An Evaluation of the Efficiency of Sobriety Testing to Detect Blood Levels of Cannabis and Impaired Driving Ability

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Declaration

I declare that this thesis does not incorporate without written acknowledgement any material previously submitted for a degree in any University, College or Advanced Education, or other educational institution; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

I further declare that the ethical principles and procedures specified in the Swinburne University of Technology Human Research Ethics' document on human research and experimentation have been adhered to in the presentation of this thesis.

Name: Katherine Papafotiou

Signed:

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List of Abbreviations

SFSTs	Standardised Field Sobriety Tests
HGN	Horizontal Gaze Nystagmus
W AT	Walk and Turn
OLS	One Leg Stand
RB	Romberg Balance
FTN	Finger to Nose
LSP	Lack of Smooth Pursuit of the Eyes
NMax	Nystagmus at Maximum Deviation
N45	Nystagmus at 45 degrees
VGN	Vertical Gaze Nystagmus
BS	Body Swaying
HM	Head Movements
HJ	Head Jerks
HMJ	Head Moves and/or Jerks
NB	No Balance During the Instruction Stage
STS	Starts Too Soon
SW	Stops Walking During the Test
MHT	Misses Heel to Toe While Walking the Straight Line
SOL	Steps Off the Line
AB	Arms Used to Maintain Balance
IT	Improper Turn
S	Swaying
H	Hopping
FD	Foot Down
FNT	Feet Not Together
ANBS	Arms Not By Side
HNT	Head Not Tilted as Demonstrated
EO	Eyes Open
ANE	Arms Not Fully Extended
ANSH	Arms Not Shoulder Height
IFN	Index Finger Not Pointed

ANR Arms Not Returned to Original Position

MTN Misses Tip of Nose

Abstract

Road fatalities related to marijuana intoxication have steadily increased over the last 10 years (Drummer, 1994; Drummer, 1998; Drummer & Gerostamoulos, 1999). This has led to the introduction of sobriety testing in Victoria, Australia to test for driving impairment caused by marijuana and other psychotropic drugs. Surveys have reported an increase in community concern in Australia over the use of marijuana and an increase in the prevalence and use of marijuana (National Campaign Against Drug Abuse Survey; 1985, 1988, 1991, 1993; National Drug Household Survey; 1995, 1998). Commensurate with the increase in the use of marijuana in society, road statistics indicated that the number of road accidents and deaths involving the presence of THC (the active ingredient in marijuana) in driver specimens has also increased (Drummer & Gerostamoulos, 1999). Consistent with these mortality statistics, past research examining the effects of THC on driving ability indicate that THC impairs both car control (Moskowitz, 1985), and the maintenance of the lateral position of a vehicle (Ramaekers et al., 2000). Intoxication by THC is more likely to result in the crashing into obstacles on a driving course than when not intoxicated (Hansteen et al., 1976).

These findings indicate that marijuana impairs driving ability and since the prevalence of marijuana use is increasing this poses a significant risk on our roads. It is essential therefore, that a tool that detects levels of THC in drivers, similar to breath analysis instruments used for the detection of alcohol in drivers, is introduced. To date, there is no such reliable instrument, that could be used on the roadside, and that accurately measures the level of THC in humans. For this reason, some government departments have considered the use of sobriety tests to detect impaired driving. In particular, the Standardised Field Sobriety test (SFSTs) that comprises the Horizontal Gaze Nystagmus test (HGN), Walk and Turn test (WAT) and the One Leg Stand test (OLS) were implemented in Victoria, Australia from December 1st 2000. The validity of these tests have been previously examined by other researchers and their conclusions suggest that sobriety tests have a varied accuracy in detecting impairment caused by drugs, ranging from 44% to 94% (Heishman et al., 1996; Compton, 1986). The present study examines the efficiency of sobriety tests to detect impairment in driving caused by marijuana. The SFSTs were examined, as well as the Romberg Balance test (RB) and

the Finger to Nose test (FTN) taken from the Drug Evaluation and Classification Program (DECP) (Los Angeles Police Department, USA).

The present study was conducted by Swinburne University, Victoria, Australia. The National Institute on Drug Abuse in the USA (NIDA) provided the marijuana cigarettes. The major objectives of the study were to examine the influence of cannabis on driving performance and on performance on the sobriety tests. The relationship between simulated driving performance and sobriety test performance was then examined to establish the accuracy of sobriety tests to predict driving ability. The present study also examined whether any differences in performance either on the driving tests or on the sobriety tests exist between regular cannabis users and non-regular cannabis users. Driving stress was an additional variable assessed to establish whether individuals with low, normal or high driver stress perform differently on the driving task after the consumption of a low and high dose of cannabis.

We tested 40 participants comprising 14 females and 26 males. All participants completed a medical examination questionnaire, demographics questionnaire, Frequency of Cannabis Use Questionnaire and Intoxication Rating Questionnaire. All participants completed 3 marijuana sessions involving the administration of a placebo cigarette (0% THC, weight 702mg, .000gm Δ-9-THC; 0.0mg/kg THC), the administration of a low THC cigarette (1.74% THC, weight 779mg, .813gm Δ-9-THC; 0.2mg/kg THC) and the administration of a high THC marijuana cigarette (2.93% THC, weight 790mg, 1.776gm Δ-9-THC; 0.73mg/kg THC). All sessions were randomised (using Latin-square design), counter-balanced and double-blind. In each session, participants completed 3 sobriety tests and 2 driving simulator tests. Sobriety tests were scored by allocating a score of 1 for each sign (error, e.g., hopping during test performance to maintain balance) observed by the administrator. Generally, a score of 2 or more constituted impairment to a degree equivalent to a blood alcohol concentration (BAC) above 0.10%. The driving simulator test comprised 36 variables. Each time the participant performed an error, a loading factor was added to the corresponding variable (e.g., collision (variable) loading factor is 10, if a collision occurred twice a score of 20 was allocated to this variable). The sum of all 36 variables constituted the level of overall driving impairment. Blood samples were taken throughout each session approximately 20 minutes apart.

Intoxication Rating Questionnaires revealed that participants reported that the subjective effect of placebo cigarettes was much weaker than the cigarettes that they usually smoke and that no psychological (such as time distortion) and physiological (such as increased heart rate) changes were experienced. For the low THC cigarettes most participants described the strength, and the effects, as similar to cannabis that they usually smoke. The high THC cigarette was described by most participants as being much stronger, and having some different symptoms, when compared to cannabis that they usually smoked. There were however, some differences in the description of the low THC and the high THC cannabis cigarettes between regular and non-regular cannabis users. Regular users reported that the high THC cigarette was more similar to the cannabis that they usually smoke, whereas non-regular users stated that this was more likely to be the case for the low THC cigarette.

Results from the driving simulator task revealed that THC impaired the driving variables: 'straddling the solid line' and 'straddling the barrier line'. The results indicated that increasing levels of THC increasingly impaired the ability to maintain the steady position of a vehicle within the correct traffic lane. The consumption of low and high doses of THC resulted in two or more wheels of the vehicle moving over a solid line marked out for traffic moving in the opposite direction. Low and high doses of THC also resulted in two or more wheels of the vehicle moving over a broken/barrier line marked out for traffic moving in the same direction. Increasing levels of THC appear to impair both balance and attention required to control the position of a vehicle in traffic. These results are consistent with past research that indicates that THC impairs car control (Moskowitz, 1985) and increases the standard deviation of the lateral position of a vehicle (Smiley et al., 1981; Ramaekers et al., 2000). Research into the effects of THC on brain cannabinoid receptors indicate that THC interferes with normal functioning of the cerebellum, the brain region responsible for balance, posture, and the coordination of movement (Childers & Breivogel, 1998). When driving ability was impaired the level of THC in the blood was between 3 and 5 ng/ml. These findings are consistent with previous research that has reported that driving is maximally impaired by THC plasma levels of 13 ng/ml (approximately 8ng/ml in blood, using a multiplication factor of 1.6 (Giroud, et al., 2001) (Berghaus et al., 1995).

The results of the present study also indicated that THC impairs performance on sobriety tests with more individuals impaired with increasing levels of THC (e.g., at Time 1; placebo: 2.5%, low THC: 23.1%, and high THC: 46.2%). Performances on the sobriety tests RB and FTN were unrelated to the level of THC. The test most related to the level of THC was the OLS test, where almost all signs of this test were observed, after the consumption of both low and high THC cigarettes. The accuracy of a 'new' sign in the scoring procedure of the HGN test: head moves/jerks (HMJ) was also identified. Including HMJ increased the percentage of individuals scored as impaired after the consumption of low and high THC cigarettes (e.g., at Time 1; placebo: 2.5%, low THC: 38.5% and high THC: 56.4%). Including HMJ as a sign significantly improved the accuracy of the SFSTs to detect impairment associated with the level of THC. The mean level of THC in the blood, when the highest number of participants were classified as impaired, was 70 ng/ml.

Differences in performance were observed between regular cannabis users and non-regular cannabis users. Non-regular cannabis users were more impaired on the driving simulator task after the consumption of low and high levels of THC when compared to regular users. Non-regular users recorded significantly longer RTs to emergency situations, more collisions, and shorter distances between the vehicle and an object (after an emergency stop) when compared to regular cannabis users. Signs exhibited during sobriety test performance were related to the level of THC more often for non-regular users compared to regular users. The level of THC in the blood was higher in regular users, compared to non-regular users, at all times in both THC conditions.

When driving ability was impaired and significantly related to the level of THC, the SFSTs were also related to level of THC. Sobriety test performance was related to driving impairment, because, as driving impairment increased with the level of THC, so did the number of signs present during the performance of the sobriety tests. Since non-regular users performed more poorly on the driving task compared to regular users, it is no surprise that they exhibited a larger number of signs during the sobriety testing.

Although there was a positive linear relationship between driving ability and sobriety tests, such as the relationship between straddling barrier lines and the OLS test, the validity of sobriety tests to predict driving impairment in part depends upon the size of

this relationship. Using performance on the SFSTs to assess "impairment", 46.7% of individuals in the high THC condition were impaired. A discriminant analysis was performed to determine whether the remaining 53.3% of participants were also impaired but not classified as impaired, or whether the SFSTs correctly classified them as not impaired. The results indicated that the sobriety tests (SFSTs; HGN, WAT and OLS) correctly assessed 76.3% of participants in the high THC condition as either impaired on driving or not impaired on driving. Specifically, this percentage included the correct identification of 84% of impaired drivers as impaired, but only 61.5% of unimpaired drivers as unimpaired. The best predictor of driving impairment was the OLS test. In the low THC condition the sobriety tests correctly classified 100% of impaired drivers as impaired, but this occurred at the expense of falsely classifying most unimpaired drivers as also impaired. This finding suggests that sobriety tests detect the presence of THC even when driving is not impaired.

Examining the utility of including the 'new' sign HMJ in the SFSTs indicated that when identifying impairment on the driving task performed at Time 2, in both the low and high THC condition, the SFSTs were a better predictor of driving impairment when HMJ was included than when the sign was not included. This finding suggests that the inclusion of HMJ in SFSTs scoring procedure increases the likelihood of detecting drivers who are impaired by THC.

In conclusion, the results suggest that THC impairs driving ability by reducing one's ability to maintain a safe position in traffic. At this time THC blood levels are between 3 and 5 ng/ml. THC also impairs driving ability differently for non-regular and regular users of cannabis, where non-regular users are more impaired by THC than regular users. When this occurs, THC blood levels in non-regular users are between 2 and 12 ng/ml, and in regular users between 5 and 16 ng/ml. Performance on the sobriety tests is also impaired by increasing levels of THC. The OLS test is the most sensitive test in detecting the presence of THC. In the present study the SFST battery and each individual test that it comprises are moderate predictors of driving impairment but do misclassify 16% of impaired individuals and 38.5% of not impaired individuals. In addition, the results suggest that sobriety tests are more sensitive to the presence of THC than actual driving impairment. This was revealed by the large number of individuals judged as impaired on driving in the low and high THC conditions even

when driving was unaffected. It is important to note that when this occurred, the sobriety tests were accurate in detecting 100% of impaired individuals. Finally, the introduction of the 'new' sign HMJ is likely to increase the accuracy of the SFSTs to detect individuals impaired by THC and this sign should be considered for inclusion by policing agencies.

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Chapter One: Introduction

This chapter outlines the main aims and hypotheses of the project. An overview of the method is also reported. A literature review of previous research in the area are discussed in later section of this thesis.

1.1 Project aims

The aim of the project was to examine the accuracy of sobriety tests to detect impairment caused by cannabis consumption. This was achieved by examining the;

- effects of cannabis consumption on sobriety test performance
- effects of cannabis consumption on driving ability
- relationship between sobriety test performance and driving performance
- differences between the effects of cannabis on performance between regular and non-regular cannabis users
- relationship between the level of THC (the active ingredient in cannabis) in blood and performance on sobriety tests and a driving task

1.2 Hypotheses

Based on previous research a number of hypotheses were generated regarding the relationship between cannabis consumption, driving ability and sobriety test performance.

1.2.1 Cannabis

It was predicted that cannabis would impair both driving ability and sobriety test performance. More specifically, as the level of THC consumed increased it was hypothesised that the degree of impairment in both driving and sobriety test performance would also increase.

1.2.2 Driving ability

It was predicted that driving ability would be impaired by the consumption of cannabis, so that as level of THC increased, the degree of driving impairment would also increase. More specifically, it was predicted that tracking ability, the distance between vehicles after stopping and reaction time would be linearly impaired by the level of cannabis consumption.

1.2.3 The sobriety test

It was predicted that performance on the sobriety tests would be impaired by cannabis consumption. Specifically it was hypothesised that as the level of THC consumed increased, the number of signs of impairment/intoxication (errors) observed during sobriety test performance would also increase. It was also predicted that impairment on the sobriety tests would positively correlate with impaired driving ability, with increasing errors on the sobriety tests associated with increasing errors on the driving task.

1.3 Overview of method

The project involved 40 participants. Participants were required to complete four stages. The first three stages involved the completion of a consent form, a medical examination, a demographics questionnaire and a Frequency of Cannabis Use questionnaire. Stage 4 consisted of 3 experimental sessions that involved the smoking of cannabis cigarettes containing either; no THC (placebo), 1.74% THC and 2.93% THC, and completing the Intoxication Rating questionnaire. The 3 sessions were randomised, double blind, counter-balanced and placebo controlled.

In the experimental sessions, after the administration of each THC condition, participants performed the tests comprising the SFSTs and two additional sobriety tests (taken from the Drug Evaluation and Classification Program (DECP)), and a driving simulator test. Blood samples were taken throughout each session. Performance on sobriety tests and the driving simulator task were correlated with the presence of THC in blood and frequency of cannabis use.

Chapter Two: Cannabis

This section explains what cannabis is and how it affects human performance.

2.1 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 1.

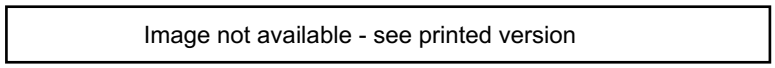


Figure 1 Chemical structure of Δ-9-tetrahydrocannabinol (THC) (Leonard, 1994).

Cannabis is usually available in 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).

2.2 Cannabis and levels of THC in blood

Unlike alcohol, which is distributed exclusively in body water, the components of marijuana are lipophilic (very soluble in fat) and have a higher volume of distribution. When marijuana 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 2a shows 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 blood 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 it's parent (THC) and therefore contributes to the total effect of marijuana. 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 2b represents the mean plasma concentrations of 11-OH-THC and THC-COOH compared to THC during and after smoking a marijuana cigarette containing 3.55% THC.

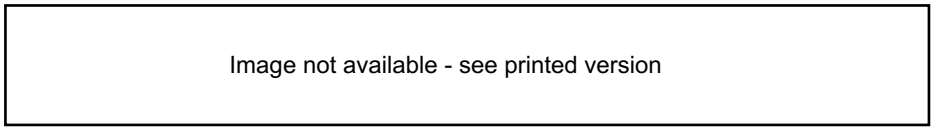


Figure 2a Mean THC concentrations during smoking of a single marijuana cigarette (Cone & Huestis, 1993).

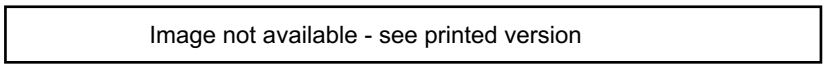


Figure 2b Mean plasma concentrations of 11-OH-THC and THC-COOH compared to THC during and after smoking a marijuana cigarette containing 3.55% THC (Cone & Huestis, 1993).

2.3 Cannabinoid receptors and how they work

The investigation of receptors in the animal brain for molecules of plant origin and existing endogenous ligands capable of binding to them, has led to the characterisation and subsequent cloning of the first cannabinoid receptor in the mammalian brain in 1990. Two years later the first endocannabinoid, anandamide was discovered, and then in 1993 the cloning of a second cannabinoid receptor. This section will discuss the history behind the discovery of cannabinoid receptors, and the pharmacological actions of cannabinoids, in particular the endogenous cannabinoid anandamide (Childers & Breivogel, 1998).

The existence of cannabinoid receptors was confirmed when Howlett (1984) discovered that cannabinoids decreased cAMP formulation in neuroblastoma cell cultures causing a blockage of Ca2+ mediation by a Gi/o-coupled receptor (DiMarzo & De Petrocellis, 1997) (see figure 3). Following this was the discovery of cannabinoid receptor binding, receptor localization, cloning and sequencing of the brain cannabinoid receptor CB1 and the discovery of CB1A (an alternative splice variant of CB1). The cloning of the peripheral cannabinoid receptor CB2 from the spleen later indicated that there are at least two major types of cannabinoid receptors (CB1 and CB2), where both are members of the seven transmembrane-domain, G-protein-coupled family of receptors, with 44% homology between the two (Childers & Breivogel, 1998).

Between the discovery of CB1 and CB2, the endogenous ligand of the CB1, anandamide, was identified. Anandamide was able to mimic the behavioural effects observed with THC suggesting it is an endogenous cannabinoid agonist (Felder & Glass, 1998). Anandamide also shared the same G-protein mediated actions on adenylate cyclase and Ca2+ channels as CB1. The only other metabolites characterised in the brain that have shown to behave as functional agonists of cannabinoid receptors have been polyunsaturated fatty acid derivatives, which have no higher efficacy than anandamide in assays of THC-like activity, and are referred to as endocannabinoids (Di Marzo et al., 1998).

From these discoveries, many studies have examined the signal transduction mechanisms of cannabinoid receptors in several cell types and in brain membranes. In general, cannabinoid receptor activation of G proteins influences multiple effector systems. The

proposed signal transduction mechanisms are described in Figure 3 below (Childers & Breivogel, 1998).

