTICIPANT'S NAME:

SUBJECT CODE: ***CODE*** _____

Part of our research on the efficiency of the Standardised Field Sobriety Test (SFSTs) involves the videotaping of participants while they perform the SFST. This video footage is likely be shown in training sessions on the SFST to Police Officers and other professionals.

I (the participant) have read and understood the information above. Any questions I have asked have been answered to my satisfaction.

I (the participant) have seen/reviewed the footage of myself (the participant) and agree to allow the video footage of myself (the participant) to be shown to Police officers and other professionals in training sessions for the SFST.

NAME OF PARTICIPANT _____

SIGNATURE _____DATE_____

NAME OF PRINCIPAL INVESTIGATOR/_____

_____

SIGNATURE _____DATE_____

SIGNATURE _____DATE_____

Appendix C

Demographics Questionnaire

Name:_____ Subject Code: _____

Age: _____

Sex: _____

Marital Status: _____

Education Level: **(e.g. Year 12/B.App.Sc./etc.)**

_____

Do you currently have any physical or mental illness? **(if so, what?)** (includes the flu, substance abuse, depression, etc.)

_____

_____

_____

Have you had any physical or mental illness in the past? **(if so, what?)** (includes the flu, substance abuse, depression, etc.)

_____

_____

_____

Appendix D

Frequency of Cannabis Use Questionnaire

The results from this questionnaire will help the researchers decide whether you will be an appropriate participant for this study. Any exclusion from the study will be for your own safety.

Have you ever consumed cannabis?

☐ No ☐ Yes

When was the last time you consumed cannabis? (e.g. 10 days/last month/etc.)

_____

How often do you consume cannabis?

☐ Once a day

☐ Once a week

☐ Once a month

☐ Once every two months

☐ Rarely

How do you consume cannabis?

☐ Smoked in a cigarette/joint

☐ Smoked using a pipe/bong

☐ Orally/eaten

When you consume cannabis, how much do you have? (e.g. two cigarettes/one pipe/etc.)

_____

What are the general effects of cannabis on you? _____

_____

_____

_____

Appendix E

Standardised Field Sobriety Tests results for the low alcohol (0.03%) and high alcohol (0.05%) groups separately

Cannabis and low alcohol (0.03% BAC)

Horizontal Gaze Nystagmus: Lack of Smooth Pursuit (LSP)

There was a significant difference in the percentage of participants who displayed the error LSP across the six drug conditions (Cochran Q = 35.93, df = 5, $p < 0.001$).

Figure 1A: Percentage of participants in each of the six drug conditions that had the Horizontal Gaze Nystagmus LSP sign present for the low dose alcohol group

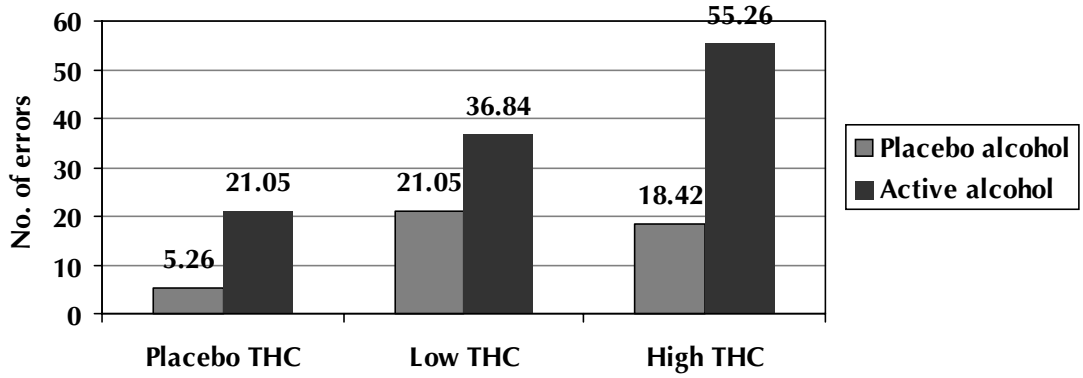


Figure 1A displays that the LSP sign was present more often in the alcohol condition than in the placebo condition. In the alcohol condition, LSP was present more often in the low and high THC conditions than in the placebo THC conditions.

Horizontal Gaze Nystagmus: Nystagmus at Maximum Deviation (NMax)

There was a significant difference in the percentage of participants with the error NMax across the six drug conditions (Cochran Q = 42.24, df = 5, $p < 0.001$).

Figure 2A: Percentage of participants in the low alcohol group across the six drug conditions that had the Horizontal Gaze Nystagmus sign, NMax, present in their SFST

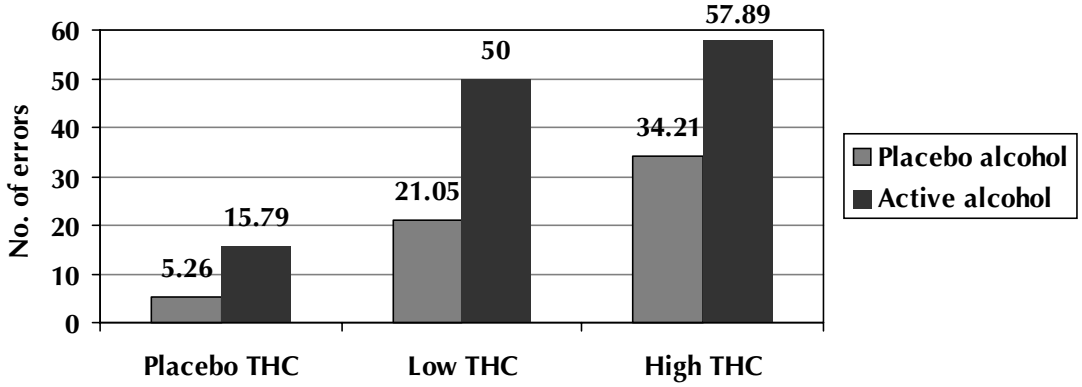


Figure 2A displays that the NMax sign was present more often in the alcohol condition than in the placebo condition. Furthermore, the NMax sign was present more frequently in the low and high THC conditions than in the placebo THC conditions.