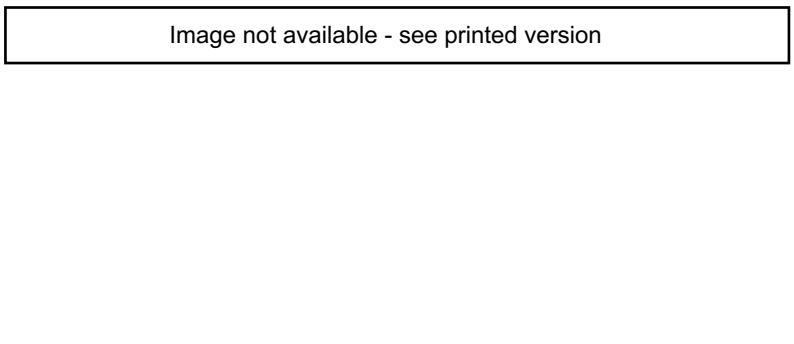


Figure 3 Transduction mechanisms of THC and cannabinoid receptors (Childers & Breivogel, 1998).

Figure 3 shows that after binding by agonist (top), CB1 activates G proteins (Giα, Goα and βγ), which in turn act upon various effectors including: adenylyl cyclase (AC), Ca 2+ and K+ channels, and mitogen-activated protein kinase (MAPK). Inhibition of AC and subsequent decreases in cAMP decreases activation of cAMP-dependant protein kinase (PKA), which leads to decreased phosphorylation of the K+ channels shown. Stimulatory effects are shown by open arrows, and inhibitory effects by filled arrows. The 'open' or 'closed' states of the channels and "X's" over the arrows reflect the final effect of the cannabinoid agonists (Childers & Breivogel, 1998).

2.4 Location of cannabinoid receptors

Most CB1 receptors are widespread throughout the brain. They exist in high amounts in the cerebral cortex, hippocampus, basal ganglia, and cerebellum (Shen et al., 1996). The location of CB1 receptors in these areas relates to the reported effects of cannabis in humans, such as memory deficits, impaired perception and impaired control of movements (Felder & Glass, 1998). CB1 receptors also exist to a lesser extent in the vas

deferens, adrenal glands, heart, lung, prostate, uterus, ovary, testis, bone marrow and thymus tonsils (Rhee, et al., 1997).

CB2 receptors are not generally found in the CNS, but rather are mostly found in the immune system (Rhee et al., 1997). Due to the high abundance of CB2 receptors in immune cells, it is likely that cannabinoids modulate immune function in health and/or disease (Pertwee, 1999).

2.5 General effects of cannabinoids in humans

Studies have revealed that low doses of cannabinoids increase motor activity, while high doses of cannabinoids inhibit motor activity and can produce catalepsy (Miller & Walker, 1996). Most effects on movement are inhibitory and have been attributed to the high density of cannabinoid receptors in the basal ganglia (Sanudo-Pena & Walker, 1997). In the substantia nigra, cannabinoids decrease transmission from the striatum and subthalamic nucleus, which in turn decreases the inhibitory and stimulatory inputs to the substantia nigra, providing dual regulation of movement (Childers & Breivogel, 1998). In addition, it has also been suggested that the globus pallidus of the basal ganglia is also associated with the motor effects of cannabinoids. Cannabinoids inhibitory effects on the activity of neurons in the globus pallidus can produce catalepsy in rats (Miller & Walker, 1996).

The effects of cannabinoids on memory have been attributed to the high density of cannabinoid receptors in the hippocampus, where endocannabinoids inhibit the release of the neurotransmitter acetylcholine. Cannabinoid receptors have been hypothesized to suppress hippocampal electrical activity resulting in memory "intrusions" (Herkenham, et al., 1990). It has also been suggested that memory deficits may be the result of increased dopamine levels after the administration of cannabinoids (Childers & Breivogel, 1998). Although it should be mentioned that cannabinoid receptors in the basal ganglia are not localized on dopamine neurons (Herkenham, et al., 1990).

Smoking a cigarette that contains about 2% THC can cause changes in motor coordination and memory, and in addition, cognition and sense of time (Leonard, 1994). Other psychological effects that have been reported are a sense of well-being, euphoria

and relaxation, and sleepiness. The effect on short-term memory and memory-dependant behaviours is referred to as "temporal disintegration". These effects are accompanied by confusion of the past, present, and future, as well as a feeling of depersonalisation. Cigarettes containing higher doses of THC can produce hallucinations, delusions and paranoia and intensify depersonalisation. Chronic cannabis users may exhibit "amotivational syndrome", where apathy, impaired judgment, memory deficits and loss of interest in "normal" social pursuits occurs (Leonard, 1994).

All these effects may contribute significantly in the execution of important everyday tasks such as driving a motor vehicle. Some studies have attempted to associate specific blood levels of THC with impaired performance on specific tasks. The presence of such research is crucial in terms of identifying safe levels of THC in the blood for situations involving the operation of machinery and also driving. However it is likely that the level of THC that causes impairment will vary considerably from individual to individual. Therefore the measurement of blood levels may be less important than tests of performance in determining drug related impairment.

2.6 Impairment and the level of THC in blood

As shown in Figure 2a, the concentration of cannabinoids in the blood peaks at 10 mins (to approximately 180ng/ml) and then drop rapidly (to approximately 20 ng/ml) over time (depending on smoking procedure). The rapid drop in levels occurs because the cannabinoids cross membranes and become stored in fatty tissue. Because of this, the level of THC in the blood may not be indicative of the dose of THC consumed or the amount THC stored in the body, therefore the level of THC in the blood may not be a reliable predictor of driving impairment. Repeat administration of marijuana can result in accumulation of inactive cannabinoids in fatty tissue and a high concentration of cannabinoids in the body may not necessarily indicate that an individual is impaired.

Some studies have concluded that there are causal relationships between the level of THC in the plasma and driving performance. Berghaus et al. (1995) reviewed several studies and concluded that although THC impairment is subtle (compared to impairment due to alcohol), some relationships between blood THC concentration and impairment exist. He reported that driving performance is maximally impaired by marijuana

smoking once THC plasma levels have dropped to 13 ng/ml. In addition marijuana impairs performance mostly between 40 minutes and 1 hour after smoking. These findings parallel those from kinetic research (Cone & Huestis, 1993). More specifically, impairment on several performance variables and the level of THC found in the blood has been described as; tracking- 6 ng/ml; psychomotor skills- 8 ng/ml; attention- 9ng/ml; divided attention- 11ng/ml; visual functions- 12ng/ml; simulator/driving- 13ng/ml; en/de-coding- 15 ng/ml; RT- 15 ng/ml; all performance measures- 11ng/ml (Berghaus et al, 1995). If research can determine at what level of blood THC there exists impairment in driving and impairment on sobriety tests, legislation may be able to be introduced in which there is a legal THC level, much like legislation defining and limiting legal levels of alcohol for traffic safety purposes.

In conclusion, it is likely that marijuana impairs actual driving ability. In order to provide evidence of this claim, data indicating the prevalence of road accidents and crashes associated with cannabis use, and previous research examining the effects of THC on actual driving ability, may clarify how cannabis impairs human performance. Chapter three presents the statistics on the prevalence of cannabis use and road accidents and crashes associated with cannabis use. Chapter Four presents the literature examining the effects of THC on driving ability.

Chapter Three: Statistics on Cannabis

This chapter highlights the patterns in community attitudes, drug prevalence, and drug-related road deaths, associated with marijuana consumption in Australia, and specifically in Victoria. This chapter outlines the importance of studying the effects of drugs such as marijuana, by demonstrating the serious concerns and prevalence of use in the community. The statistics identify the extent to which marijuana poses a problem amongst the community and in turn in road traffic accidents and deaths.

3.1 Community attitudes towards drugs in Australia

Changes in community attitudes towards drugs have been monitored using responses from household surveys throughout the states of Australia. The results of these surveys reflect the changes in attitudes towards drugs in the community from 1985 to 1998. The surveys are most commonly referred to as the National Campaign Against Drug Abuse surveys, or more recently, the National Drug Household Surveys. For the purpose of demonstrating trends and changes in attitudes towards and the prevalence of various drugs, the present chapter discusses the changes in community attitudes concerning alcohol, marijuana and heroin, as these are often the most popular drugs.

The surveys contain questions that assess the main drug-related concerns of the community. One question in the drug surveys asks, "When people talk about a 'drug problem' what drug do you think of?" In 1985, heroin was the first drug identified in 48.1% of the cases, marijuana was the first in 31.7% of the cases, and alcohol in only 5.0% of the cases. These figures changed dramatically over the years, especially with reference to heroin and alcohol. In 1988, the percentage of people indicating that heroin was their first choice dropped to 45.3%, marijuana dropped to 24.2%, and alcohol increased to 6.8% of cases. In 1991, heroin was the first drug regarded as being a "drug problem" in 37.3% of the cases, marijuana in 24.7% and alcohol in 10.6% of the cases. In 1993, heroin decreased again to 29.6% of cases, marijuana to 28.6%, and alcohol increased to 15.6%. In 1995, the trends appeared to be qualitatively different with respect to alcohol and marijuana. Heroin continued to drop to 28.3%, marijuana stabilised at 28% and alcohol dropped to 13.4%. Finally in 1998, heroin rose to 39%,

marijuana dropped to 20.9%, and alcohol remained unchanged at 12.3% (National Campaign Against Drug Abuse survey; 1985, 1988, 1991, 1993; National Drug Household Survey; 1995, 1998). These types of percentages indicate that through the years 1985 to 1998, community attitudes towards drugs have changed dramatically. With reference to the three drugs reported in this section, the majority of the community thought of heroin first when asked about a "drug problem", the next most popular response was marijuana, followed by alcohol. The data suggests that since community concern percentages are increasing, so should research into the effects of these drugs on performance. Research should demonstrate whether any potential health problems or performance decrements exist to justify opinions that each drug poses a problem.

Another important question in the drug surveys was: "Which drug do you think is the most serious concern for the general community?". In 1985, most people agreed that heroin was the most serious (65.3%), and then alcohol (46.9%) followed by marijuana (33.7%). The relationship in frequency of responses between these drugs remained the same through 1988 to 1991, but in 1993 and 1995, the percentages changed significantly, where alcohol became the drug thought of as most serious (1993; 33.4%, 1995; 30.5%), followed by heroin (1993; 8.7%, 1995; 9.9%) and then marijuana (1993; 3.8%, 1995; 3.9%). Finally in 1998, the most obvious change was the increase in the number of individuals that felt heroin was again becoming a serious concern; alcohol 27%, heroin 20.1% and marijuana 4.1% (National Campaign Against Drug Abuse survey; 1985, 1988, 1991, 1993; National Drug Household Survey; 1995, 1998).

The statistics show that heroin was always the first choice, as the drug considered a serious community concern, through years 1988 to 1991, but from 1993 to 1998, alcohol was the first. The interesting trend here is that even though alcohol was the drug considered a "drug problem" by the least percentage of individuals surveyed, it was alcohol that generated the most community concern. It is important to note that over the years, the percentage of individuals that consider either alcohol, marijuana or heroin to be a serious community concern has dropped drastically overall.

The surveys describe the extent of community concern over drugs, and it appears that drugs were not considered, in 1998, to be as problematic as they were previously in 1985. This change may have resulted from a change in drug prevalence over these

years. Since community concern has decreased over the years, it is expected that the prevalence of drugs, and the dangers associated with them (such as road accidents and deaths) would have also decreased over these years. The next two sections will examine if this is the case.

It should be noted that the number of people actually surveyed, the time of survey and the media coverage of drugs in the period preceding survey can significantly influence survey results. Early surveys were limited in number and were representative of those people who stay at home during mostly working days and have the time and inclination to participate in a survey. The relevance of this group to a "at risk" illicit drug using group is very questionable.

3.2 Drug prevalence in Australia

The prevalence of drugs in Australia has varied from 1985 to 1998. For the purposes of this report this section concentrates on the two most prevalent drugs in terms of consumption, alcohol and marijuana. The national household surveys have gathered data on personal contact with these drugs, as well as the extent of use of these drugs.

From 1985 to 1998, the number of individuals who were "offered" alcohol decreased. Percentages as high as 94.8% and 92.4% in years 1985 and 1988 respectively, dropped to 82.4% in 1998. For marijuana the same trend was observed, where percentages of 47.7% in 1985 dropped to 29.4% in 1998. With respect to having ever "tried" the drug, for alcohol the percentages remained relatively constant over the years, varying from 93.4% in 1985 to 93.7% in 1998. Marijuana use on the other hand increased steadily over the years from 31.6% in 1985 to 46.8% in 1998 (National Campaign Against Drug Abuse survey; 1985, 1988, 1991, 1993; National Drug Household Survey; 1995, 1998). These figures suggest that over these years, the number of individuals being offered drugs decreased, but the number of individuals who individually experimented with these drugs increased.

The extent of use of these drugs has also been documented. Over these years the pattern of alcohol consumption has remained relatively the same, with most of the individuals who had ever tried alcohol, reporting that they consume alcohol at least 2 to 3 days a

week (1988 18%; 1993 22.2%; 1998 16%). Most of the same individuals reported that the number of drinks on a "regular" drinking occasion is 1 to 2 drinks (1988 47.2%; 1993 57%; 1998 34%), with the most popular alcoholic beverage being bottled wine. With respect to individuals who had ever tried marijuana, the percentage of individuals who consumed marijuana in the last 12 months changed drastically. In 1988, 49.4% of those individuals had consumed cannabis in the last 12 months, and this figure dropped to 40.4% and 40.5% in 1993 and 1995 respectively and then drastically decreased to 22.7% in 1998. The number of individuals who consumed cannabis daily decreased from 7.8% in 1988 to 3% in 1998 (National Campaign Against Drug Abuse survey; 1985, 1988, 1991, 1993; National Drug Household Survey; 1995, 1998).

These statistics imply that alcohol use has remained relatively constant over the years, but the extent of use of marijuana has changed dramatically. Based on these statistics marijuana is becoming a more popular drug, although the number of individuals experimenting with marijuana has increased, these individuals do not necessarily become, or are, every day/regular users. This is an important aspect that is further discussed later in the thesis in the context of understanding differences in behaviour between regular and non-regular cannabis users. Accordingly, the increase in prevalence of cannabis use calls for an increase in education concerning the drug itself and it's effects on human performance. If the effects of these drugs on health and performance (such as driving) are detrimental to safety, then these statistics should raise serious concern and promote further research in the area.

3.3 Road statistics on drug related accidents and deaths in Victoria, Australia

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, 1994; Drummer, 1998; Drummer & Gerostamoulos, 1999).

The Transport Accident Commission (TAC) has reported the number of road deaths in Victoria from 1989 to 2000. Over the years the number of deaths on Victorian roads has decreased by almost half from 776 in 1989 to 391 in 1998 and to 407 in 2000 (TAC, 2000). The patterns of alcohol related deaths from 1990 to 1998 have been previously

reported by Drummer and Gerostamoulos (Drummer, 1994; Drummer, 1998; Drummer & Gerostamoulos, 1999). From 1990 to 1993, the percentage of drivers killed on Victorian roads with alcohol in their blood was 32%. This figure dropped to 26.6% from 1995 to 1996, and, to 25.8% from 1997 to 1998. From 1990 to 1993, 22% of drivers killed tested positive for drug use. The drugs identified were: cannabis (9.6% of cases); benzodiazapines (4.5% of cases), amphetamines and other stimulants (3.9% of cases) and opioids (3.3% of cases). In 1995 to 1996 the percentage of drug related deaths increased to 27.6%, where in 12.2% of cases cannabis was involved, 4.4% benzodiazapines, 4.4% amphetamines and other stimulants, and 4.4% opioids. Finally, the most recent report for 1997 to 1998, shows that a high 32.1% of drug related deaths involved primarily cannabis (16.5% of cases) and also benzodiazapines (4.8%), amphetamines and other stimulants (3.0%), and opioids (4.8%). The most obvious trend is that the number of cases involving cannabis has increased, while in comparison, the number of cases involving other drugs has remained relatively constant, and the number involving alcohol has decreased.

It is important to highlight here that the percentages on the incidence of cannabis in drivers killed is comprised of specimens tested for 9-carboxy-THC (THC-COOH) an inactive (not psychoactive) metabolite of cannabis, as opposed to the active delta-9-THC. The reported percentages therefore may not be indicative of drivers impaired by THC, or "at risk", but rather drivers who had THC metabolites in their system because they had consumed cannabis as long as weeks prior to the time of the accident.

Between the years 1989 to 2000 many laws were introduced to reduce the number of road deaths in Victoria. These legislative changes included the introduction of infringements for excessive speed in 1989. In the same year Random Breath Testing (RBT) campaigns and enhanced Radio Detecting and Ranging (RADAR) surveillance were introduced. In 1990, high profile "Booze Buses" (testing drivers for alcohol consumption) were introduced, the Traffic Camera Office commenced and RADAR speed enforcement was enhanced. In 1991, the Road Safety Co-ordination Strategy was implemented and Community Road Safety Councils were established. In 1992, zero BAC limits were introduced for truck drivers, in 1993 the new "Left Turn Priority" was introduced to road rules and in 1995 the Road Safety Strategy developed "Safety First" (The Age newspaper, 21 August, 1997).

It is possible that the decrease in alcohol related deaths was most influenced by the introduction of high profile "Booze Buses", where breath analysis instruments are used to measure alcohol levels in drivers. If a decrease in marijuana related deaths is desired, a "Booze Bus" type strategy is required, where drug intoxicated drivers can be successfully intercepted and tested for the presence of drugs. However unlike alcohol, there is no reliable device that can be used to detect drug levels in drivers. However, Victoria Police in Australia has recently implemented legislation that involves sobriety test administration to test for drug impairment. The main concern over the use of these sobriety testing procedures is that unless these tests are accurate predictors of drug related impairment, it is unlikely that the use of the tests will result in a decline in road deaths, similar to those reported for alcohol. Nevertheless, the research into the effects of cannabis on driving ability reports that generally, marijuana intoxication can impair driving ability, therefore any strategy attempting to target marijuana-impaired drivers is a positive step.

Chapter Four: Cannabis and Driving Ability

This section concentrates on the research into the effects of cannabis on driving. The research in this area has assessed driving ability using various types of simulators as well as on-road driving tests. This section discusses the main studies in the area and outlines the various means of testing driving ability and the major findings.

4.1 Cannabis and the driving simulator

Early studies on the effects of marijuana on simulated driving performance established that some driving variables are impaired by the consumption of marijuana, and these impairments are dose related. The first study to assess the effects of cannabis on driving, using a driving simulator task with limited measurements, concluded that marijuana (22mg THC) increased the number of errors in monitoring of the speedometer of the vehicle (Crancer et al., 1969). This finding has been interpreted as reflecting the impairing effect of marijuana on perceptual ability (Moskowitz, 1985). However, it should be noted, that the dosing procedure and conclusions of Crancer et al.'s study have been previously criticized in terms of the use of only one marijuana dose (smoked to achieve a 'social high') being compared to one alcohol dose (consumed to achieve effects beyond a 'social high') (Kalant, 1969).

Using a driving simulator task, Rafaelson et al. (1973) examined the effect of three different doses of cannabis on driving ability (8, 12 and 16 mg THC). The results indicated that the 12 mg THC dose and the 16 mg THC dose significantly increased the latency to respond to lights that required the participant either to stop (brake) or to start (accelerate). One participant of the study was excluded from some analysis because of failure to respond to 8 out of 10 red signals. In addition, the study reported that the 16 mg THC dose significantly increased the cumulated deviations from the obligatory speed of 40 km/hr. These findings highlight that perhaps impairment in perceptual ability results in an increase in the number of street signs not detected and a loss of capacity to monitor speed.

Dott (1972) examined risk taking associated with driving behaviour. He reported that after the consumption of cannabis (11.25 mg THC and 22.5 mg THC) participants more frequently rejected instructions to pass another vehicle, and increased decision time to pass another vehicle (in non-emergency situations only). Ellingstad et al. (1973) reported similar effects of cannabis, where intoxicated drivers allowed more time for passing a vehicle when compared to drivers in the placebo condition. The findings of both these studies can be interpreted as either marijuana consumption resulting in more conservative driving, in which decision-making time is increased, or alternatively marijuana consumption resulting in a distortion of actual time and distance available to execute a successful overtake of another vehicle.

These early studies, utilized what can be described as primitive driving simulator tasks. The simulators were unable to assess abilities such as tracking, as the scenery was fixed and the pathways were presented independent of whatever the subject decided to do (Moskowitz, 1985).

Later studies examining marijuana intoxication and driving utilised driving simulators that were more realistic in terms of measuring actual driving processes and also examined a wider range of driving related variables. These studies reported a range of impairing effects of marijuana on driving ability. Smiley et al. (1981) examined the effects of marijuana on driving using a simulator that included curve following, velocity maintenance in wind gusts, car following, emergency decision making and overtaking. A subsidiary task (that required a response to a random light display) was also included to encourage monitoring of the entire visual scene. Unlike the results of earlier simulator studies, Smiley et al. (1981) found that marijuana (100 μg/kg and 200μg/kg) increased the variability of both velocity and lateral position of the vehicle when following curves and in wind gusts. An increase in variability of headway and lateral position while following cars was also reported. In the high THC condition, participants more often hit obstacles in the emergency response task and RT to the subsidiary task was increased. Participants in the marijuana condition also missed signs instructing them to follow another route more often compared to the placebo condition. As in earlier studies, it appears that marijuana, although reported by these studies as reducing risk-taking behaviour (conservative driving), increases RT to important signs. This decrement would be detrimental in a real life driving situation (Robbe, 1995).

Finally, Stein et al. (1983), in a similar study to that of Smiley et al. (1981), used a simulator that assessed more driving variables than the earlier studies, and included a subsidiary task. It was reported that the consumption of high dose marijuana was associated with a mean decrease in speed. Although Stein at al. (1983) did not find any impairment on the subsidiary task (unlike in Smiley et al.'s (1981) 40 minute driving task), Stein et al. (1983) used a driving task that ran for 15 minutes, and the subsidiary task used was not a random test (where participants were aware of the location the sign would appear). This attribute of the subsidiary task may have been one reason Stein et al. (1983) did not observe any impairment by marijuana, as it is likely that impairment will be observed when continuous attention is required and the subsidiary response is unexpected (Robbe, 1995).

A review by Moskowitz (1985) summarised that research conducted in the 1960s and early 1970s showed no effects of low doses of cannabis on car control (maintaining steady and consistent position of the vehicle when driving straight and turning). However, there was an observed increased latency before starting, stopping or overtaking, impaired monitoring of the speedometer, and a reduction in risk-taking behaviour in tasks requiring a decision to overtake a vehicle in the presence of an oncoming car. In later studies (1980s), where simulators were considered more realistic measures of driving performance, results showed that the consumption of cannabis affected many variables related to car control.

One of the more recent investigations on marijuana and simulated performance has revealed that after the administration of a 1.77% and 3.95% THC cigarette, there is a marginal change in mean brake latency (response to road obstacles in a barrier task), when compared to the placebo (Liguori, et al., 1998). Specifically, the high THC session increased brake latency by 54 ms and the low THC session by 38 ms (these results approached significance). These effects were described as similar to changes in brake latency while driving with a BAC of .05%. No changes observed in the judgement task between each THC condition (more complex driving scenario with obstacles), was attributed to the 70% slower travel speed in the judgement task compared to the barrier task. The judgement task stimuli that required responses, appeared at the same time point within the trial, whereas in the barrier test they were

random. It is not surprising therefore that no significant relationships were found on the judgement task, as previous research has indicated that marijuana is more likely to impair responses to random subsidiary tasks (Smiley, et al., 1981).

Finally, a study by Krueger and Vollrath (1998) examined the effects of marijuana (among other drugs) on driving simulator performance, using drivers that were either arriving or leaving discotheques. Participants whose specimen contained THC were classified as having recently consumed cannabis, and those that contained the inactive metabolite THC-COOH (11-nor-9-carboxy-THC) were classified as having consumed cannabis some time ago. Performance on the driving simulator was compared to performance by a control group (had not consumed any drug). Results indicated that THC-COOH decreased speed and improved the maintenance of lateral position of the vehicle. For THC the same results were observed for lateral position of the vehicle but speed and performance on secondary tasks was unaffected. The investigators conclude that marijuana has no impairing effects on driving ability. It should be noted however that with an experiment relying on between-subject-design, and not measuring the levels of THC consumed by participants (as opposed to only the presence), it is difficult to conclude that the changes or patterns observed are a result of the drug consumed. In addition, it would be inappropriate to compare these findings to the studies reviewed in this section as most previous research included placebo sessions and retested the same participants.

In conclusion, the majority of the research indicates that marijuana impairs perceptual process, such as monitoring the speedometer and maintaining speed, response to stimuli such as stopping and starting, and subsidiary tasks. In addition, it appears that marijuana intoxication is also associated with impaired car control.

Finally, driving simulator studies provide a safe environment to test the effects of marijuana on driving performance. Driving simulators provide more opportunities for researchers to manipulate driving courses and emergency situations, as well as accurately test many variables that may otherwise be missed by human examiners.

4.2 Cannabis and closed-course driving

There have been several on-road driving studies examining the effects of cannabis on driving performance. The research in this area is important because results from these studies provide the most accurate assessment of driving (in a research environment), in which the environment is real (not computer graphics) and a drivers peripheral vision is not limited (computer projection/monitor). Relative to real life driving, on-road driving studies allow the investigation of driving and drug consumption without placing participants (drivers) and pedestrians in as much danger, since researchers to some extent can manipulate potentially dangerous situations. One of the earliest studies examining real driving was conducted by Klonoff (1974). Klonoff (1974) examined the effects of three doses of THC (placebo, 4.0 mg THC & 8.4 mg THC) on driving using both a closed course test and a city streets test. The closed course driving test consisted of a driving course that was marked out using cones and tunnels. Errors were calculated by the number of cones hit. This performance was then compared to performance on three initial drives where no drug was administered. The report revealed that low doses of THC impaired performance on two tests (tunnel and corner) and that the high dose impaired performance on five tests (slalom, two tunnel, funnel and risk judgement). High doses of THC impaired judgement and concentration in the city streets test, compared to placebo, but this was not the case for the low THC dose. However, a small percentage of subjects performed better in both the low and high dose condition, compared to the placebo condition. This indicates that there are qualitatively different effects of THC across different individuals. The city streets test involved driving a specific route in city traffic, and performance was rated by a qualified driver-license examiner. Results in each marijuana condition were analysed by comparing performance to the placebo condition. Any difference in score was considered a representation of impairment. Results indicated that marijuana impaired judgement and concentration in the high THC condition, but not in the low THC condition, however, the means in which these results were obtained have been regarded by other experimenters as problematic, because the definition of each variable measured differs between raters. In addition, the requirement that examiners must assess many measures at once may result in the loss of some driving related errors (Smiley, 1986) .

Hansteen et al. (1976) studied the effects of THC (21 μg/kg THC and 88μg/kg THC) on a closed driving circuit set out with cones and poles. Participants were asked to complete the test as quickly as possible without hitting any cones. Performance was measured by recording the number of cones hit. Results showed that marijuana intoxication resulted in poor car handling, where the number of cones hit increased with the dose of THC. In the low dose condition 13.4 cones were hit and in the high dose 16.8 cones were hit, compared to 3.2 cones hit in the placebo condition. Although Hansteen et al. (1976) demonstrated some impairing effects of THC, these findings may not be representative of the real life effects of marijuana because of the requirement to complete the test as quickly as possible. Driving simulator studies have previously demonstrated that participants intoxicated by marijuana drive more conservatively, with a decrease in driving velocity and risk taking behaviours. If a participant is required to complete a task quickly, it is likely that an increase in errors may be the result of risks being taken, that under normal driving circumstances may not have occurred.

Caswell (1979) examined the effects of cannabis on driving performance using measures that were considered more applicable and representative of actual driving ability. These measures included overtaking, presence of road signs, hairpin turns, and narrow gaps. A subsidiary auditory task was also included in the driving test. Cannabis alone (6.25 mg THC) resulted in drivers driving significantly slower on straight sections of the driving course as well as when performing hairpin turns. Unlike the results reported in previous research, marijuana consumption was not associated with any changes in the lateral position of the vehicle. The author concluded that subjects under the influence of cannabis compensated for the effect of the drug on performance and therefore drive slower. A reported increase in RT to the subsidiary task under the THC condition was interpreted as the direct impairing effects of the drug on attention. These results are consistent with those reported in earlier studies.

A study by Atwood et al. (1981) examined driving ability in a similar manner to Caswell (1979), with the main difference being the administration of a higher dose of THC. The report revealed that marijuana had no impairing effects on a single variable (univariate analysis), however, overall driving ability was worse in the THC conditions compared to the placebo condition (multivariate analysis). The lack of findings (univariate) may be attributed to the absence of a subsidiary task, where less demand is

placed on attentional and perceptual processes, making it easier to focus on a basic driving test alone.

Peck et al. (1986) in a similar conclusion to Caswell (1979), reported that marijuana (1.9% THC) reduced speed of driving and impaired stopping behaviour. However unlike the results of previous research, marijuana significantly reduced the number of cones knocked over in a chicane driving task. The impairment was described as more rapid compared to alcohol, but less severe. Interestingly, when the speedometer was covered, marijuana resulted in increased speed of the vehicle. This finding may be indicative of the effect of marijuana on time and distance estimation. In the same year Smiley (1986) examined the effects of placebo, 100 μg/kg THC and 200 μg/kg THC on driving performance. The results showed that the high THC dose increased headway and headway variability. The author stated that although cannabis appeared to impair driving performance, this decrement, if perceived, might be compensated for by the subject. In some cases however, such as in emergency situations, compensation may be impossible.

In a more recent study Robbe (1998) examined three on-road driving courses (rural highway with no traffic; rural highway with traffic; and city traffic) with the administration of 100 μg/kg THC, 200 μg/kg THC and 300 μg/kg THC (and placebo). This study found that on the rural highway with no traffic and on the rural highway with traffic, increasing doses of THC resulted in an increase in the lateral position of the vehicle (increased sideway movements of the vehicle and impaired road tracking). In rural highway with traffic, the high THC dose slightly decreased speed and increased headway distance. In city traffic no significant differences were observed between performance under the low THC condition and placebo condition (only the low dose (100 μg/kg THC) was administered in the city traffic test). The authors concluded that drivers under the THC conditions tended to over-estimate the effects of the drug and hence compensated by increasing headway distance and by reducing speed, however, it was reported that subject's caution was greatest in the first session involving THC, and progressively less thereafter. The authors nevertheless concluded that a THC dose up to 300 μg/kg has a significant but not a dramatically impairing effect on driving behaviour. In addition, the effects of THC on driving was described as similar to those produced by

many common medicinal drugs and less than that produced by a BAC of .08%, suggesting that the impairing effects of marijuana should be considered 'slight', relative to other drugs including alcohol.

In a later study, Ramaekers, Robbe and O'Hanlon (2000) revised their previous conclusion and considered the effects of marijuana on performance to be more severe than previously reported. Results of the study showed that two THC doses (100 μg/kg THC and 200 μg/kg THC) impaired performance on a road tracking test and a car following test. Specifically, the standard deviation of the lateral position of the vehicle and the percentage of time spent out of a lane, increased with THC. The authors concluded that although the effects of low doses of THC were not blatantly dangerous, they were of sufficient magnitude to warrant concern in terms of dangerous driving. The differences in the results obtained in the 1998 and 2000 study were explained as being attributed to the participants' respective experience with smoking THC. The 2000 study was described as comprising participants who were less experienced and who had not developed the same tolerance to THC as participants of the earlier study by the same investigators. Again, this is an important finding that is relevant to the results of the current thesis (differences in performance between regular and non-regular cannabis users).

Finally, one of most recent reports on marijuana and driving examined visual search frequency and overall driving proficiency after the administration of 100 μg/kg THC (Lamers & Ramaekers, 2000). The study showed that marijuana alone did not affect the mean frequency of visual search at an intersection, compared to placebo. In addition, there were no significant differences between mean scores on the driving proficiency test between the THC condition and the placebo condition. The researchers explained the results in terms of the subjects being aware of the impairing properties of THC, and therefore compensating for them by driving more carefully. It was also highlighted that the sample consisted of regular cannabis smokers, and possibly, their previous experience with the drug under driving conditions had resulted in a developed tolerance to the effects of THC and a better strategy to compensate for the impairing effects of THC.

In conclusion, past research indicates that although the effects of THC on driving behaviour is at times minimal, even relatively small impairing effects may prove important in situations requiring quick/emergency responses. Generally the main effects of cannabis on driving ability appear to be an increase in headway distance, a slower reaction to subsidiary tasks and an impairment of the lateral position of the vehicle (tracking). Impaired tracking ability was highlighted by an increase in the number of cones hit on a driving course, an increase in sideway movements of the vehicle and an increase in the percentage of time spent out of a lane. In addition, the literature highlighted that it is possible that regular users are able to efficiently compensate for the impairing effects of THC, compared to non-regular users. Nevertheless, all the decrements reviewed in this chapter may prove fatal in a situation that requires prolonged attention, such as in real life driving. For this reason, the ability to successfully detect and detain drug-impaired drivers is an important issue and should be addressed.

Chapter Five: Drug Detection

This chapter describes different procedures/techniques for drug detection. These techniques vary from specimen analysis, such as immunoassays and chromatography, to performance testing, such as sobriety tests. The main focus of this chapter is the validation of performance tests, specifically the Standardised Field Sobriety Tests (SFSTs), to detect drug intoxication in drivers.

5.1 Methods of drug detection

There are several ways in which drug consumption/intoxication can be detected. These methods include the analysis of drug levels in body tissues; blood; urine; sweat; and hair samples, as well as the administration of performance tests. The most common means of testing for the presence of drugs in the body is blood and urine sample analysis. This section will briefly discuss two methods for detecting drug levels in blood and urine, but will primarily focus on the use of performance testing for detecting drug intoxication and impairment in drivers.

5.2 Testing for drugs using blood and urine specimens

There are two main methods used to test for drugs in blood and urine. These include immunoassay and chromatography. Each method will be described briefly, as an in depth description of each procedure is not necessary in the context of the current research.

Immunoassay is most commonly used for testing for drugs in urine samples. Immunoassays use an antigen-antibody procedure to detect illegal substances. Antibodies are developed that bind selectively to certain drugs or drug metabolites. The sample to be tested is mixed with antibodies and the presence and extent of antigen/antibody reaction is used to estimate the amount of drug present. The sensitivity and the specificity of this test is only as good as the antibody (Gombos, 1999). More often this method of detection is used to screen for a class of a drug, for example opiates,

as opposed to a specific drug within the class, for example heroin. Immunoassays can result in false positives, for example the anti-inflammatory and pain-killing drug ibuprofen, may give a false-positive result for cannabis. Positive screening tests must be confirmed by specific testing such as chromatography (Addiction Research Foundation, 1993).

Chromatography involves separating chemicals as they pass through a medium (paper, gas or liquids). The result can be read by detecting known patterns of diffusion or identification of the separated compounds. Chromatography techniques can test for a range of drugs at once, and is often considered the most accurate means of quantification (Gombos, 1999). The most precise method for drug testing uses chromatography to separate the compounds present and then mass spectrometry for identification and quantification (GC/MS) (Addiction Research Foundation, 1993).

5.3 Testing for drugs using performance tests

Performance testing involves the assessment of performance on a given task to test for the presence of drugs. The most popular performance tests known to the drugs and driving research community are sobriety tests. The tests assess abilities such as balance, divided attention and some physiological process such as involuntary eye jerks. The most popular sobriety test battery is the Standardised Field Sobriety Test (SFSTs), and was developed by the Southern California Research Institute (contracted by National Highway Traffic Safety Administration, NHTSA, US Department of Transport) to facilitate the accurate recognition of alcohol intoxicated drivers in the United States of America. NHTSA adopted the SFSTs, developed training curricula and sponsored training. The tests were initially most commonly used by the Los Angeles Police Department (LAPD), but today are used in all 50 states of the U.S.A. Even though the use of this test has had some recorded success in the detection of alcohol intoxicated drivers, the reliability of these tests to successfully detect drug impaired drivers is constantly under review.

5.4 What are the Standardised Field Sobriety Tests?

Sobriety testing involves the administration of tests that originated in the U.S.A 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 (BAC) 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 SFSTs and other sobriety testing methods used predominantly in the U.S.A.