Horizontal Gaze Nystagmus: Nystagmus at 45 degrees (N45)

There was a trend towards a significant difference in the percentage of participants that displayed the error N45 across the six drug conditions (Cochran Q = 12.38, df = 5, $p < 0.05$).

Figure 3A: Percentage of participants in the low alcohol group who had the Horizontal Gaze Nystagmus N45 sign present across the different drug conditions

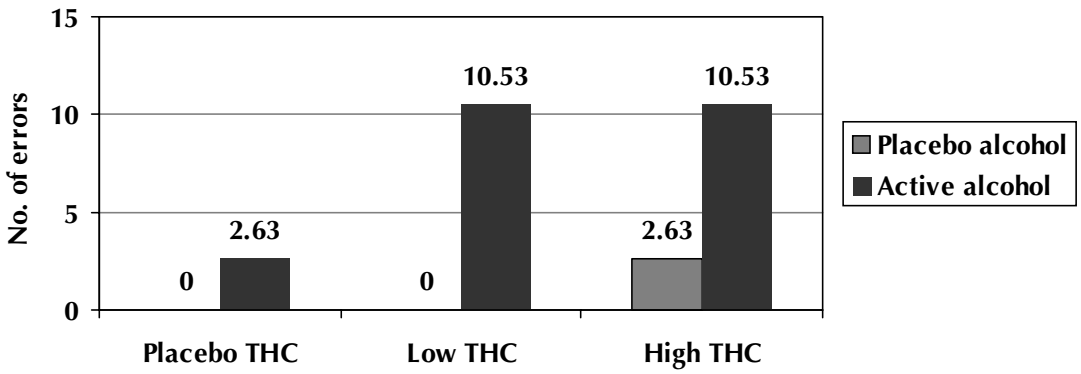


Figure 3A reports that N45 was present more often in the alcohol condition than in the placebo condition. In the alcohol conditions, N45 was present more frequently in the low and high THC conditions than in the placebo condition.

Horizontal Gaze Nystagmus: Head Movements/Jerks (HMJ)

There was a significant difference in the percentage of participants who displayed the error HMJ across the six drug conditions (Cochran Q = 16.88, df = 5, $p < 0.01$).

Figure 4A: Percentage of participants in the low alcohol group who had the Horizontal Gaze Nystagmus HMJ sign present across the six drug conditions

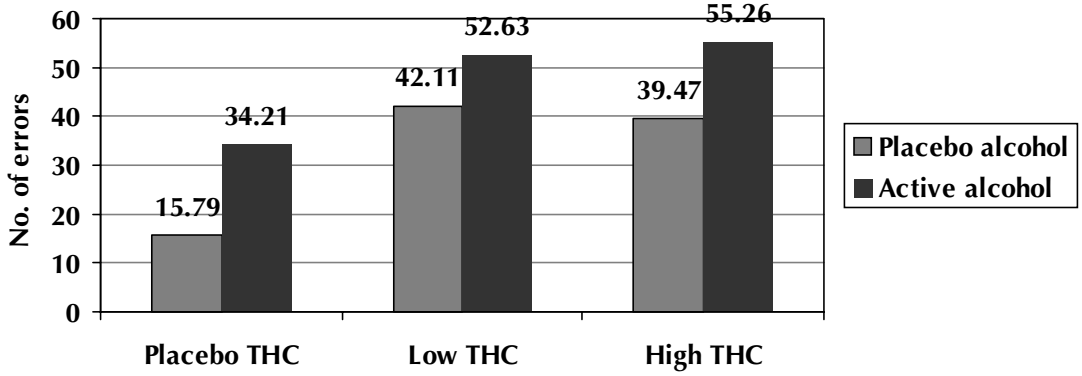


Figure 4A displays that the HMJ error was present more often in the active alcohol condition than in the placebo alcohol condition. HMJ was present more frequently in the low and high THC conditions than in the placebo THC conditions.

Overall Horizontal Gaze Nystagmus: Overall HGN

There was a significant difference in the percentage of participants who displayed impairment during the administration of the HGN test (Cochran Q = 39.39, df = 5, $p < 0.001$).

Figure 5A: Percentage of participants in the low alcohol condition who exhibited impairment on the Horizontal Gaze Nystagmus test overall