The first study conducted on sobriety tests took place in 1977 by Burns and Moskowitz. This study aimed to identify which sobriety tests out of a group of ten 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) showed highest correlations 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 et al. (1981) further examined the accuracy of sobriety tests by testing the reliability and validity of the three tests chosen in the earlier study. 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 and below .10%. Results from the field setting study revealed a 20% increase in arrest rates involving BACs above .10% with the use of the three test battery. A study by Anderson et al. (1983) supports these findings by indicating 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 test was the best test of alcohol intoxication, and in addition, the combination of scores derived from the administration of the HGN and WAT test was most accurate in predicting BAC. The three test battery used in these studies is currently referred to as the Standardised Field Sobriety Tests (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 SFSTs 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 where arresting officers are highly trained in the administration of the SFSTs. 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 and below .10%. The aim of the next study by Burns and Anderson was therefore to examine the accuracy of arrest decisions, made by experienced skilled officers in a field setting based upon the SFSTs (Burns & Anderson, 1995). The study found that the SFSTs correctly classified 86% of drivers as having a BAC above .10%. More specifically; in 1977 54% of arrest decisions (BAC above .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 .10%. Since some states of America later required that a driver may not have a BAC above .08%, the SFSTs validation studies that were previously conducted no longer provided sufficient support for the use of SFSTs to detect this level of 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 .04% and .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 performance on SFSTs where highly accurate. More than 91% of arrests based on .08% BAC estimates were correct, and 94% of estimates that BAC was between .04% BAC and .08% BAC were correct. The researchers concluded that the SFSTs were a valid test battery for the detection of drivers with BAC levels as low as .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 .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 (1998), 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 .1% and .149%. 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 BACs levels between .08% and .10% failed. For the OLS test, 30% of individuals with BAC levels of zero failed, and 49% of individuals with BAC levels between .1% and .149% 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. Nevertheless, the findings of Perrine et al. (1993) encourage the further validation of the SFSTs, especially when new tests or scoring procedures are implemented, or when the purpose of the tests is altered (i.e. testing for drugs other than alcohol).

The SFSTs, although designed only for the detection of alcohol-intoxicated drivers (up to .08%), has been implemented in some programs for the detection of drugs other than alcohol. No published studies exist that validate the SFST battery for the detection of drug impaired/intoxicated drivers. A very limited number of studies however, have tested procedures that include the SFSTs in addition to other tests in their drug impaired driver detection programs, however these studies validate an entire testing program as opposed to the administration of the SFST battery alone. One such program is the Drug Recognition Expert (DRE) program (later renamed the Drug Evaluation and Classification Program (DECP) by the National Highway Traffic Safety Administration), a twelve-step procedure that includes the administration of the SFSTs 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 LAPD developed the DRE program 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 DRE are those more commonly known as the "Johns Hopkins Study" (Bigelow et al., 1985) and the "173 Case Study" (Compton, 1986). The "Johns Hopkins Study" was a controlled clinical study conducted to test the validity and reliability of the procedure (DRE/DECP) used by Drug Recognition Experts (DREs). The study involved the analysis of data gathered from 80

participants who were administered amphetamine, marijuana, diazepam, secobarbital or placebo. The researchers claimed that the DREs were over 90% accurate in determining intoxication (not the presence of a drug), 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 comprised of opinions of 'intoxicated' and it was in this group that over 90% of 'intoxicated' opinions were correct classifications of drug type (opiate, stimulant, marijuana or depressant). In addition, of those individuals who were administered marijuana (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). It is possible that the opinions of "not intoxicated" may have been correct even though a drug was administered, since DREs were asked to predict "intoxication" associated with a drug, not the presence of a drug even if it was not causing impairment.

The "173 Case Study", unlike the "Johns 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. Marijuana was the second most common drug detected and was commonly found in combination with alcohol and PCP. DRE 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 DRE 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 "Johns 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 "Johns Hopkins Study" (administered specific doses). This would have made the identification of impairment in the "173 Case Study" easier. 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 consisted only of drivers that were suspected of drug use prior to the administration of the entire DECP. DREs were aware that these suspects were arrested for DUI 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 why 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 are 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.

A later DRE validation study addressed some of the limitations of the "Johns 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 marijuana 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 successful in predicting drug intoxication. Adler and Burns (1994) acknowledge this limitation when they concluded that the DRE program requires scientifically sound support from the laboratory.

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 marijuana, where in each session there was one active dose as well as a placebo. The study was double blind and randomized. 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 marijuana 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 marijuana when 28 variables were assessed. In contrast, the DEC program 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. repeated the earlier study, where the main difference was the class of drugs administered and the number of variables utilised. In 1998 the drugs examined were alprazolam, d-amphetamine, codeine and marijuana. The results revealed that the use of the DECP resulted in accurate predictions of drug intake in 82.7% of cases, when 7 variables were utilized. The decrease in percentage compared to the 1996 study (for marijuana) 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 marijuana 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 a drivers admission of drug use. It should be considered however, that it is in the absence of these cues the DECP should be most accurate, because when such clues are present, it is likely that an opinion of 'impaired' is formed prior to the administration of any test.

The most recent investigations of sobriety test programs were presented at the International Council on Alcohol, Drugs and Traffic Safety (ICADTS) conference in Stockholm, 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 battery, 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 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.

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: marijuana; alprazolam; codeine; and amphetamine. The results showed that out of 102 cases in which placebo was administered, DREs decision

was unimpaired in only 43.1% of cases. In 49 cases where marijuana was administered, the DRE's decision was unimpaired in 24.5% of cases. In terms of the specific class of drug predicted by the DREs, marijuana 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 it is highly accurate in predicting drug influence and impairment in a field setting. However, the ability of the DECP to identify the specific drug class causing impairment is not as impressive. When reviewing the research in this area, one must prioritise the reason for using such tests. Once it is clear that the detection of impairment is the most important aspect of its use, as opposed to the identification of drug class, then the research generally supports the use of programs similar to the DECP.

The use of the SFSTs on the other hand, for the detection of drug related impairment, has not been tested or validated. None of the studies mentioned in this chapter test the efficiency of the SFST battery (HGN, WAT and OLS) to detect impairment caused by drugs. 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). The SFSTs do not take into account any physiological variables (apart from horizontal gaze nystagmus), although driver behaviour prior to interception and other cues (mouth odor, speech) are taken into consideration when interpreting performance. A study that identifies the accuracy of the SFSTs to predict drug intake is critical before it is used for that purpose.

Chapter Six: Victorian (Australia) Legislation

This chapter outlines the major attributes and changes to the Victorian (Australia) legislation on driving when impaired by/under the influence of, alcohol and/or drugs. Specifically, the Road Safety Act 1986 was amended in the year 2000 to include new definitions, provisions and offences applicable to impaired driver enforcement. These changes and the new drug enforcement program are now discussed.

6.1 Impaired Driver Enforcement Legislation

Prior to the introduction of the drug impaired driver program (which includes the administration of the Standardised Field Sobriety Tests (SFSTs)), the Road Safety Act 1986, under section 3, defined a drug as:

".....any substance or preparation for the times being declared by Order made by the Minister and published in the Government Gazette to be a drug for the purposes of this Act." (Road Safety Act, 1986)

In 2000, Victoria police declared that this definition did not keep pace with the development of many hundreds of new substances that came into use. The definition of a drug was therefore amended to:

".....a substance that is a drug for the purpose of this Act by virtue of a declaration under sub-section (3) or any other substance (other than alcohol) which, when consumed or used by a person, deprives that person (temporarily or permanently) of any of his or her normal mental or physical faculties." (Road Safety Act, 1986)

After the amendment to the definition of a drug, it was important to make various amendments to what constitutes an offence. Section 49 (1) of the Road Safety Act (1986) describes under what circumstances a person is guilty of an offence. The additions to this section are as follows:

"A person is guilty of an offence if he or she-

(a)….
(b)….
(ba) drives a motor vehicle or is in charge of a motor vehicle while impaired by a drug; or
(c)….
(ca) refuses to undergo an assessment of drug impairment in accordance with section 55A when required under that section to do so or refuses to comply with any other requirement made under section 55A (1); or
(d)….
(e)….
(ea) refuses to comply with a requirement made under section 55B(1); or
(f)….
(g)…." (Road Safety Act, 1986).

The above additions often refer to sections 55A and 55B. These sections describe drug assessment, and blood and urine samples, respectively, and are all new additions to the Road Safety Act, 1986. 55A Drug assessment states that:

"A member of police may at any time require-
(a) any person…..(b), (c), (d), (e), (f)….
to undergo an assessment of drug impairment if, in the opinion of the member, that person's behaviour or appearance indicates that he or she may be impaired for a reason other than alcohol alone and for that purpose may further require the person to accompany a member of the police force to a place where the assessment is to be carried out and to remain there until the assessment has been carried out or until 3 hours after driving, being an occupant of or being in charge of the motor vehicle, which ever is sooner." (Road Safety Act, 1986).

Section 55B outlines in detail the process of obtaining blood and urine samples and the offences associated with drivers refusing to submit samples. The specific details will not be discussed as they are not relevant to the context of the current project.

Finally, there are a number of particulars that must be included in a report of assessment of drug impairment. The particulars are outlined in section 209 of the Road Safety Act,

1986. These details are essential if a driver is to be prosecuted for committing an offence under the Act.

"For the purposes of section 55B(5) of the Act, a report of assessment of drug impairment must contain the following particulars-
(a) particulars of the identity of the person on whom the assessment was carried out, including, if known, the person's name, address, date of birth and gender;
(b) the date and time at which the person underwent the assessment;
(c) the place at which the person underwent the assessment;
(d) the time (if any) reported to the member of the police force carrying out the assessment as the latest time the person drove, was in charge of or was an occupant of a motor vehicle;
(e) whether the person underwent a preliminary breath test in accordance with section 53 of the Act or furnished a sample of breath for analysis by a breath analysing instrument and, if so, the result of the test or analysis, if known;
(f) the record of interview of the person carried out by a member of the police force carrying out the assessment;
(g) particulars of any medical treatment sought by or for the person;
(h) any statements made by the person concerning a drug or drugs;
(i) any observations made by the member of police carrying out the assessment of the person in relation to-

(i) any apparent injury or illness of the person;
(ii) whether the person smelt of intoxicating liquor;
(iii) the person's speech;
(iv) the person's eyes;
(v) the person's breathing;
(vi) the person's skin;
(vii) the person's balance;
(ix) The state of the person's movement;
(x) the person's balance;
(xi) the person's demeanor;
(xii) any physical signs of drug use by the person;
(xiii) the person's ability to comprehend instructions;
(xiv) the person' ability to divide attention;

> *(xv) whether the person, during the assessment, exhibited signs that indicated that the person was impaired by a drug or drugs;*
> *(j) whether the assessment, in the opinion of the member of the police force carrying it out, indicates that the person may be impaired by a drug or drugs;*
> *(k) the name, rank, station and signature of the member of the police force carrying out the assessment."* (Road Safety Act, 1986).

The information above indicates that generally, all drivers intercepted and suspected of drug use, must undergo an assessment. If the presence of a drug is supported, drivers must then submit specimens for analysis, where this information is then used to establish whether or not that driver has committed an offence under the Road Safety Act, 1986.

6.2 Assessing drug impairment

The assessment of drug impairment described in section 55A is outlined in the Victoria Government Gazette (No. G46 Thursday 16 November 2000). The Gazette clearly outlines the procedures carried out by an authorised police officer when a driver is under suspicion of driving while impaired. It is important for the purpose of the current project that this procedure be discussed in detail, as the tests outlined in the Gazette are also examined in this project. The three performance tests will also be described in detail, as this information is vital to the administration of the tests used in the current study.

"1. The procedure for assessing drug impairment is carried out by a member of the police force authorised to do so under section 55A(4) of the Road Safety Act 1986 (the 'assessing officer').

2. The procedure consists of the following:

- *an interview by the assessing officer of the person who is to be assessed ('the subject');*
- *a request by the assessing officer to the subject to perform the Horizontal Gaze Nystagmus Test as described in* chapter 7 section 7 (of this report);
- *the performance of that test by the subject;*

- *observation by the assessing officer of the performance of the subject during that test;*
- *a request by the assessing officer to the subject to perform a Walk and Turn Test as described in* chapter 7 section 7 (of this report);
- *the performance of that test by the subject;*
- *observation by the assessing officer of the performance of the subject during the test;*
- *a request by the assessing officer to the subject to perform a One Leg Stand Test as described in* chapter 7 section 7 (of this report);
- *the performance of that test by the subject;*
- *observation by the assessing officer of the performance of the subject during that test;*
- *the progressive completion by the assessing officer of a Standard Impairment Assessment Report in accordance with the Regulations……"* (Victoria Government Gazette, 2000)

The Victoria Government Gazette further describes the three test battery in detail, and outlines what instructions are given for each test and what errors are important to the scoring and interpretation of each test.

"Interview procedure

3. The interview consists of questions about the subject' name, address and date of birth, the circumstances that led to the interception of the subject and any recent history of illness, injury, medical treatment or drug use.

4. The purpose of these questions is to obtain relevant information as well as to permit observations to be made that may assist in establishing whether impairment is present or not.

5. If at any time during the interview the assessing officer suspects that the subject may be suffering from an injury or illness that may be the cause of impairment, the assessing

officer must take immediate steps to arrange for the subject to be examined by a registered medical practitioner." (Victoria Government Gazette, 2000).

The initial interview in the drug assessment procedure suggests that impairment is suspected prior to the administration of any test. It appears that once impairment is suspected, the results from the three test battery are used to merely support whether a drug is causing this impairment.

"Horizontal Gaze Nystagmus Procedure (HGN)

6. The assessing officer informs the subject that the assessing officer is going to check the subject's eyes. If the subject is wearing eyeglasses the assessing officer directs the subject to remove them. The assessing officer asks the subject if the subject wears contact lenses and notes the reply. The assessing officer instructs the subject to keep the subject's head still, and follow the movement of an object held by the assessing officer by moving the eyes only. The assessing officer directs the subject to focus on the object until directed to stop. This test should not be administered if the subject has an obvious abnormal eye disorder or an article eye.

7. The assessing officer observes and notes whether the subject's eye track the stimulus together or one eye lags behind the other, whether both pupils are equal size, whether the subject's eyes are able to pursue the stimulus smoothly, or with a jerky motion.

8. The assessing officer then observes each of the subject's eyes separately to determine-

(a) whether nystagmus is visible in the left eye when the eye is held far to the left as possible or in the right eye when the right eye is held far to the right as possible;

(b) whether, when each eye is observed separately, nystagmus is observable in the left eye before the left eye has moved beyond 45 degrees from the extreme right position, or whether vertical nystagmus is present.

9. The assessing officer also notes any other observations that may be relevant to the subject's performance in the test." (Victoria Government Gazette, 2000).

Many drugs produce different symptoms in the HGN test. Some drugs produce nystagmus and others do not. The presence or absence of some signs is often used by LAPD officers in the U.S.A. to distinguish between the drug class/es consumed (e.g., stimulants, cannabis, depressants, etc.). However, performance on the HGN, as well as the other tests administered, is not being used by Victoria Police assessing officers to distinguish between drug class, but rather to assess whether a drug, if any, is impairing driving ability (Boorman, 1999).

"Walk and Turn Procedure (WAT)

10. The test is conducted on a dry, hard, level, non-slippery surface marked with a straight line. There should be sufficient room for the subject to complete nine heel-to-toe steps.

11. The assessing officer directs the subject to place the subject's left foot on the marked line, and the right foot in front of the left foot, with the heel of the right foot against the toe of the left foot. The assessing officer demonstrates these actions. The assessing officer then directs the subject to place the subject's arms by the subject's side and stay in that position until directed to begin. The assessing officer tells the subject not to start to walk until told to do so. The assessing officer asks the subject whether the instructions have been understood, and if necessary, repeats them to the subject.

12. The assessing officer then explains the test requirements, using oral instructions, accompanied by demonstrations. The subject is directed that, when told to start, the subject is to take nine heel-to-toe steps down the line, turn around, and take nine heel-to-toe steps back up the line. The assessing officer demonstrates two or three heel-to-toe steps. The subject is then directed to turn by keeping the subject's front foot on the line and taking a series of small steps with the other foot. The assessing officer demonstrates this manoeuvre.

13. The subject is directed to keep the subject's arms down by the subject's side throughout the test, to watch the subject's feet at all times, and to count the subject's steps out loud. The subject is also directed to not stop walking until the subject has

completed the test. The assessing officer asks the subject whether the instructions have been understood, and if necessary, repeats them.

14. The subject is then directed to begin and to count the steps, with the first step from the heel-to-toe position to be counted as 'One'.

15. The assessing officer notes whether the subject maintains balance while listening to instructions, starts to walk before being instructed to do so, stops while walking, does not walk 'heel-to-toe', steps off the line, uses arms to balance, takes and incorrect number of steps or does not turn as directed. The assessing officer also notes if the subject fails to complete the test." (Victoria Government Gazette, 2000).

Depending on the number of errors made during the WAT test, the assessing officer forms an opinion as to whether the subject is impaired on this test. Any additional errors made during the WAT, such as counting incorrectly or not watching the subject's feet while walking, are errors noted, but not scored (Boorman, 1999). In terms of drug impairment, it is likely that a number of drugs will produce different errors, the WAT scoring procedure however, would not classify a subject as impaired unless the errors outlined in the Victorian Government Gazette (2000) are observed. Research should examine the reliability of the errors scored in the WAT in terms of drug impairment, as the above errors have only been validated in the presence of alcohol as high as .08% BAC.

"One Leg Stand Procedure (OLS)

16. The assessing officer directs the subject to stand with the subject's feet together and the subject's arms by the subject's sides, and to not start the test until told to do so. The assessing officer demonstrates this. The assessing officer the asks the subject whether the instructions have been understood, and, if necessary, repeats them.

17. The assessing officer then directs the subject that when told to start the subject must raise one leg approximately 15 centimetres off the ground with toes pointed out, with both arms straight, and by the subject's side. The assessing officer demonstrated this.

18. The assessing officer then directs the subject to hold that position and count out loud for thirty seconds in the manner demonstrated while the subject keeps the subject's arms by the subject's sides and watches the raised foot. The assessing officer then asks the subject whether the instructions have been understood, and, if necessary, repeats them.

19. The assessing officer then directs the subject to start. The assessing officer allows the test to continue for 30 seconds. The test is discontinued after 30 seconds." (Victoria Government Gazette, 2000).

The manner in which the subject must count is 1001, 1002, 1003 and so on, for thirty seconds (Boorman, 1999). It is likely that the subject will assume that they have been instructed to count 'up to' 30. It the subject counts up to 1030, they are instructed to continue counting until directed to stop. Thirty seconds is required, as generally, after alcohol consumption, errors are observed after 25 seconds. It is not clear whether this is the case for drugs other than alcohol, nevertheless, this procedure has been implemented.

"20. The assessing officer then directs the subject to repeat the test while standing on the other leg.

21. The assessing officer notes whether the subject sways while balancing, uses arms to balance, hops, or puts the subject's foot on the ground. The assessing officer also notes if the subject is unable to complete the test. This information is recorded separately for each leg." (Victoria Government Gazette, 2000).

Depending on the number of errors made during the OLS test, the assessing officer forms an opinion as to whether the subject is impaired on this test. Any additional errors made during the OLS, such as counting incorrectly or not watching the subject's raised foot, or toes not pointed, are errors noted, but not scored (Boorman, 1999). In terms of drug impairment, it is likely that a number of drugs will produce different errors, the OLS scoring procedure however, will not classify a subject as impaired unless the errors outlined in the Victorian Government Gazette (2000) are observed. Research should examine the reliability of the errors scored in the OLS in terms of drug impairment, as these errors have only been validated in the presence of alcohol as high as .08% BAC.

Finally,

"22. At the conclusion of the above impairment assessment procedure, the assessing officer reviews all the available information including the investigator's roadside impairment assessment report, the result of any evidential breath alcohol test, any information obtained from the observation or questioning and the results of the three tests referred to in paragraph 2 above. The assessing officer then considers all of this information and forms an opinion as to whether the subject may be impaired by a drug or drugs." (Victoria Government Gazette, 2000).

In conclusion, the assessing officer takes into account all details concerning the interception of the subject as well as performance on the three test battery. A medical examination is also performed at the end of sobriety test performance (only if the subject fails) to eliminate the possibility that the subject has an illness that is interfering with performance. An opinion on the cause of impairment is then formed, and appropriate action is taken. In a case where the assessing officer forms the opinion that the subject is impaired by a drug, the subject must provide a blood and/or urine sample. If a drug is found in the specimen, the subject will be prosecuted, charged with 'driving while impaired by a drug', and the subject's license will be suspended. If a drug is not found in the specimen, the subject will not be prosecuted, the subject will undergo administrative procedures, the subject's license will be reviewed and the subject's license will be suspended. In either case, the subject will have to undergo some type of education and/or rehabilitation before the license is renewed (Boorman, 1999).

Victoria Police has implemented penalties for driving while impaired by a drug. Generally, the penalties are as follows:

"1st Offence
Fine: not more than $1,200
License: suspended for not less than 12 months

Subsequent Offence

Fine: not more than $2,500; or

Prison: not more than 3 months

License: suspended for not less than 2 years" (Road Safety Act, 1986).

Since the penalties for driving while impaired are severe, it is likely that the entire drug impairment assessment procedure will be reviewed and criticized by many, especially those prosecuted. Victoria Police (Australia) should therefore concentrate on testing and retesting the reliability and validity of these sobriety tests to detect impairment caused by drugs other than alcohol. Research on this would not only be essential for Victoria Police, but also the community, as the successful detection of drug impaired drivers will deter driving while intoxicated, and decrease the number of road accidents and deaths associated with drug use.

Chapter Seven: Materials and Method

This section outlines the entire procedure of the study, and includes information on the drug doses, and the entire battery of questionnaires administered. This section also outlines the various steps taken to initiate and complete the project.

7.1 Participants

7.1.1 Selection Criteria

The selection criteria included; previously smoking cannabis; no history of cardiac disorders; no current or past substance abuse; no mental health problems; no allergies to drugs; and no other medical illness. Participants were required to have a valid full drivers license (no probationary or learner drivers) to ensure that driving experience was at least 3 years or more. Notices were placed in local papers and on community and university notice boards. Interested participants were briefly advised of the study requirements and procedure and were then booked in for a medical examination. Individuals who passed the medical examination, therefore fitting the above criteria, were recruited as participants.

7.1.2 Sample Characteristics

The sample comprised 40 individuals (14 female and 26 male). Age varied between 21 and 35 years (mean age of 25.5, SD=3.1). All participants completed a medical examination (selection criteria outlined in section 7.1.1). Using a Frequency of Cannabis Use questionnaire, participants were divided into non-regular and regular cannabis users. Non-regular cannabis users comprised individuals who smoke cannabis less than once a month. Regular cannabis users comprised individuals that smoke cannabis more often than once a month. The regular and non-regular cannabis user group categorization (more or less than once a month) was used because cannabinoid metabolites are completely eliminated from the body in approximately 30 days (1 month). Therefore, an individual consuming cannabis after this time would not have an accumulated level of THC metabolites (non-regular user). A finer-grained

categorization would have resulted in too smaller numbers in each group which would have lowered statistical power in the analysis. The non-regular users group comprised 18 participants (8 male and 10 female) with a mean age of 25.7 (SD=2.9) and the regular users group comprised 22 participants (18 male and 4 female) with a mean age of 25.4 (SD=3.3).

All participants were provided with an information sheet outlining the drug conditions to be administered and the entire procedure of the study (Appendix A). If the participant agreed with the details of the study they then signed a consent form. All participants were informed that they were free to discontinue from the study at any time. The research was approved by the Human Research Ethics Committee of Swinburne University of Technology.

7.2 Drug conditions

The following conditions were used in the study:

0% THC (placebo)
1.74% THC (low dose)
2.93% THC (high dose)

The above marijuana conditions were examined by administering marijuana cigarettes containing each of the levels of THC to all participants. The National Institute on Drug Abuse (NIDA) in the U.S.A. donated the marijuana cigarettes used in this study. Each marijuana cigarette was 85mm in length and had a 25mm circumference. Each cigarette differed in the type of marijuana it contained, moisture content, weight and cannabinoid content. Table 1 shows the major differences between each cigarette.

Table 1 Differences between each cannabis cigarette: Placebo, Low and High THC.

	Placebo	**Low Dose**	**High Dose**
Marijuana type	Mississippi grown Mexican marijuana	Mississippi grown Jamaican, Special Hybrid and Mexican	Mississippi grown Jamaican, Special Hybrid and Mexican
Weight	702 +/- 40 mg	779 mg	790 mg
Delta-9-THC content (%)	0.005 +/- .002%	1.74 +/- 0.14%	2.93 +/- .18%
Delta-9-THC content (gm)	.000gm	.813 gm	1.776gm
Moisture content	12.4%	10.8%	11.5%

One marijuana cigarette was administered in each session using a controlled smoking procedure, similar to that used by Cone & Huestis (1993). Participants were instructed to inhale marijuana smoke for 2 seconds, hold the smoke in their lungs for 10 seconds (if less, as long as they could) and exhale and rest for 35 seconds. This procedure was repeated 8 times, or when the cannabis cigarette finished, whichever came first. The study was randomised, counter-balanced, double blind, and used a within subject design.

7.3 Mental and physical health

All participants completed a medical exam administered by a medical practitioner. The completion of two questionnaires comprised the examination.

1. Patient Questionnaire

This questionnaire was completed by the participant and consisted of several questions concerning medical history such as allergies, medications, medical problems, medical operations, diet, alcohol consumption, and pregnancy for females. See Appendix B for the entire list of questions.

2. Medical Questionnaire

During the medical examination the medical practitioner completed a medical questionnaire. This questionnaire consisted of several questions concerning medical history and physical characteristics such as heart rate, skin colour, pulse rate and

urinalysis (testing of the urine to screen for any abnormalities). See Appendix C for the entire list of questions.

7.4 Demographics

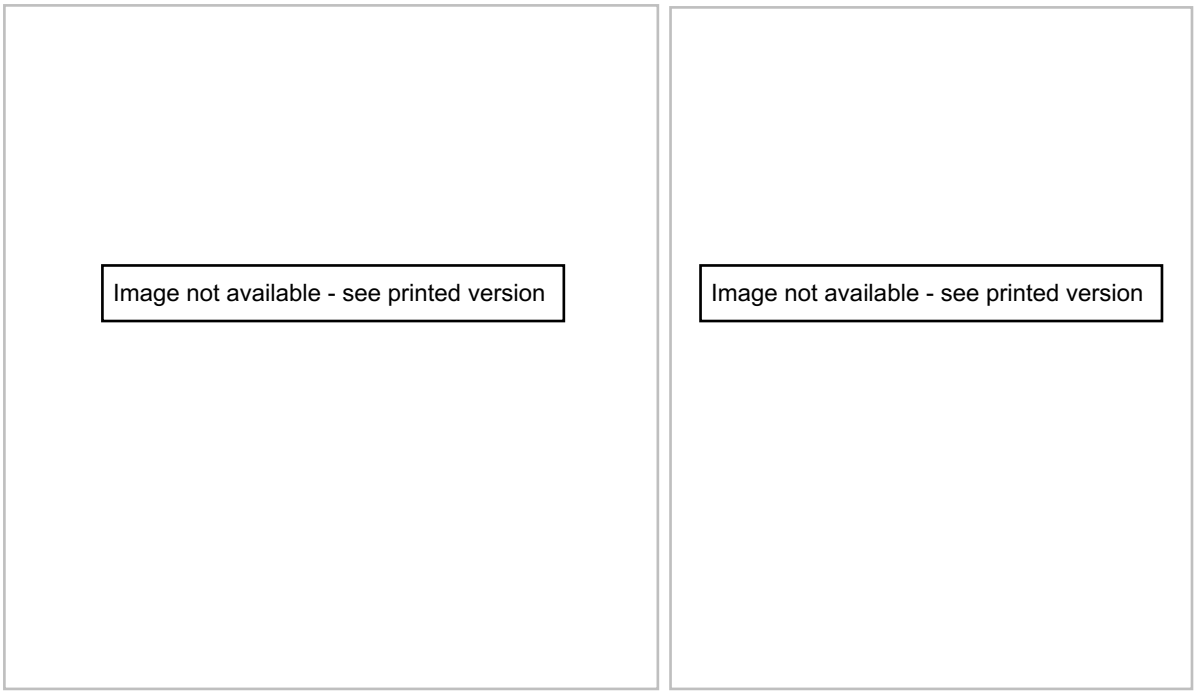
Demographics were obtained using a questionnaire that consisted of 7 questions involving age, sex, education and health. See Appendix D for the entire list of questions.

7.5 Cannabis use

Cannabis use of the participants involved in this study was examined using a Frequency of Cannabis Use questionnaire. This questionnaire consisted of 6 questions involving past and current frequency of cannabis use and method of consumption and the drugs general effects on the individual. See Appendix E for the questionnaire.

7.6 Driving performance

Driving performance was measured using a driving simulator. The driving simulator used in this study was the Cybercar simulator manufactured by DNS Business Group Pty. Ltd. The simulator is a large capsule 1930mm in height, 1050mm in width, 2200mm in length and weighs approximately 300kg. The simulator required normal mains outlet (220V +/- 10% 50Hz @ 10A) and was stored in a custom built enclosure in temperatures between 20 and 25 degrees Celsius. The simulator was a computer-based program that included a large 38cm screen and full car interior (steering wheel, indicators, horn, gear stick (5 speed), speedometer, rear view mirrors, side mirrors, adjustable seat, seat belt, etc.). The Cybercar simulator is predominantly used in industry, government and education as training for both novice and experienced drivers. A member of DNS Business Group Pty. Ltd trained the investigator in the administration of the computerised driving task. See Figure 4 and 5.



The Basic Module:

This module is broken up into two different tasks that are used to assess basic steering ability and basic speed control. This study used these tests to familiarise the participants with the driving simulator to ensure that they felt comfortable with the steering, accelerator and brake.

1. Basic Steering: in this test the simulator automatically controls the speed of the vehicle so that the participant is only required to concentrate on steering. The specific instructions given were as follows:

"This test is to familiarise you with the steering of the simulator. You don't need to use the accelerator or brake pedals. Only concentrate on your steering by maintaining the left lane on the road. Do you understand?" If the participant said "no" the instructions were repeated and clarified. If the participant answered "yes" the test was performed.

2. Basic Speed Control: in this test the simulator did not control steering or speed. The participant was required to steer and control the speed of the simulator. The specific instruction were as follows:

"This test is to familiarise you with the steering, accelerator and brake pedals of the simulator. Concentrate on both steering and speed by maintaining the left lane on the

road, and keeping under the speed limits indicated. Do you understand?" If the participant said "no" the instructions were repeated and clarified. If the participant answered "yes" the test was performed.

Scoring: The simulator calculated percentage scores for each test. If the participant scored above 60% on each test, they were classified as being familiar enough with the task to proceed to the Driving Module. These percentage scores were not used in the analysis of the effects of cannabis on driving ability.

The Driving Module:

This module is broken up into two different sections that assess driving ability in freeway traffic and driving ability in city traffic. The specific instruction were given as follows:

1. Freeway Traffic Test:

"This test will assess your overall driving ability in freeway traffic. Concentrate on both steering and speed by maintaining your lane on the road, and keeping under the speed limits indicated. You may overtake traffic at anytime and don't forget to use your indicators and mirrors (indicators and mirrors shown). Do you understand?" If the participant said "no" the instructions were repeated and clarified. If the participant answered "yes" the test was performed.

2. City Traffic Test:

"This test will assess your overall driving ability in city traffic. Concentrate on both steering and speed by maintaining your lane on the road, and keeping under the speed limits indicated. You may overtake traffic at anytime and don't forget to use your indicators and mirrors (indicators and mirrors shown). There will be traffic lights in this test, so be prepared to make some stops. I will let you know when and where to turn right or left. Do you understand?" If the participant said "no" the instructions were repeated and clarified. If the participant answered "yes" the test was performed. A specific map was used for all participants. The same route was used in all city traffic tests.

Scoring: The driving simulator scored 126 variables varying from uncontrolled dangerous action, to economic driving. Only thirty-three variables were examined, as these were the most relevant to the focus of the study. Each variable described an error that could be made during each test. Each time the participant made the error once, the simulator recorded one point, and every time that same error re-occurred another point was recorded. At the end of the task the simulator produced a score sheet that showed the number of times each error occurred. The investigator then multiplied each score by that variable's "loading factor". A "loading factor" is a number that expresses the severity of the error. In terms of driving, a serious error would be a collision, which would have a "loading factor" of 10, where an error such as failing to use a signal when changing lanes would have a "loading factor" of 2. Below is the list of variables examined in the project and the "loading factor" for each (Table 2).

Table 2 Driving simulator variables and corresponding loading factors (DNS Business Group Pty Ltd.)

Driving Simulator Variables	Loading Factor
Over-revved too long	1
Park Break on while travelling	1
Skid	1
Off the road	1
Collision	10
Straddled the solid line	2
Exceeded speed limit	2
No observation when moving off	5
No signal when moving off	5
Car rolling when moving off	10
No signal cancel when moving off	4
Incorrect steering method	1
No observation when steering	5
Wide/Cut	4
Wandering	2
Incorrect position of car	2
Straddled barrier line	2
No signal when changing lane	5
No signal cancel when changing lane	4
Not sufficient clear space when overtaking	5
No mirror checks	3
Driving too fast	5
Driving too slow	1
Inappropriate Acceleration	1
Inappropriate Deceleration	1
Inappropriate Braking	2
No safe following distance	5
Not sufficient clear space when stopping	2
Needless/Unnecessary stop	1
Not sufficient clear space when merging	5
No stop for emergency	5
Uncontrolled stop for emergency	5
Reaction time (emergency stop)	x 10 ms
Stopping distance from vehicle/object	x 10 ms
Distance from vehicle/object at stop	in metres
Skidding when stopping	1

7.7 The sobriety tests

The sobriety tests administered in this study were taken from the Standardised Field Sobriety Tests (SFSTs) and the Drug Evaluation and Classification Program (DECP). Each test provides reliable results only if a trained person administers them. Each test 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 classified as impaired. A

member of Victoria Police, Inspector Martin Boorman, trained the investigator in the administration of the SFSTs. Inspector Boorman received 10 days of training from a member of the Los Angeles Police Department, Officer-In-Charge of DRE Unit, Sergeant Tom Page (retired). The training involved theory on the administration and scoring of the SFSTs, as well as supervised administration and scoring of the SFSTs. The investigator of the present study received 7 days training from Inspector Boorman. The training included theoretical and practical aspects of the administration and scoring of the SFSTs (including supervised administrations) as well as completion of the Victoria Police Impaired Driver Enforcement Training CD-Rom (1999).

7.7.1 The Standardised Field Sobriety Test (SFSTs)

All tests that comprise the SFSTs were included in the study, as they have not previously been tested alone to detect drugs other than alcohol. It is not clear from previous research whether these tests will be successful in determining drug intake. This study used the same administration procedures employed by the Victoria Police, since it is Victoria Police who are using this test battery for the purpose of testing for drug impairment.

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

This test involved asking the participant to follow an object moving horizontally and then vertically 12 to 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. See Figure 6 and 7.

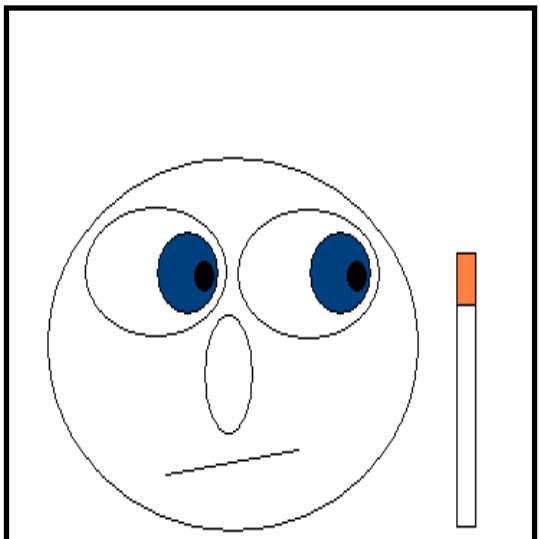


Figure 6 HGN

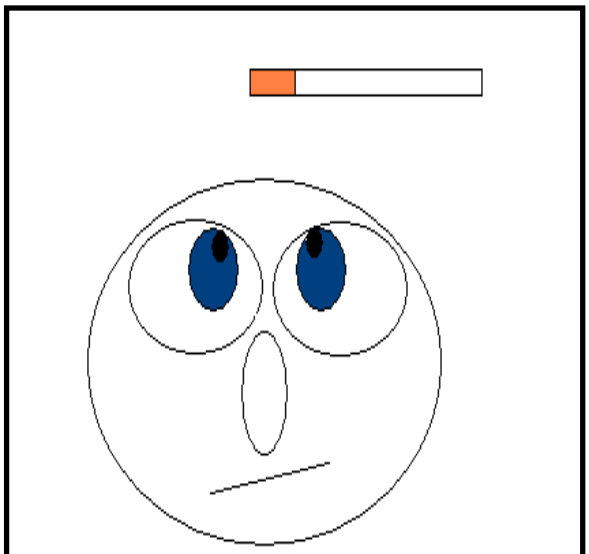


Figure 7 VGN

Scoring: The investigator's aim during this test was to observe the eyes and note if any nystagmus was present. Nystagmus is an involuntary jerking or shaking of the eyeball. Specifically the signs recorded were as follows (the left and right eye were scored separately):

1. Eyes do not pursue 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 up most 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 judged as impaired to a degree equivalent to a blood alcohol concentration (BAC) above 0.10%. One small difference between the typical scoring of SFSTs and the sobriety tests implemented by the Victoria Police is that the Victoria

Police procedure includes the VGN test which incorporates the observation of an additional two possible signs.

2. Walk and Turn (WAT)

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. See Figure 8.