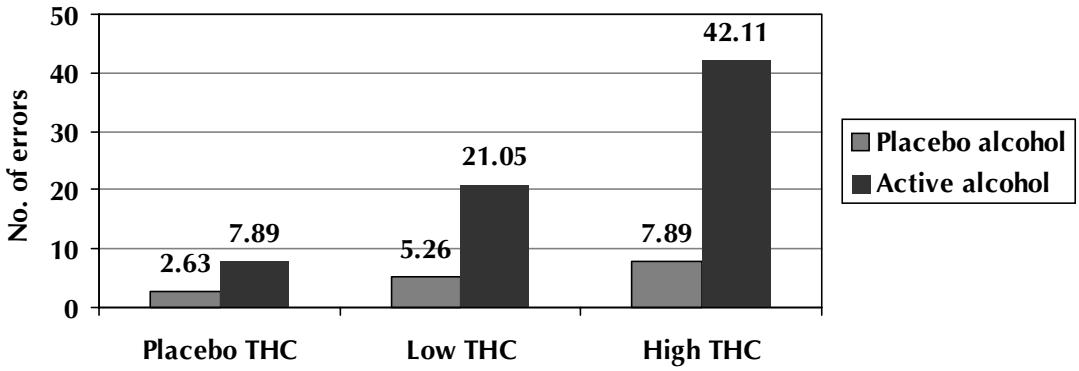


Figure 5A displays that impairment on the HGN test was present more often in the active alcohol conditions than in the placebo alcohol conditions. For the active alcohol conditions, impairment on the HGN test was present more frequently in the high THC condition than in the low THC condition. Furthermore, impairment was present more often in the low THC conditions than in the placebo THC conditions.

Horizontal Gaze Nystagmus Test including HMJ: Overall HGNHMJ

There was a significant difference in the percentage of participants displaying impairment during the HGN test including HMJ across the six drug conditions (Cochran Q = 47.13, df = 5, $p < 0.001$).

Figure 6A: Percentage of participants in the low alcohol group who were impaired on the Horizontal Gaze Nystagmus when HMJ was included

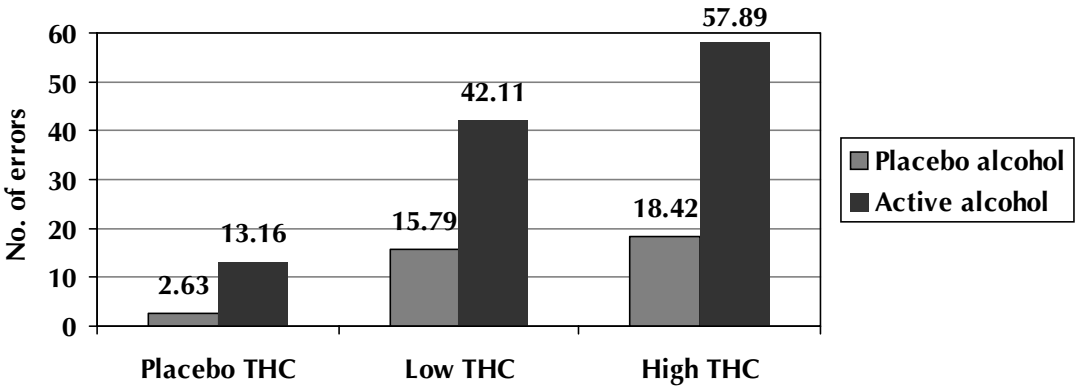


Figure 6A displays that presence of impairment on HGNHMJ occurred more often in the active alcohol condition than in the placebo alcohol condition. Impairment on HGNHMJ was present more frequently in the high and low THC condition than in the placebo THC condition.

One Leg Stand (OLS): Sways

There was a significant difference between the six drug conditions for the percentage of participants who swayed while performing the one leg stand (Cochran Q = 12.22, df = 5, $p < 0.05$).

Figure 7A: Percentage of participants in the low alcohol group across the six drug conditions who swayed during the One Leg Stand test

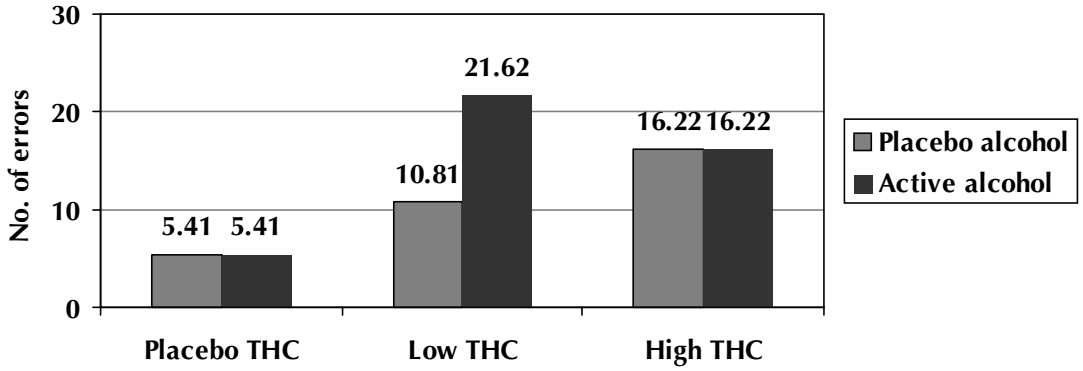
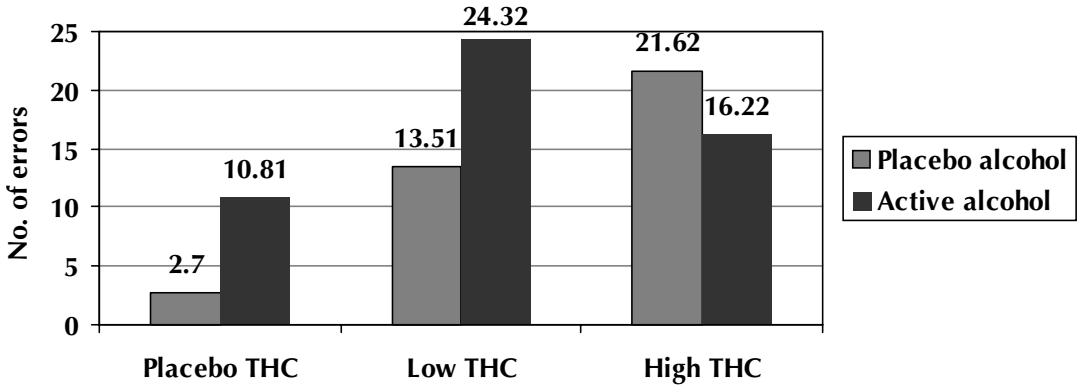


Figure 7A displays that the there were more errors in the active alcohol with low THC condition than in the placebo alcohol with low THC conditions. There were more errors in the low and high THC conditions than in the placebo THC conditions.