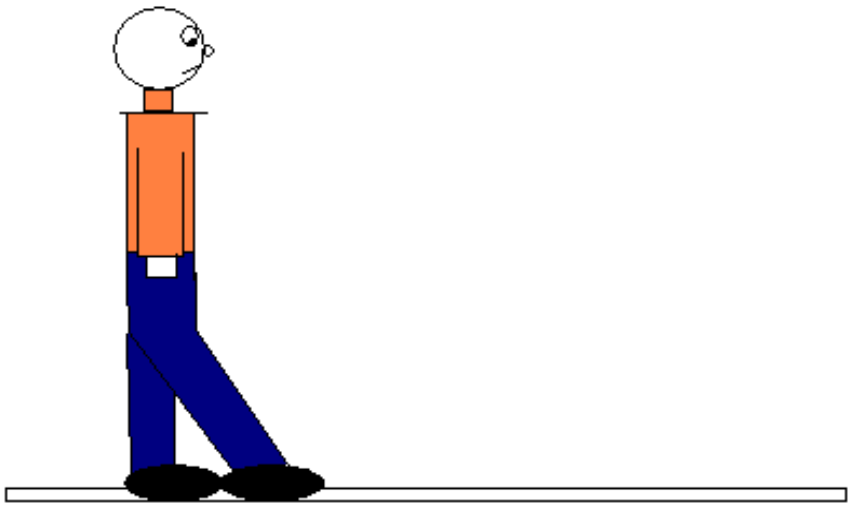


Figure 8 WAT

Scoring: The investigator's aim during this test was to examine 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 judged 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)

This test involved asking the participant to stand on one leg, with the other stretched out in front of them, while counting out 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 aloud 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. See Figure 9.

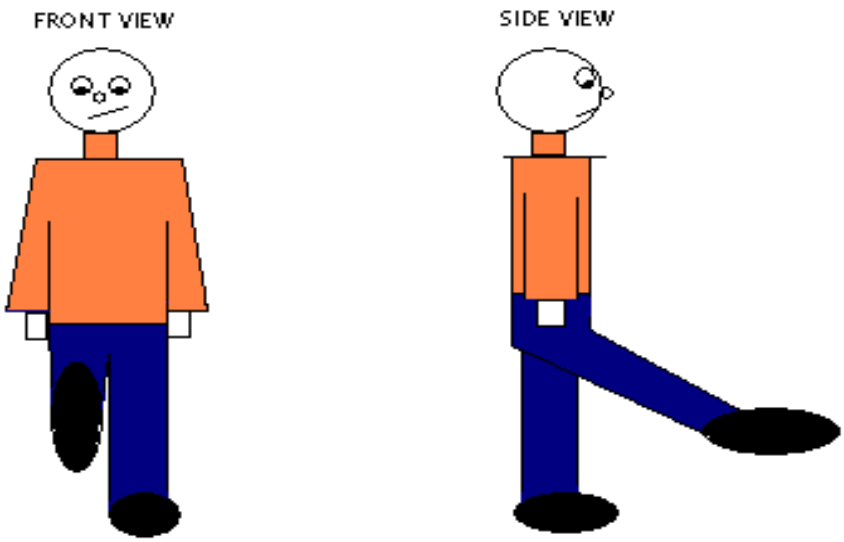


Figure 9 OLS

Scoring: The investigator's aim during this test was to examine 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 judged 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.

7.7.2 Drug Evaluation and Classification Program (DECP) Sobriety Tests

Only two performance tests from the DEC were chosen for this study. The tests were included only to test whether, since these tests are being used in a drug detection program, these tests are more accurate in predicting drug intake compared to the SFST battery alone.

1. Romberg Balance Test (RB)

This test involved asking the participant to stand with their feet together, arms by their side, head tilted back slightly and eyes closed for 30 seconds (estimated by participant). 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 begin, tilt your head back slightly like this (correct head tilt demonstrated) and close your eyes (investigator did not close eyes). Stand perfectly

straight in that position and estimate 30 seconds. After that 30 seconds, open your eyes then tilt your head forward and say 'stop'. 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 begin the test". See Figure 10.

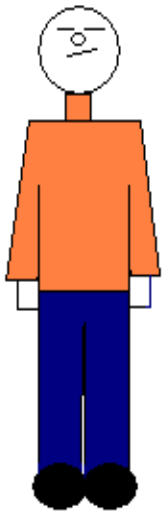


Figure 10 RB

Scoring: The investigator's aim during this test was to examine the stance of the participant during performance. The specific signs recorded were as follows:

1. Feet not together
2. Arms not by side
3. Head not tilted as demonstrated
4. Eyes not closed
5. Swaying during test performance

Each sign observed was recorded as one sign (therefore the maximum number of signs for this test was 5). If two or more signs were observed the participant was judged as impaired to a degree equivalent to a BAC above 0.10%. If the participant failed to complete the test, all 5 signs were recorded.

2. Finger to Nose Test (FTN)

This test involved asking the participant to extend their arms to shoulder height, tilt their head back and close their eyes and then bring the index finger of the specified arm to touch the tip of their nose. 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, keeping your feet together, hold your arms up level with your shoulders with your index fingers pointed. Then tilt your head back slightly and close your eyes (correct stance demonstrated, but investigator did not close eyes). When I say 'right', bring your right index finger to touch the tip of your nose and then return your arm, and when I say 'left', bring your left index finger to touch the tip of your nose and return your arm (correct movements demonstrated). When I say 'stop', bring your arms down, open your eyes and tilt your head forward. 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 "Now get into position". Once the participant was in position the investigator continued "Right (pause after each direction until participant returned arm to original position), Left, Left, Right, Left, Right, Right, Stop". See Figure 11.

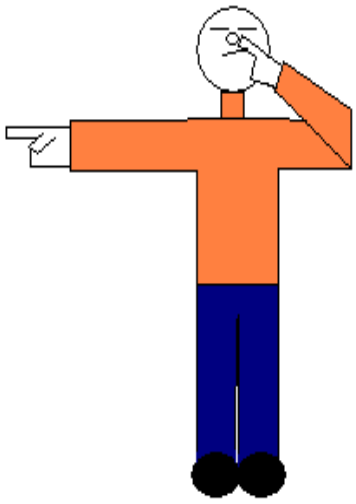


Figure 11 FTN

Scoring: The investigator's aim during this test was to examine the stance and behaviours of the participant during performance. The specific signs recorded were as follows:

1. Eyes not closed
2. Arms not fully extended
3. Arms not level with shoulders
4. Head not tilted as demonstrated
5. Index fingers not pointed/ Index finger not used to touch nose
6. Arms not returned to original position after touching nose
7. Tip of nose not touched

Each sign observed was recorded as one sign independent of how many times it occurred (therefore the maximum number of signs was 7). If 3 or more signs were observed the participant was judged as impaired to a degree equivalent to a BAC above 0.10%. If the participant failed to complete the test, all 7 signs were recorded. It is acknowledged that the administration procedure for the FTN used in the present study differs slightly from the typical administration of the FTN in the DECP. The difference being that the arms in the DECP procedures are placed by the participants sides, as opposed to stretched out.

* All participants were videotaped during their performance. This video footage was used by the investigator to double-check the signs recorded. The score sheet used for the SFST battery is attached as Appendix H.

7.8 Blood samples

Blood samples were taken from each participant throughout all sessions, by a registered nurse. Seven 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 an IV cannula that was inserted into a vein in the forearm of the participant (see Figure 12). Each time a blood sample was taken 10 ml of blood was collected into a heparinised plastic tube. If

participants required saline injections after each sample taken, because of blood clotting, the next sample discarded 2ml (which contained mostly saline) and then 10ml of blood was taken and placed into the tube. Blood samples were immediately placed into a –20ºC freezer. Blood samples were transported (10 minutes travel time) to a –70ºC freezer after 5-7 days.

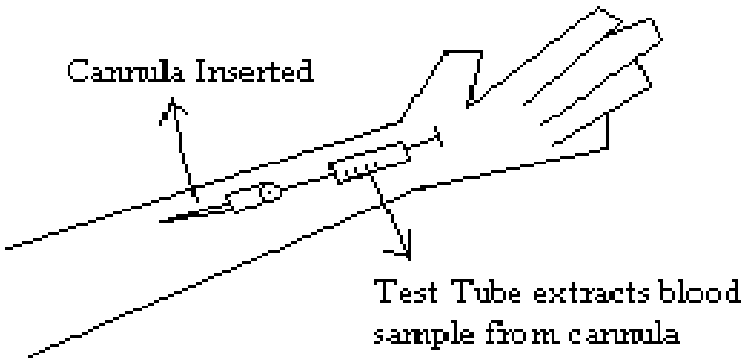


Figure 12 Method used for taking blood samples

Blood samples were analysed for THC levels using the GC/MS method. This method has been documented as the most accurate means of testing for drugs in blood and is often used to verify the presence of drugs for other methods (Gombos, 1999). GC/MS provides a means to confirm and quantify THC in both clinical and postmortem specimens. Specifications of this method are as follows:

Standards: Pure standards of THC and a deuterated analogue of the analyte was used as internal standard (D3-THC) . Stock and working solutions of THC and d3-THC were prepared in methanol, fresh for each assay, to give concentrations in methanol ranging from 1 to 100ng/mL.

Reagents and chemicals: All solvents used were of HPLC grade, while chemicals were of analytical grade or better.

Glassware: All glassware used in the extraction was silanised prior to use to reduce the amount of adsorption of THC to glass. This involved immersing glassware for 1h in a 5% Surfasil solution in toluene (Pierce Scientific, USA) and then rinsing with methanol.

Chromatography and Equipment: A Hewlett-Packard (Melbourne, Australia) Model 6890 gas chromatograph equipped with a Model 5973 mass-selective detector and a Model 7683 automatic liquid sampler was used. The mass spectrometer was operated in the selected ion mode (SIM). Injections (splitless) were performed on a Hewlett-Packard Ultra 2 (5% phenyl methyl siloxane) fused silica capillary column (25m×0.2mm id., 0.33μm film thickness). Helium was used as the carrier gas at a flow rate of 1.6mL/min, in an EI mode. The operative temperatures were as follows: injector 250 °C; column maintained at 70 °C for 1 min and programmed at 20 °C/min to 300 °C, the final temperature being held for 6 min. Analyses of blood were performed by monitoring the following ions: m/z 463, 420 (D3-THC) and 460, 417, 445 (THC).

Extraction: To 1mL of standards, quality controls and blood specimens, 1mL ammonium sulphate reagent was added followed by 7mL of hexane. After extracting for 1h, the solvent was evaporated to dryness and the dried extracts were derivatised with 25μL of pentafluoropropanol and 50μL pentafluoropropionic anhydride for 25 min at 65 °C. The derivatised extracts were evaporated to dryness under nitrogen and reconstituted with 100μL ethyl acetate. 1μL was injected into a gas chromatograph-mass spectrometer

Assay validation: The average extraction recovery in blood for THC is 60-70%. The assay is linear to 100ng/mL and calibration curves are better than r^2=0.99.

Accuracy and Precision: The intra-assay and inter-assay performance is shown in the table below.

Table 3 The intra-assay and inter-assay performance of the GC/MS

Concentration	Coefficient of Variation	Accuracy
Intra-assay variability		
5ng/mL	5.2% (n=10)	5.0 ± 0.1 ng/mL
25ng/mL	3.1% (n=3)	25 ± 2 ng/mL
50ng/mL	2.7% (n=6)	50 ± 1 ng/mL
Inter-assay variability		
10ng/mL	9.6% (n=55)	10 ± 0.3 ng/mL
50ng/mL	9.6% (n=54)	50 ± 2.5 ng/mL

7.9 Procedure

The entire procedure of the project included 5 essential steps, where the final step was comprised of 3 experimental sessions. Prior to commencing the study, a number of application forms had to be completed since the study involved the administration of a drug that is illegal in Victoria. The procedures undertaken to allow the study to proceed are outlined below.

7.9.1 Obtaining Cannabis Cigarettes (Step One)

Since the manufacture and possession of marijuana in Victoria is illegal, and no study in Victoria had ever involved the administration of marijuana to participants, there were many legal and ethical issues that had to be addressed.

Prior to the application of any permits, the investigator had to contact an agency that provides marijuana for research purposes. The National Institute of Drug Abuse (NIDA) is one such agency. A protocol describing in detail the aims and methodology of the current project was delivered to NIDA for review by a research committee. Several months later the protocol was approved and appropriate approval and permits were then sought. These permits consisted primarily of Ethics Approval and a License to Import Controlled Substances.

The first application was submitted to the Swinburne Human Research Ethics Committee (HREC). The application described the project and outlined what doses of cannabis were to be administered. Details on the general effects of cannabis and safety procedures to be implemented in case of any adverse effects were described. After considerable debate over safety concerns the application was finally approved and the investigator proceeded to obtain a License to Import Controlled Substances (LICS).

Prior to an import license application, a Clinical Trials Notification (CTN) was submitted together with an application for a Permit to Purchase or Otherwise Obtain Poisons or Controlled Substances for Industrial, Educational or Research Purposes for schedule 8 and 9 drugs (permit to obtain marijuana). After several requirements were fulfilled and an extensive review process was complete, the permits were obtained. An application form for a LICS was submitted with the CTN, and the permit to obtain

marijuana, attached. Some time after, the LICS was granted and sent off together with the HREC (ethics) approval, to NIDA. Three months later the marijuana cigarettes arrived in Victoria and the project commenced.

The submission and approval of all permits and licenses required over 10 months to complete.

7.9.2 Consent Forms and Information Sheet (Step Two)

Brief advertisements describing the need for volunteers to participate in a marijuana, driving, and sobriety study, were placed in community newspapers, and community and university notice boards. All individuals interested in participating in the study were then handed an information sheet that described the study in more detail (see Appendix A). Any queries were answered, and if the individual was satisfied with the details, they completed and signed a consent form (Appendix A). Participants were then booked in for their medical examination and allocated a subject number.

7.9.3 Medical Examinations (Step Three)

All participants underwent a medical examination administered by a general practitioner. Before the examination participants completed a patient questionnaire (Appendix B). The questionnaire was discussed in detail during the medical examination and other medical tests were performed (Appendix C). The medical practitioner then formed an opinion on whether the participant was fit to participate in the study. Individuals fit to participate were handed a number of questionnaires (outlined below). Individuals not fit to participate were thanked for their interest in the study and informed that they did not fit the appropriate criteria to participate.

7.9.4 Treatment Order

Once participants passed the medical examination and other entry criteria to participate in the study, their subject number was used to determine their initial treatment condition. Subjects were allocated to treatment conditions using a double-blind (coding), randomised (Latin square design) and counter-balanced procedure (see

Appendix F). The counter-balanced procedure was used to determine which treatment session the subject would first participate in. The first participants to begin the study was determined by subject number, allocation of participants to the trial was random and therefore there was no ordered sequence of drug administration.

7.9.5 Questionnaires (Step Four)

Participants were given a number of questionnaires including a Demographics questionnaire and Frequency of Cannabis Use questionnaire. Participants were allowed to take the questionnaires home to complete and return on the first experimental session. See Appendix D and E.

7.9.6 Experimental Conditions (Step Five)

Participants were escorted to the Pharmacology lab where they were fitted with an IV cannula that was inserted into a vein in their forearm. Once the cannula was comfortable one 10ml blood sample was taken. The participant was then handed a cannabis cigarette which contained either 0% THC (.000gm Δ-9-THC), 1.74% THC (.813gm Δ-9-THC) or 2.93% THC (1.776gm Δ-9-THC). Each subject was allocated the first treatment condition using a Latin square randomization, counter-balanced, repeated measures design (Appendix F). 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 secs they were asked to exhale when they felt they could no longer hold. Eight inhalations were completed and the cigarette was wet and disposed of in a hazard waste bin. This procedure is similar to that used by Cone and Huestis (1993). The amount of cigarette remaining after each smoking session was not measured (discussed in 10). Another 10ml blood sample was taken and the cannula was then covered with a cotton wool square.

Participants proceeded onto the Sobriety testing laboratory where they were asked to perform the HGN test, the WAT, the OLS, the RB and finally the FTN test. Participants were then escorted to the pharmacology lab for another blood sample.

Participants then proceeded to the driving simulator, which was located at the rear of the building in a custom built enclosure. Once subjects were comfortably seated in the simulator they performed the Basic Module Test to familiarise themselves with all the controls. Once subjects felt comfortable, they were asked to complete the Driving Module Test consisting of freeway and city traffic. Participants were then escorted to the pharmacology lab for another blood sample.

Subjects completed the sobriety tests again, another blood sample was taken, the driving simulator test was performed for the last time, another blood sample was taken, the sobriety test was performed for a last time and a final blood sample was taken. The cannula was then carefully removed and a band-aid was placed over the incision.

Participants were finally asked to complete an Intoxication Rating questionnaire (Appendix G). Once this was done, a taxi was called for the participant and a taxi voucher was provided. At the end of the final session participants were paid and thanked for their participation.

Table 4 details a timeline for one experimental session.

Table 4 The timeline for one experimental session

Time	Task
0 mins	Blood sample 1
5 mins	THC Consumption
15 mins	Blood sample 2
20 mins	SFSTs
40 mins	Blood sample 3
45 mins	Driving Task
65 mins	Blood sample 4
70 mins	SFSTs
90 mins	Blood sample 5
95 mins	Driving Task
115 mins	Blood sample 6
120 mins	SFSTs
140 mins	Final Blood sample 7
145 mins	End of Test (Taxi)

All experimental sessions for 40 participants required 300 hours of testing to complete.

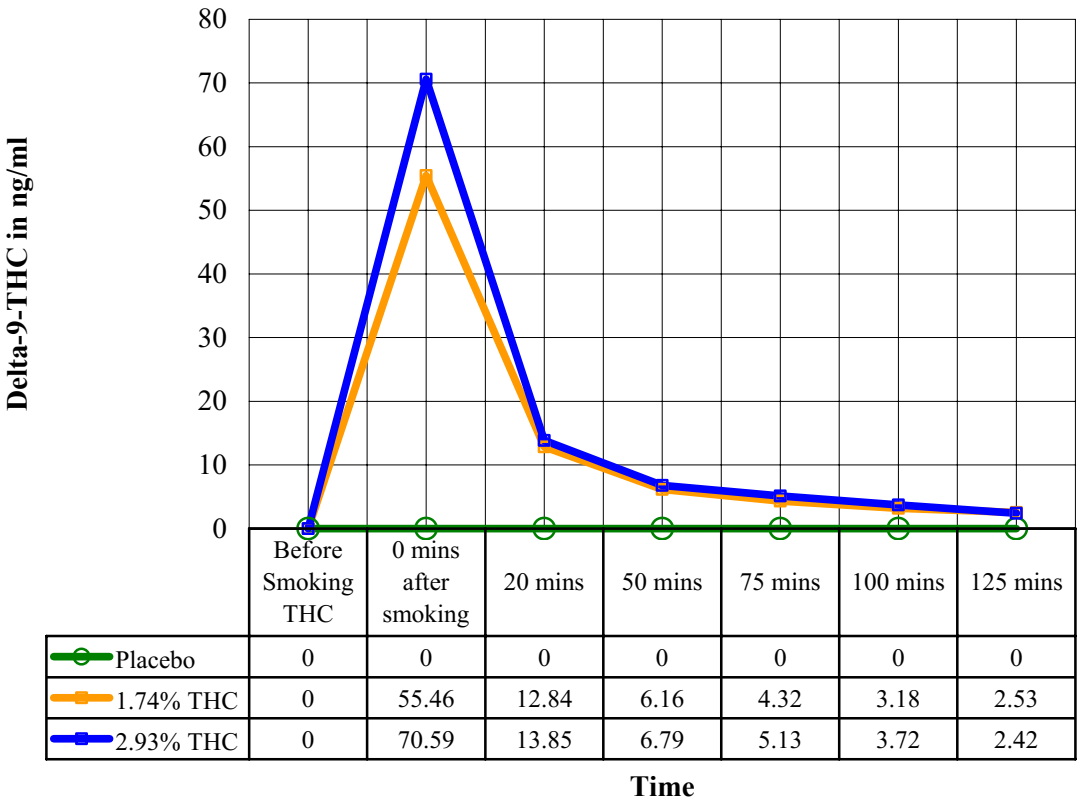
Chapter Eight: Results

8.1 The level of THC in blood

8.1.1 Cannabis Dose and Level of THC in Blood

Blood samples were taken throughout each experimental session approximately 20 minutes apart. A blood sample was taken before smoking cannabis, immediately after, and an additional 5 blood samples were collected after the administration of each test. In total 7 blood samples were taken. Figure 13 displays the mean level of THC (delta-9-tetrahydrocannabinol) present in each blood sample across all subjects.

Figure 13 Level of THC in blood after smoking placebo, low and high dose cannabis cigarettes.



	Before Smoking THC	0 mins after smoking	20 mins	50 mins	75 mins	100 mins	125 mins
Placebo	0	0	0	0	0	0	0
1.74% THC	0	55.46	12.84	6.16	4.32	3.18	2.53
2.93% THC	0	70.59	13.85	6.79	5.13	3.72	2.42

Using SPSS Statistical Package (version 10) a repeated measures ANOVA revealed that there was a significant difference between the levels of THC found in the blood between

the three THC conditions at 0 mins, 20 mins, 50 mins, 75 mins, 100 mins and 125 mins after smoking cannabis. There was no significant difference between the levels of THC in the blood between THC conditions prior to smoking cannabis. The difference between the level of THC in blood between the low and high THC conditions, 50 mins and beyond, is not different. It appears that at 50 mins and later, the metabolism of THC occurs at a fast enough rate to reduce the level of THC in blood to a constant low level. A more detailed table of the level of THC in blood for each subject at each time point is attached as Appendix I.

8.1.2. Cannabis Dose, Level of THC in Blood and Frequency of Cannabis Use

The frequency of cannabis use for non-regular and regular cannabis users was evaluated using SPSS Statistical Package (Version 10) Crosstabulation tests. The concentration of THC in blood was examined using a mixed design 3 x 2 ANOVA for each time point (7 samples), in order to examine whether there were any differences in the level of THC in the blood for each THC condition between non-regular and regular cannabis users. We also specifically examined whether the mean level of THC (ng/ml) at any time point was significantly different for non-regular and regular users.

Table 5 "How often do you consume cannabis?" by Frequency of Cannabis Use

How often do you consume cannabis?	Frequency of Cannabis Use		Total
	Non-Regular Users	Regular Users	
Once a day		5	5
Once a week		8	8
Once a month		9	9
Once every two months	10		10
Rarely	8		8
Total	18	22	40

A Crosstabulation analysis revealed that all non-regular users smoked cannabis less often than once a month, where the majority smoked once every two months. All

regular users smoked cannabis more often than once a month, where the majority smoked cannabis once a week to once a month (see Table 5).

Table 6 "How do you consume cannabis?" by Frequency of Cannabis Use

How do you consume cannabis?	Frequency of Cannabis Use		Total
	Non-Regular Users	Regular Users	
Smoked in a joint	15	7	22
Smoked using a pipe/bong	3	15	18
Total	18	22	40

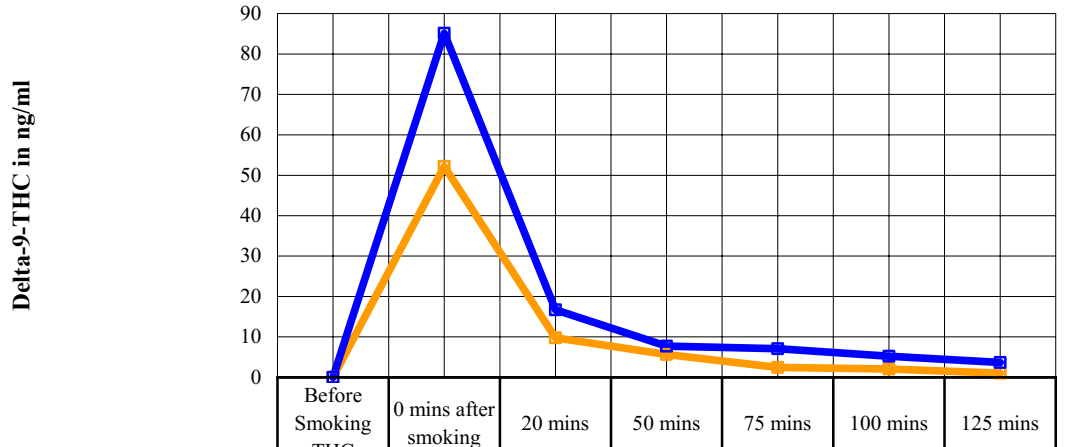
A Crosstabulation analysis revealed that the majority of non-regular users smoked cannabis as a cigarette ("joint"), whereas the majority of regular cannabis users smoked cannabis with a pipe ("bong") (see Table 6). This difference indicates that regular users may often obtain higher levels of THC, compared to non-regular users, as when cannabis is smoked using a pipe/bong, there is a smaller loss of THC with side stream smoke (Hall et al., 1998).

The results revealed that there were no differences in the linear relationship between the level of THC in blood and THC condition. For both groups there was a positive linear relationship between level of THC in the blood and THC condition, for all time points with the exception of sample 1 (before smoking). There was, however, a significant difference in the mean level of THC at sample 2 (peak blood level, immediately after smoking) between both groups. Regular users had significantly higher levels of THC in their blood in both the low THC condition and the high THC condition, when compared to non-regular users ($F(1,30)=69.8$, $p<.05$). The mean level of THC in the blood was not significantly different for the remaining samples for both groups.

Figure 14 Level of THC in blood for regular users and non-regular users for the low THC condition.

	Before Smoking THC	0 mins after smoking	20 mins	50 mins	75 mins	100 mins	125 mins
Non-regular Users	0	39.09	12.44	6.28	4.19	2.51	2.75
Regular Users	0	68.56	13.19	6.07	4.43	3.69	2.34

Figure 15 Level of THC in blood for regular users and non-regular users for the high THC condition.



	Before Smoking THC	0 mins after smoking	20 mins	50 mins	75 mins	100 mins	125 mins
Non-regular Users	0	52.19	9.79	5.65	2.46	2.07	1.04
Regular Users	0	85.13	16.72	7.71	7.09	5.23	3.7

Figure 14 displays the differences in the level of THC in the blood for regular users and non-regular users for the low THC condition. Figure 15 displays the differences in level of THC in the blood for regular users and non-regular users for the high THC condition.

8.2 Cannabis and intoxication ratings

8.2.1 Cannabis Dose and Intoxication Ratings

Participants completed an Intoxication Rating Questionnaire at the end of each experimental condition. Participants were blind to the level of THC they had consumed in each session. The questionnaires were used to assess the relationship between the level of THC in the cannabis cigarettes used in this study compared to the strength of cannabis usually smoked by the participants ("street" cannabis). The data from the questionnaires were analysed using the SPSS Statistical Package (Version 10).

Strength of Cannabis Cigarettes

Table 7 Intoxication Rating: Strength of Cannabis for each dose of THC administered

Intoxication Rating: Strength of Cannabis	Placebo THC	Low THC	High THC
"Much weaker"	**87.5%**	12.8%	5.1%
"A little weaker"	12.5%	15.4%	7.7%
"The same"		**43.6%**	17.9%
"A little stronger"		17.9%	**30.8%**
"Much stronger"		10.3%	**38.5%**
Total	100%	100%	100%

The results of the Intoxication Rating Questionnaire showed that after smoking the placebo THC cigarettes (0% THC) the majority of participants stated that it was "much weaker" compared to the cannabis cigarettes that they usually smoke.

For the low THC cigarette condition (1.74% THC) the majority of participants stated that the cigarette that they had smoked was "the same" as the cannabis cigarettes that they usually smoke.

For the high THC cigarette condition (2.98% THC) the majority of participants stated that the cannabis cigarette that they had smoked was "much stronger" and "a little stronger" than the cannabis cigarettes that they usually smoke (see Table 7).

These results suggest that the objective of using cigarettes that contain levels of THC equivalent to those found in "street" cannabis, was achieved. Most participants agreed that each level of cannabis cigarette could indeed be classed as they were labeled, ie. 0% THC was the placebo, 1.74% THC was low or moderate dose and 2.93% THC was high dose. Using this data, it is assumed that any decrements in performance observed in this study can be generalised to the consumption of "street" cannabis.

General Effects of Cannabis Cigarettes

Table 8 Intoxication Rating: Effects of Cannabis for each dose of THC

Intoxication Rating: Effects of Cannabis	Placebo THC	Low THC	High THC
"No effects at all"	**85%**	5.1%	
"The same effects"	2.5%	**53.8%**	**41%**
"A few different effects"	7.5%	38.5%	**41%**
"Very different effects"	5%	2.6%	18%
Total	100%	100%	100%

The results showed that for the placebo cigarettes, the majority of the participants felt "no effects at all", physiological or psychological, compared to cannabis cigarettes that they would usually smoke.

For the low THC cigarette condition (1.74% THC) the majority of participants described the general effects of the cannabis cigarette they had smoked as having "the same effects" as cannabis that they usually smoke.

The high THC (2.93% THC) cigarette condition was described as having "a few different effects" and "the same effects" by of the majority of participants (see Table 8).

These results indicate that in most cases, the effects experienced after the consumption of each cannabis cigarette are representative of the strength of that cigarette, in which the higher the THC content, the more effects were reported, such as relaxation, changes in motor coordination, attention, distorted sense of time, and laughter.

Since the group was comprised of both regular and non-regular cannabis smokers, the actual perceived effects were slightly different for each group (discussed in 8.2.2). Overall, the perceived effects described by each participant appears consistent with the average "street" cannabis cigarette that they have previously or regularly consumed. The main changes recorded included; red eyes; increased heart rate; decreased motivation; increased relaxation; time distortion; the feeling of heavy limbs; and the most frequent, uncontrollable laughter.

8.2.2 Cannabis Dose, Intoxication Ratings and Frequency of Cannabis Use

Strength of Cannabis

Table 9 Differences between Non-regular and Regular Cannabis Users: Strength of the dose of THC administered

Intoxication Rating: Strength of Cannabis	Non-regular Cannabis Users			Regular Cannabis Users		
Dose of THC	Placebo THC	Low THC	High THC	Placebo THC	Low THC	High THC
"Much weaker"	**94.4%**			**81.8%**	**22.7%**	**9.2%**
"A little weaker"	**5.6%**	17.6%		**18.2%**	13.6%	**13.6%**
"The same"		**47.1%**	11.8%		**40.9%**	**22.7%**
"A little stronger"		**23.5%**	**41.1%**		13.6%	**22.7%**
"Much stronger"		11.8%	**47.1%**		9.2%	**31.8%**
Total	100%	100%	100%	100%	100%	100%

With respect to the strength of the cannabis cigarettes used in the present study the majority of non-regular users described the placebo cigarette as being "much weaker" compared to cannabis that they usually consumed. A smaller percentage of regular

users on the other hand described the placebo as being "much weaker" and larger percentage "a little weaker" compared to non-regular users.

The low THC cigarette was described as "the same" strength as cannabis that they usually smoked for the majority of non-regular users and also "a little stronger". Regular users on the other hand described the Low THC as "the same" in the majority of cases but was also described as "much weaker", unlike in non-regular users.

The high THC cigarette was described by non-regular users as either "much stronger" and "a little stronger" compared to the cannabis that they usually consumed. No non-regular users described the cigarette as weaker. In comparison, regular users described the High THC cannabis cigarettes as "much stronger" in a smaller number of cases compared to non-regular users. A higher percentage of regular users also reported that the high THC cigarette was "the same", "a little weaker" and "much weaker" compared to the strength of cannabis that they usually consume (see Table 9).

These results indicate that the non-regular and regular users reported different perceptions on the strength of the cannabis cigarettes used in the present study. Specifically, the non-regular users reported to usually consume cannabis of similar strength to the Low THC cigarettes used in this study. Regular users on the other hand reported to usually smoke cannabis of the same strength as, or stronger than, the Low THC cigarettes used in this study. In addition, a higher percentage of regular users rated the High THC cigarettes as "the same" or "weaker" than cannabis usually consumed, when compared to non-regular users. These differences are most likely related to the fact that all the regular users who participated in this study consume cannabis significantly more often than the non-regular users in this study (8.1.2, Table 5 and Table 6).

General Effects of Cannabis

The psychological and physiological effects of the cannabis cigarettes used in this study were described differently by non-regular and regular users.

Table 10 Differences between Non-regular and Regular Cannabis Users: Effects of the dose of THC administered

Intoxication Rating: Effects of Cannabis	Non-regular Cannabis Users			Regular Cannabis Users		
Dose of THC	Placebo THC	Low THC	High THC	Placebo THC	Low THC	High THC
"No effects at all"	**94.4%**			**77.3%**	**9.1%**	
"The same effects"	5.6%	**47.1%**	29.2%	4.5%	**59.1%**	**50%**
"A few different effects"		**47.1%**	**52.9%**	13.7%	31.8%	31.8%
"Very different effects"		5.8%	17.9%	4.5%		18.2%
Total	100%	100%	100%	100%	100%	100%

Most non-regular users described the placebo cigarettes as having "no effects at all", with the remaining stating that they experienced "very different effects" compared to cannabis that they usually smoke. Regular users on the other hand described the placebo as having "no effects at all" in a smaller number of cases compared to the non-regular users, "a few different effects", "very different effects" and "the same effects" in the remaining cases.

The Low THC cigarettes were described as having "a few different effects" and "the same effects" in the majority of non-regular users. Most regular users described the Low THC cigarette as having "the same effects" as cannabis that they usually smoke. Unlike the non-regular users, some regular users reported that the low THC cigarette had "no effects at all".

The High THC cigarette was described by most non-regular users as having " a few different effects". The effects of the High THC cigarette were described as "the same effects" as cannabis usually smoked by most regular users (see Table 10).

These results suggest that the perceived physiological and psychological effects of cannabis are different for non-regular users and regular users. Overall, most non-regular users reported that the Low THC cigarettes produced the same psychological and physiological effects as cannabis that they usually consume. Regular users on the

other hand reported that both the Low THC cigarette and High THC cigarette produced the same effects as the cannabis that they usually consumed. One interesting finding was that when describing the effects of the placebo cigarette, almost all non-regular users described the cigarette as having no effects, whereas some regular users stated that they did feel some psychological and physiological effects. This may be an indication of the over-use of cannabis by regular users. Specifically, for regular users the act of smoking real cannabis (with its more than 60 alkaloids) may trigger a series of conditioned physiological and psychological responses. In addition, the effects of cannabis may no longer be obvious to regular users whereby they assume that some effects must exist even though they are not very apparent/intense (expected effects). These differences are most likely related to the fact that all the regular users who participated in this study consume cannabis significantly more often than the non-regular users in this study (8.1.2, Table 5 and Table 6).

8.3 Cannabis and driving performance

8.3.1 Cannabis Dose and Driving Performance

The relationship between driving simulator performance and cannabis condition was investigated using Analysis of Variance Repeated Measures design. Any differences in scores on any of the driving variables between two or more of the three THC conditions were examined. The timeline of procedures for marijuana administration, test administration and blood taking is outlined in detail in 7.9.6. Participants performed the driving task twice, once at 30 mins after THC consumption and the other at 80 mins after THC consumption, each time point was analysed separately using a repeated measures ANOVA. The results from the separate ANOVAs performed on each variable are summarised in table 11.

Table 11 Summary of separate repeated measures ANOVAs for each driving variable with level of THC

Driving Simulator Variables	Significance	Value
Time	**Time 1**	**Time 2**
1. Over-revved too long	ns	ns
2. Park Break on while travelling	ns	ns
3. Skid	ns	ns
4. Off the road	ns	ns
5. Collision	ns	ns
6. Straddled the solid line	p=.09	p<.05
7. Exceeded speed limit	ns	ns
8. No observation when moving off	ns	ns
9. No signal when moving off	ns	ns
10. Car rolling when moving off	ns	ns
11. No signal cancel when moving off	ns	ns
12. Incorrect steering method	ns	ns
13. No observation when steering	ns	ns
14. Wide/Cut	ns	ns
15. Wandering	ns	ns
16. Incorrect position of car	ns	ns
17. Straddled barrier line	p=.08	p<.001
18. No signal when changing lane	ns	ns
19. No signal cancel when changing lane	ns	ns
20. Not sufficient clear space when overtaking	ns	ns
21. No mirror checks	ns	ns
22. Driving too fast	ns	ns
23. Driving too slow	ns	ns
24. Inappropriate Acceleration	ns	ns
25. Inappropriate Deceleration	ns	ns
26. Inappropriate Braking	ns	ns
27. No safe following distance	ns	ns
28. Not sufficient clear space when stopping	ns	ns
29. Needless/Unnecessary stop	ns	ns
30. Not sufficient clear space when merging	ns	ns
31. No stop for emergency	ns	ns
32. Uncontrolled stop for emergency	ns	ns
33. Reaction time (emergency stop)	ns	ns
34. Stopping distance from vehicle/object	ns	ns
35. Distance from vehicle/object at stop	ns	ns
36. Skidding when stopping	ns	ns

ns= not statistically significant at the p<.05 level.

The results from the ANOVAs indicated that the level of THC influenced two variables: straddling the solid line and straddling the barrier line.

The level of THC influenced straddling the solid line at Time 1, with scores increasing with increasing levels of THC. This relationship approached significance ($F(2,70)=2.773$, $p=.09$). At Time 2, however the difference in scores was greater than at

Time 1 and the relationship was significant ($F(2,68)=5.016$, $p<.05$). These results suggest that THC consumption can cause individuals to straddle solid lines, indicating that two or more wheels of their vehicle moves over a solid line (unbroken) that is marked out for traffic moving in the opposite direction (oncoming traffic). This predominantly occurs approximately 80 mins after the consumption of cannabis.