One Leg Stand: Foot Down

There was a significant difference in the percentage of participants who put their foot down during the one leg stand across the six drug conditions (Cochran Q = 12.84, df = 5, $p < 0.05$).

Figure 8A: Percentage of participants in the low alcohol group who displayed the error foot down on the One Leg Stand test across the six conditions

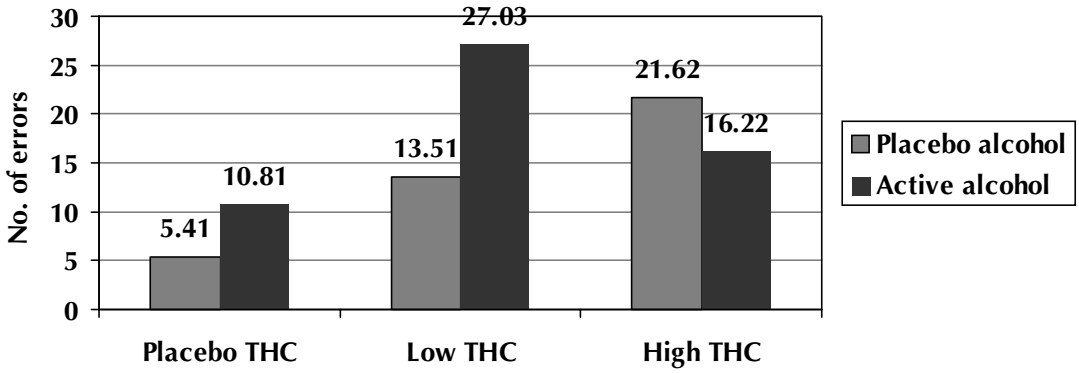


There were more errors in the active alcohol conditions than in the placebo conditions. Furthermore, participants put their foot down more in the low and high THC conditions than the placebo THC conditions (Figure 8A).

Overall One Leg Stand

There was a significant difference between the six conditions for impairment on the OLS overall in the low alcohol group (Cochran Q = 12.63, df = 5, $p < 0.05$).

Figure 8B: Percentage of participants who showed impairment on the OLS overall in the low alcohol group across each condition



Overall impairment on the OLS was observed more frequently in the active alcohol conditions than the placebo alcohol conditions for the placebo and low THC conditions; however, the opposite was true for the high THC conditions (Figure 8B). More impairment was observed in the low and high THC conditions than in the placebo THC conditions.

Overall SFST

There was a significant difference in the percentage of participants who were impaired on the SFSTs across the six drug conditions (Cochran Q = 12.22, df = 5, $p < 0.05$).

Figure 9A: Percentage of participants in the low alcohol group who were impaired overall on the SFST across the six conditions

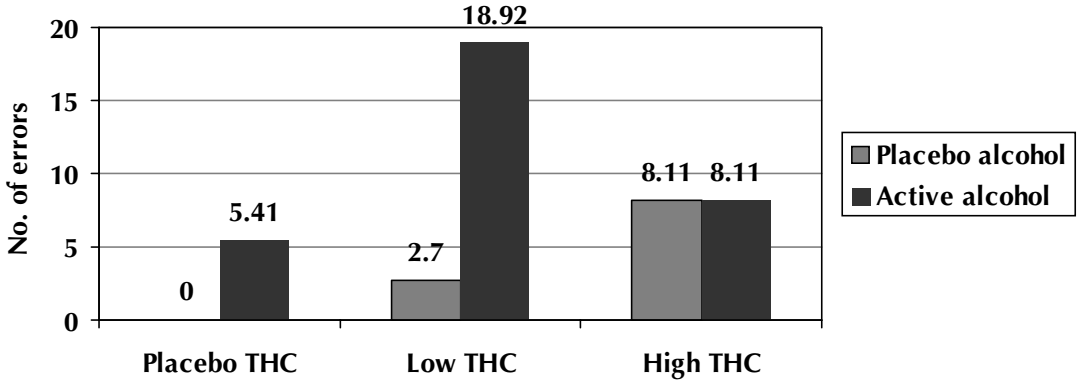


Figure 9A displays that impairment on the SFSTs was observed most often in the active alcohol plus low THC condition than all other conditions. Impairment was observed more frequently in active alcohol conditions than in the placebo alcohol conditions across the placebo and low THC conditions.

Overall SFST including HMJ (SFSTHMJ)

There was a significant difference in the percentage of participants who displayed impairment on the SFSTHMJ across the six drug conditions (Cochran Q = 16.91, df = 5, $p < 0.01$).

Figure 10A: Percentage of participants in the low alcohol group who displayed impairment on the SFST when the sign HMJ was included for the six conditions

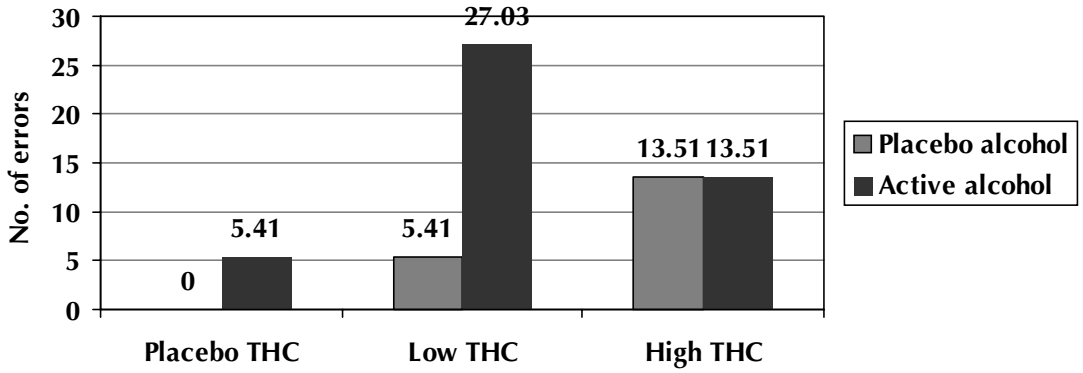


Figure 10A displays that impairment on SFSTHMJ was present in the active alcohol conditions more often than in the placebo alcohol conditions. Impairment was observed more often in the high THC and low THC conditions than in the placebo THC conditions.

Cannabis and the High Alcohol (0.05% BAC)

Horizontal Gaze Nystagmus: Lack of Smooth Pursuit (LSP)

There was a significant difference in the percentage of participants that displayed the error LSP across the six drug conditions (Cochran Q = 59.92, df = 5, $p < 0.001$).

Figure 11A: Percentage of participants in the high alcohol group who displayed LSP on the Horizontal Gaze Nystagmus across the six drug conditions

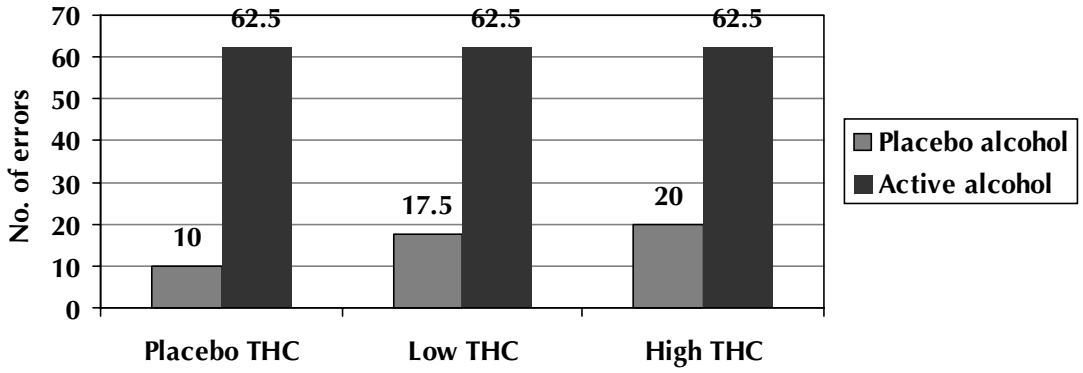


Figure 11A displays that the error LSP was present more often in the alcohol condition than in the placebo condition. In the placebo THC conditions, LSP was present more frequently in the low and high THC conditions than in the placebo condition.

Horizontal Gaze Nystagmus: Nystagmus at Maximum Deviation (NMax)

There was a significant difference in the percentage of participants who displayed the sign NMax across the six drug conditions (Cochran Q = 55.54, df = 5, p < 0.001).

Figure 12A: Percentage of participants in the high alcohol group who displayed the sign NMax on the Horizontal Gaze Nystagmus across the six conditions

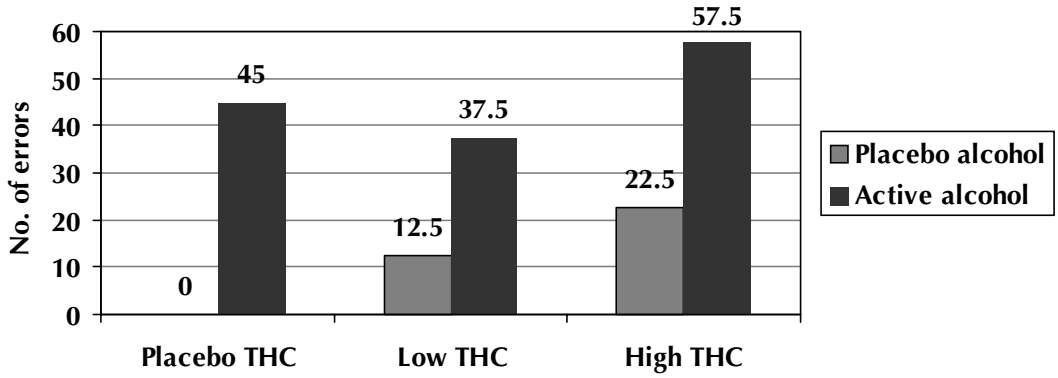
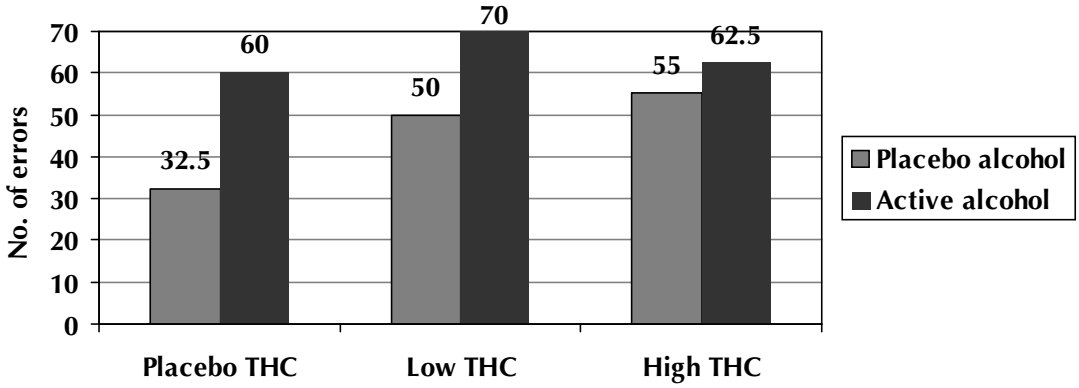


Figure 12A displays that the error NMax sign was present in the active alcohol condition more often than in the placebo alcohol condition. In the placebo alcohol conditions, the NMax sign was present more frequently in the high and low THC conditions than the placebo THC condition.

Horizontal Gaze Nystagmus: Head Movements/Jerks (HMJ)

There was a significant difference in the percentage of participants moving or jerking their head in the Horizontal Gaze Nystagmus test between the six conditions (Cochran Q = 22.09, df = 5, p < 0.001).

Figure 13A: Percentage of participants in the high alcohol group who displayed the sign HMJ across the six conditions



There was more head movements/jerks in the active alcohol conditions than in the placebo alcohol conditions (Figure 13A). HMJ was observed more in the low THC conditions than in the placebo THC conditions (Figure 13A).

Overall Horizontal Gaze Nystagmus (Overall HGN)

There was a significant difference in the percentage of participants that were impaired during the HGN overall across the six drug conditions (Cochran Q = 41.08, df = 5, $p < 0.001$).

Figure 14A: Percentage of participants in the high alcohol group who displayed overall impairment on the Horizontal Gaze Nystagmus test across the six conditions

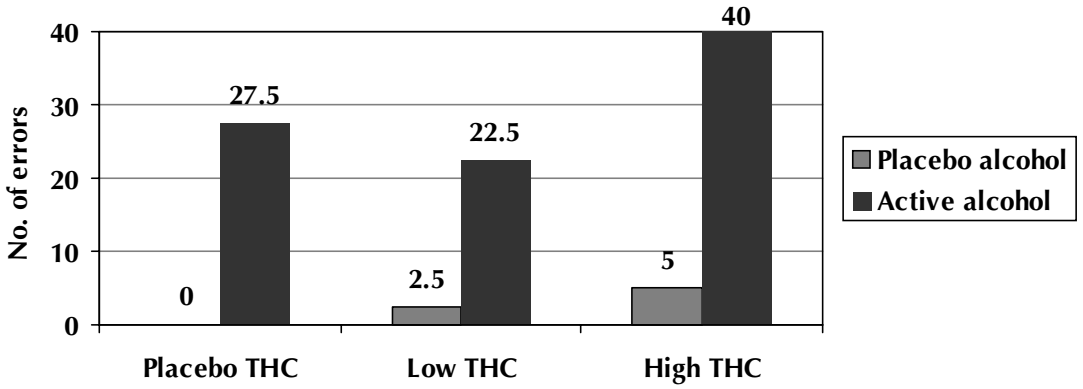


Figure 14A reports that impairment on the HGN test was present a more often in the alcohol condition than in the placebo condition.

Overall HGN including HMJ: (HGNHMJ)

There was a significant difference in the percentage of participants who displayed impairment on the HGN test including HMJ across the six drug conditions (Cochran Q = 49.50, df = 5, $p < 0.001$).

Figure 15A: Percentage of participants in the high alcohol group who displayed impairment on the Horizontal Gaze Nystagmus when the sign HMJ was included, across the six drug conditions

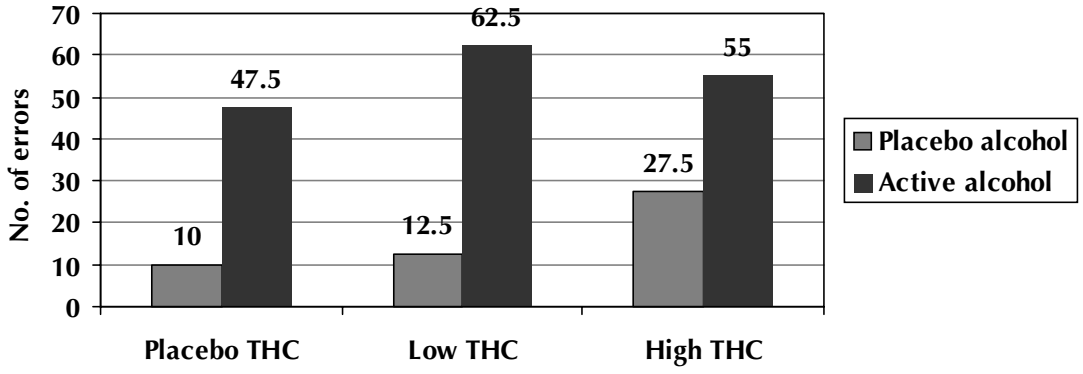


Figure 15A reports that impairment on the HGNHMJ was observed more often in the alcohol condition than in the placebo condition. Impairment was observed more frequently in the high THC condition than in the placebo and low THC condition.

Walk and Turn: Steps off Line (SOL)

There was a significant difference in the percentage of participants who displayed the error SOL across the six drug conditions (Cochran Q = 12.62, df = 5, $p < 0.05$).

Figure 16A: Percentage of participants in the high alcohol group who stepped off the line on the Walk and Turn test across the six conditions

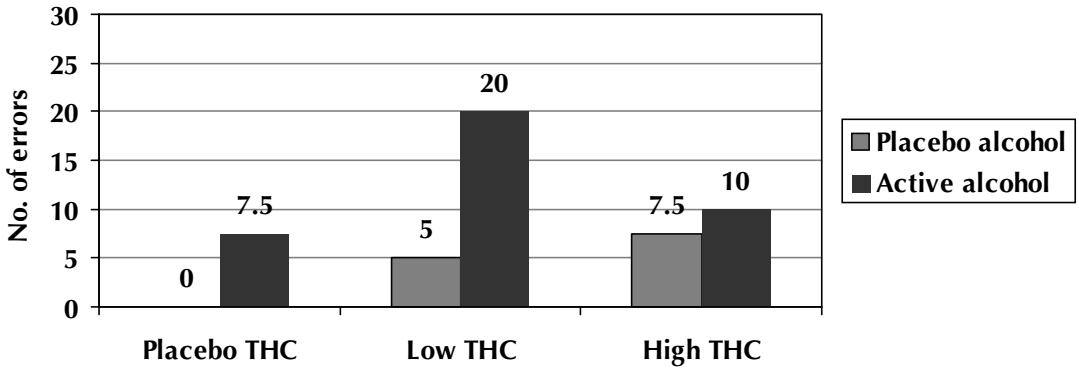


Figure 16A reports that the error SOL was present more often in the alcohol condition than in the placebo condition. Furthermore the SOL sign was present slightly more frequently in the low and high THC conditions than in the placebo THC condition.

One Leg Stand: Arms to Balance (AB)

There was a significant difference in the percentage of participants who displayed the error AB across the six drug conditions (Cochran Q = 13.64, df = 5, $p < 0.05$).

Figure 17A: Percentage of participants in the high alcohol group who used their arms to balance during the One Leg Stand test across the six drug conditions

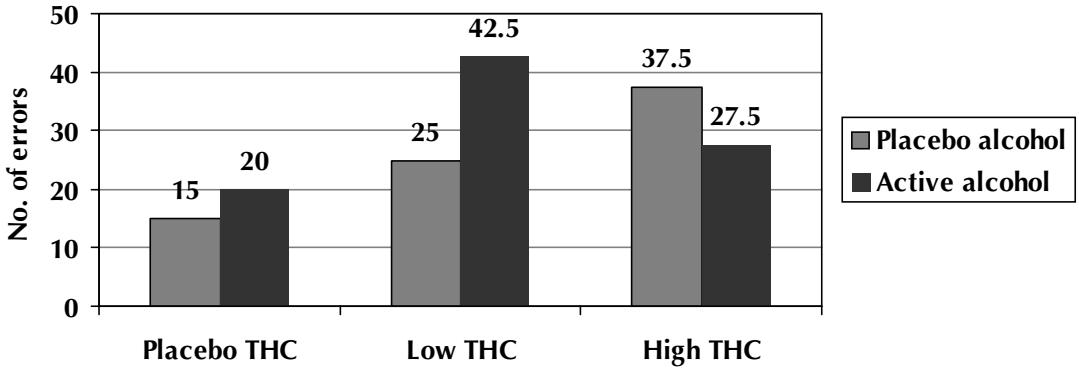


Figure17A displays that the participants used their arms to balance more often in the high and low THC condition than in the placebo condition. It is of interest that the highest frequency of this sign was in two conditions: the low THC with active alcohol condition and the high THC only condition.

One Leg Stand: Foot Down (FD)

There was a significant difference in the percentage of participants that displayed the error FD across the six drug conditions (Cochran Q = 20.00, df = 5, $p < 0.01$).

Figure 18A: Percentage of participants in the high alcohol group who put their foot down during the One Leg Stand test across the six drug conditions

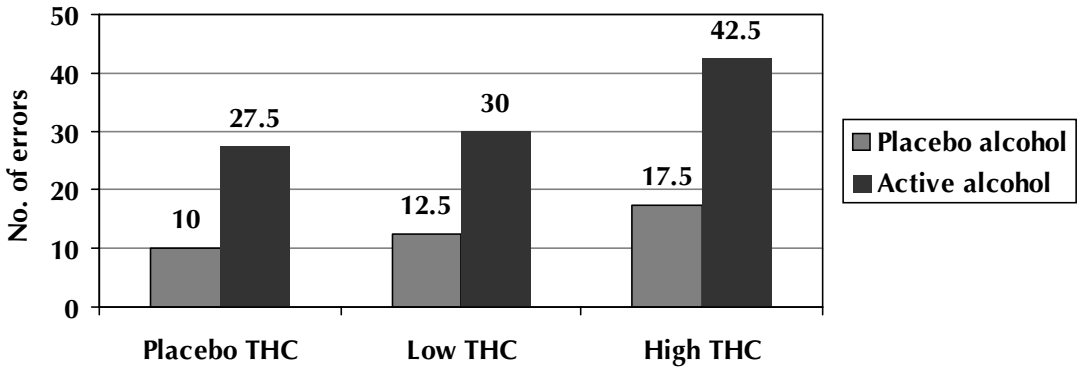


Figure 18A reports that the error foot down was observed most often in the alcohol condition than the placebo condition. Foot down was observed more often in the high THC condition than the low THC or placebo THC conditions. Furthermore, the highest percentage of participants who put their foot down were in the high THC with active alcohol condition.

Overall OLS

There was a significant difference in the percentage of participants who displayed impairment on the One Leg Stand test across the six drug conditions (Cochran Q = 11.53, df = 5, $p < 0.05$).

Figure 19A: Percentage of participants in the high alcohol group who displayed overall impairment on the One Leg Stand test across the six drug conditions

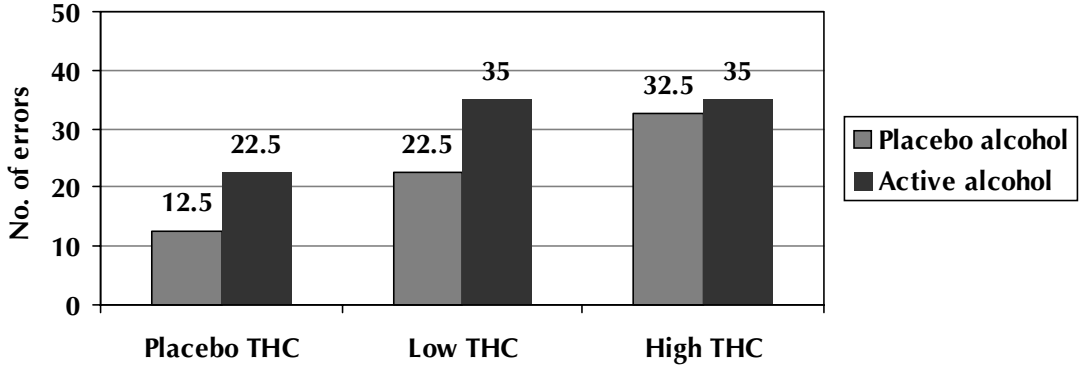
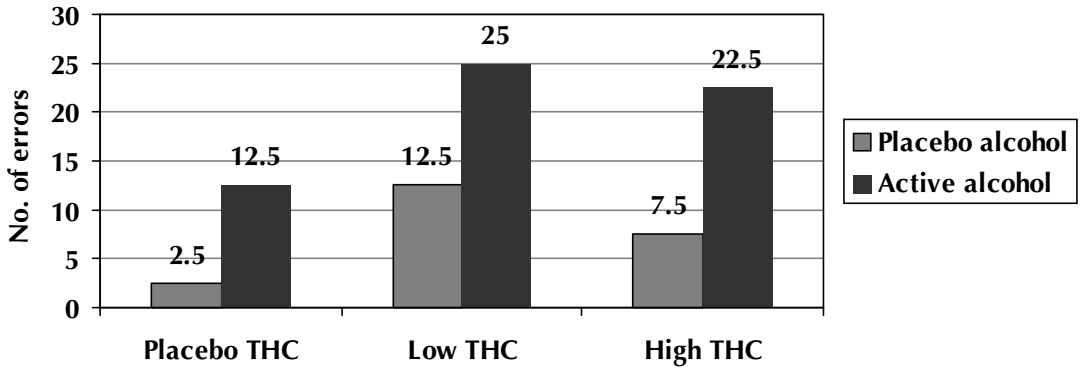


Figure 19A displays that there was more overall impairment on the OLS in the active alcohol conditions than in the placebo alcohol conditions. Impairment on the OLS was observed more frequently in the high and low THC conditions than in the placebo THC conditions.

Overall SFST

There was a significant difference in the percentage of participants who displayed overall impairment on the SFST in the high alcohol group between the six drug conditions (Cochran Q = 15.00, df = 5, $p < 0.05$).

Figure 20A: Percentage of participants in the high alcohol group who displayed impairment on the SFST overall, across the six drug conditions



Overall SFST including HMJ: SFSTHMJ

There was a significant difference in the percentage of participants that displayed impairment on the SFST including HMJ across the six drug conditions (Cochran Q = 26.10, df = 5, $p < 0.001$).

Figure 21A: Percentage of participants in the high alcohol group who displayed overall impairment on the SFST including HMJ across the six drug conditions

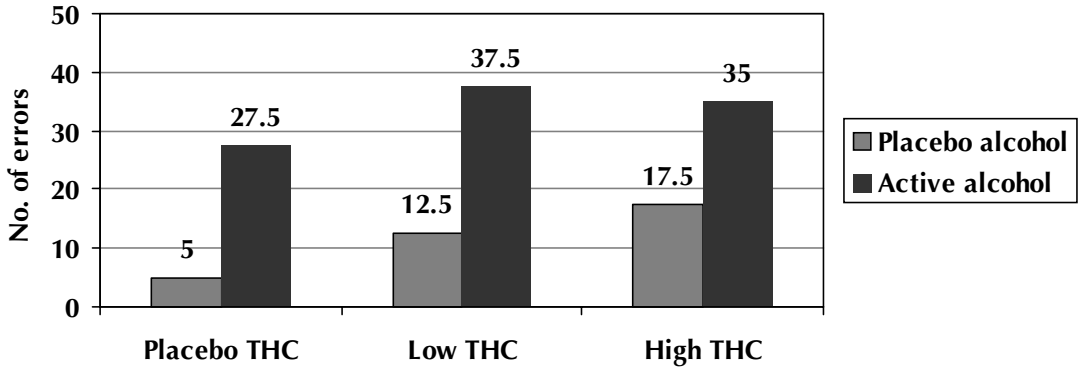


Figure 21A reports that impairment on SFSTHMJ was present more often in the alcohol condition than in the placebo condition. Impairment on SFSTHMJ was observed more often in the high THC and low THC condition than in the placebo condition.