THC also influenced the driving variable straddling the barrier line at Time 1, with scores increasing with increasing levels of THC and again this relationship approached significance at Time 1 ($F(2,70)=2.645$, $p=.08$). At Time 2 this relationship was stronger and statistically significant ($F(2,68)=9.116$, $p<.001$). These results suggest that cannabis consumption results in drivers straddling barrier lines, where two or more wheels of their vehicle moves over a broken line marked out for traffic moving in the same direction. This occurs predominantly 80 mins after the consumption of cannabis.

Assuming that the variables included in the ANOVAs are independent, we would expect (with an alpha of .05) to calculate 1 in every 20 ANOVAs to be significant by chance. However, given that many of the variables are inter-correlated, the number of Type I errors will be less than 1 in 20. Given that there was great sensitivity in the driving variables that were significant (a relationship observed at Time 1 and Time 2), it is unlikely that the ANOVAs were significant by chance. In addition, the results are consistent with findings reported in previous research on cannabis and driving behaviour (discussed in 9.2).

A repeated measures ANOVA using Time as a between subject factor was also performed on the data to examine whether there were any changes across time that were different between the three THC conditions. In other words, did one treatment condition change performance scores in a different direction over time compared to another treatment condition. All relationships were non-significant. This suggests that the direction of changes in performance over time did not differ between the treatment conditions.

These results suggest that cannabis intoxication is most likely to affect appropriate car control. Specifically, the ability to maintain a vehicle's position in allocated traffic

lanes. This impairment is most obvious approximately 80 minutes after smoking low or high levels of THC.

Overall driving performance was also examined. All variable scores were added together. An individual scoring between 0 and 75 was classified as 'not impaired on the driving simulator task'. A total score of 76 and above constituted a classification of 'impaired on the driving task'. A correlation statistic was performed to establish whether there was a relationship between overall driving impairment at Time 1 or at Time 2 (impaired/not impaired) and level of THC. The results suggest that there is no significant linear relationship between the level of THC and overall driving ability at Time 1 or at Time 2. This indicates that the number of individuals classified as impaired on the driving task did not increase or decrease from the low to the high THC condition, suggesting that in both conditions a similar number of individuals were classified as impaired. The raw data supports that the number of individuals classified as impaired on the driving task was similar for both the low and high THC condition. The number of individuals classified as impaired in the low and the high THC condition was high when compared to the placebo condition, where this difference was largest for overall driving performance at Time 2. This findings suggest that it is important to examine driving variables separately (as opposed to overall driving) when driving impairment related to increasing levels of THC is required, or a larger sample may be required to obtain significant relationships.

8.3.2 Cannabis Dose, Driving Performance and Frequency of Cannabis Use

Frequency of cannabis use was examined using a mixed design 3 x 2 ANOVA for all driving performance variables. These statistics were used to examine whether there were any differences in the effect of THC to alter performance for non-regular and regular users. If the manner by which THC consumption alters performance is the same for both groups, then whether or not the mean number of errors (the magnitude of score changes) was statistically different for non-regular and regular users was examined.

Results for the driving variables assessed at Time 1, revealed that the relationship between only one driving variable, "Car rolling when moving off" and the level of THC was statistically different for non-regular and regular users ($F(2,68)=3.2$, $p<.05$). For

non-regular users, car rolling when moving off occurred more as the level of THC increased, whereas for regular users, car rolling when moving off occurred less as the level of THC increased.

Results for the driving variables assessed at Time 1, revealed that the relationship between the driving variables "Inappropriate steering method", "Inappropriate acceleration" and "Advanced driving: RT" and the level of THC was positive for both non-regular users and regular users where as the level of THC increased so did the number of times each variable was recorded. Both groups, however, recorded a significantly different mean number of errors for each THC condition (where the magnitude of score change was greater for regular users). For "Inappropriate steering method", regular users made this error more often than non-regular users in all three THC conditions ($F(1,34)=5.4$, $p<.05$). For "Inappropriate acceleration", regular users made this error more often than non-regular users in all three THC conditions ($F(1,34)=4.4$, $p<.05$). Finally, for "Advanced driving: RT", regular users recorded significantly faster RTs than non-regular users when stopping in an emergency situation during the driving task ($F(1,34)=5.002$, $p<.05$).

The relationship between level of THC and the remaining driving variables at Time 1 showed a positive correlation for both regular users and non-regular users (there was no difference in the direction of the relationship between driving variable and THC dose between both groups). In addition, there were no significant differences in the mean scores on these variables between regular users and non-regular users.

For the driving variables assessed at Time 2, there was no significant interaction between level of THC, driving variables and frequency of cannabis use (regular and non-regular users). There was, however, a significant difference between the mean number of errors (the magnitude of the change in scores between the treatment conditions), between regular and non-regular users, for two variables at Time 2; "Collision" and "Advanced driving: Distance from object". Non-regular users had significantly more collisions than regular users during all THC conditions ($F(1,33)=3.961$, $p=.05$). Non-regular users had a significantly shorter distance between the vehicle and object, after stopping for an emergency situation, than regular users ($F(1,33)=4.942$, $p<.05$). There were no significant differences between the mean scores

obtained on the remaining driving variables at Time 2 across non-regular users and regular users.

8.4 Cannabis and sobriety test performance

8.4.1 Cannabis Dose and Sobriety Test Performance

Sobriety test performance was examined by comparing the percentage of participants exhibiting each signs/errors in each cannabis condition. Chi-square ($\chi 2$) tests were applied to the data to establish whether the presence of a sign, and the THC condition was related or independent. Spearman's coefficient (ρ) was used to determine the strength and direction of that relationship. The aim was to establish which signs are the best predictors of impaired performance associated with THC intoxication. Participants performed the SFSTs followed by the RB and FTN, three times: once at 5 mins after the consumption of THC (Time 1); a second time at 55 mins after the consumption of THC (Time 2); and a final time at 105 mins after the consumption of THC (Time 3). Each sobriety test and time interval was analysed separately.

Sobriety Test Performance TIME 1

The sobriety tests performed at Time 1 are performance at 5 minutes after the consumption of cannabis.

SFSTs

Analysis was performed on each test that comprise the SFST battery, as well as overall SFST battery performance (addition of HGN, WAT and OLS test).

1. HGN

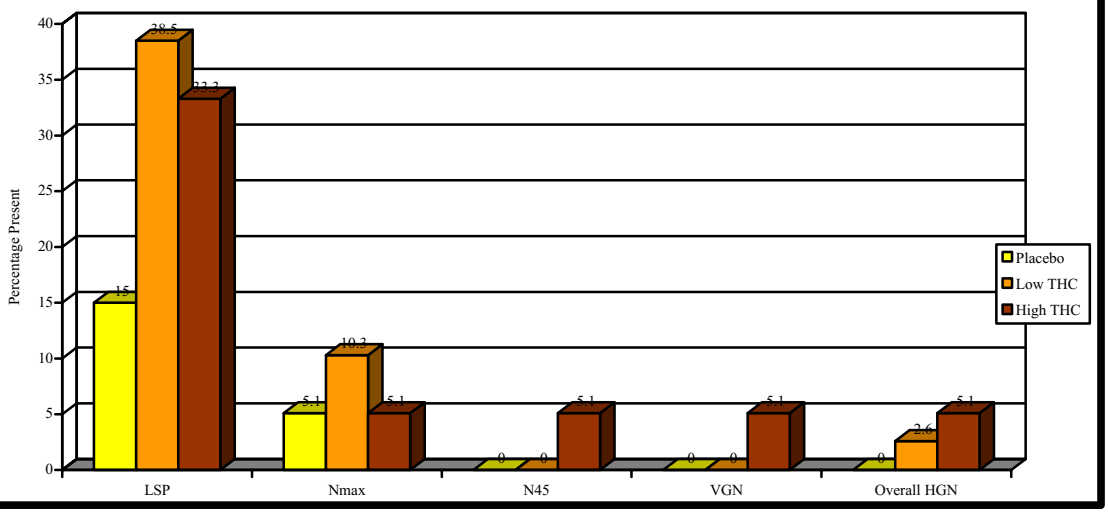
There were four signs scored in the Horizontal Gaze Nystagmus (HGN) test to determine potential impairment. These signs include:

1. Eyes do not pursue smoothly (Left: Yes/No, Right: Yes/No) (LSP)
2. Distinct Nystagmus at maximum deviation (Left: Yes/No, Right: Yes/No) (NMax)
3. Nystagmus onset before 45 degrees (Left: Yes/No, Right: Yes/No) (N45)

4. Nystagmus at up most position (vertical) (Left: Yes/No, Right: Yes/No) (VGN)

Figure 16 outlines the percentage of individuals that exhibited each sign in each THC condition.

Figure 16 Percentage of individuals exhibiting each sign of the HGN test in each THC condition at Time 1.



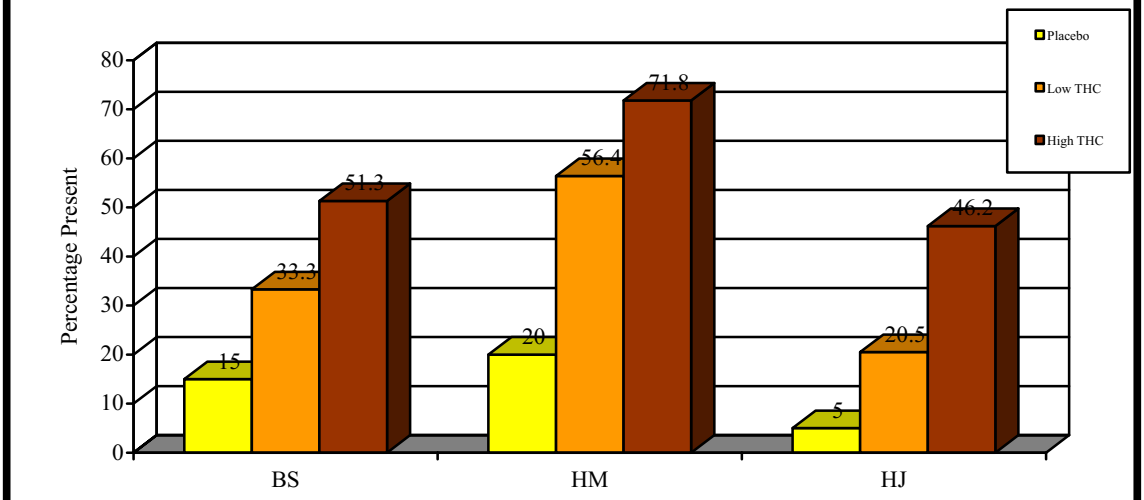
Crosstabulation Chi-square tests were performed on each sign and level of THC. This test revealed that none of the signs alone or Overall HGN performance was significantly related to THC level. These results suggest impairment on the HGN occurs independent of THC level.

Throughout the administration of the HGN test other signs were exhibited during performance, which are not included in the typical administration and scoring of the HGN test. These 'new' signs were recorded and scored to explore their possible effectiveness in detecting impairment associated with THC. These 'new' signs included:

1. Body Swaying (movement of body, back and forth/side to side, while observing stimulus) (BS)
2. Head Movements (head not kept still, moving side to side/following stimulus, while observing stimulus) (HM)
3. Head Jerks (head not still, jagged movements/head jerking) (HJ)

Figure 17 shows the percentage of individuals exhibiting these new signs, in each THC condition.

Figure 17 Percentage of individuals exhibiting each new sign during the HGN test in each THC condition at Time 1.



A chi-square test for each new sign and level of THC revealed that all three of the signs were significantly related to THC level. BS, HM and HJ were significantly related to the level of THC ($\chi 2=11.8$, df=2, $p<.005$; $\chi 2=22.4$, df=2, $p<.001$; $\chi 2=18.8$, df=2, $p<.001$ respectively). The relationship between BS, HM, and HJ, with the level of THC, was significantly positive ($\rho=.3$, $p<.005$; $\rho=.4$, $p<.001$; $\rho=.4$, $p<.001$ respectively), suggesting that as the level of THC increases, so does the likelihood that each of these signs will be observed during HGN performance. HM had the strongest relationship with THC condition.

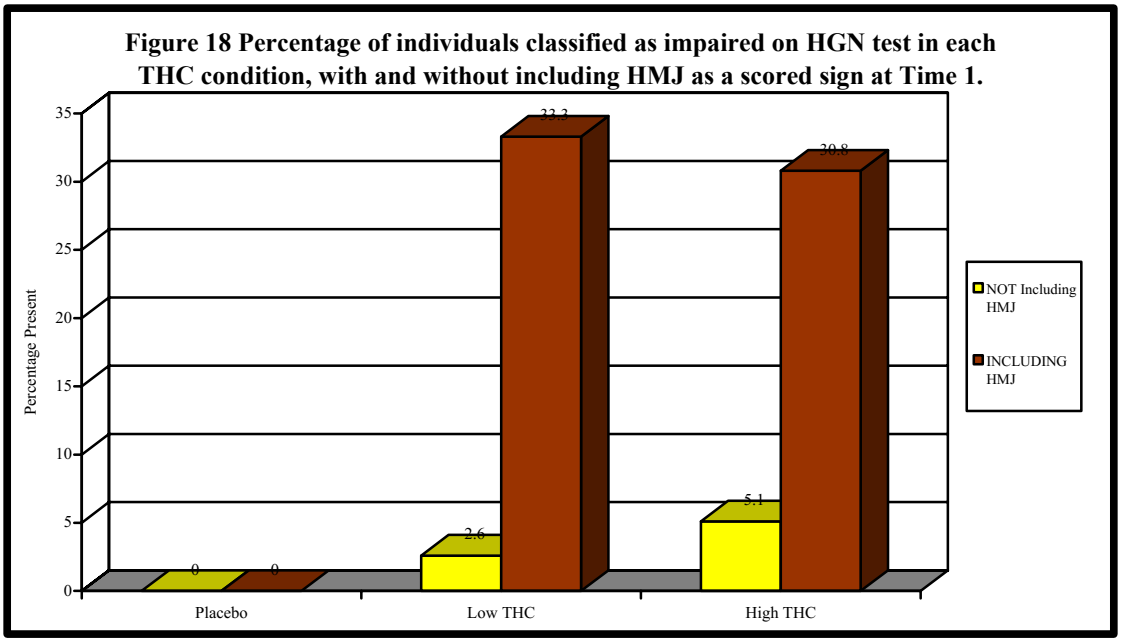
Although some of the new signs recorded in this study may be discussed in sobriety test procedures/training as signs that should be noted during performance, they are nevertheless not included in the actual scoring of the test. Head movements were observed in the highest percentage of individuals in both the low and high THC condition, compared to any other sign scored. For this reason this sign became an additional focus of the present study as it appeared to be relevant to marijuana

intoxication. Head movement/jerk (HMJ) was recorded as an observed sign if it occurred more than once, where it was then scored as 2.

The inclusion of the sign, HMJ, in the scoring procedure increased the percentage of individuals classified as impaired on the HGN test. The inclusion of HMJ did not increase the number of individuals classified as impaired in the placebo session, suggesting that HMJ is specific to impairment associated with the consumption of THC (see Figure 18).

A Chi-square test on the inclusion of HMJ as a sign scored in the HGN test and the level of THC indicated that overall HGN performance and level of THC was related ($\chi 2=16.3$, df=2, $p<.001$). This relationship was positive and statistically significant ($\rho=.3$, $p<.005$), suggesting that as the level of THC increases, so does the likelihood that an individual will be classified as impaired on the HGN test when taking into account HMJ. This is not the case when HMJ is not scored.

Figure 18 Percentage of individuals classified as impaired on HGN test in each THC condition, with and without including HMJ as a scored sign at Time 1.



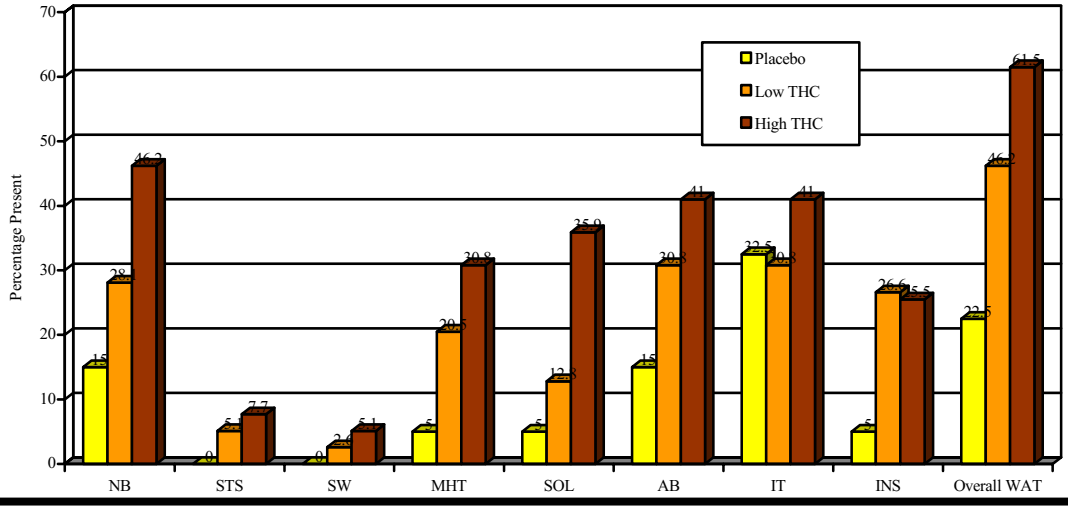
2. Walk and Turn

There were eight signs scored in the Walk and Turn (WAT) test to determine impairment. These signs included:

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

Figure 19 shows the percentage of individuals that exhibited each sign in each THC condition.

Figure 19 Percentage of individuals exhibiting each sign during the WAT test in each THC condition at Time 1.



Chi-square tests between each sign and level of THC revealed that NB, MHT, SOL, AB and overall WAT performance (Overall WAT; where all signs were taken into account), were significantly related to the level of THC ($\chi2=10.2$, df=2, $p<.05$; $\chi2=8.7$, df=2, $p<.05$; $\chi2=13.9$, df=2, $p<.005$; $\chi2=6.6$, df=2, $p<.05$; $\chi2=12.5$, df=2, $p<.005$ respectively). Each relationship was positive and significant ($\rho=.3$, $p<.005$; $\rho=.3$, $p<.005$; $\rho=.3$, $p<.001$, $\rho=.2$, $p<.05$; $\rho=.3$, $p<.001$ respectively), indicating that as the level of THC increases so does the likelihood that these signs will be observed during the administration of the WAT test and that participants will be classified as impaired on the WAT test.

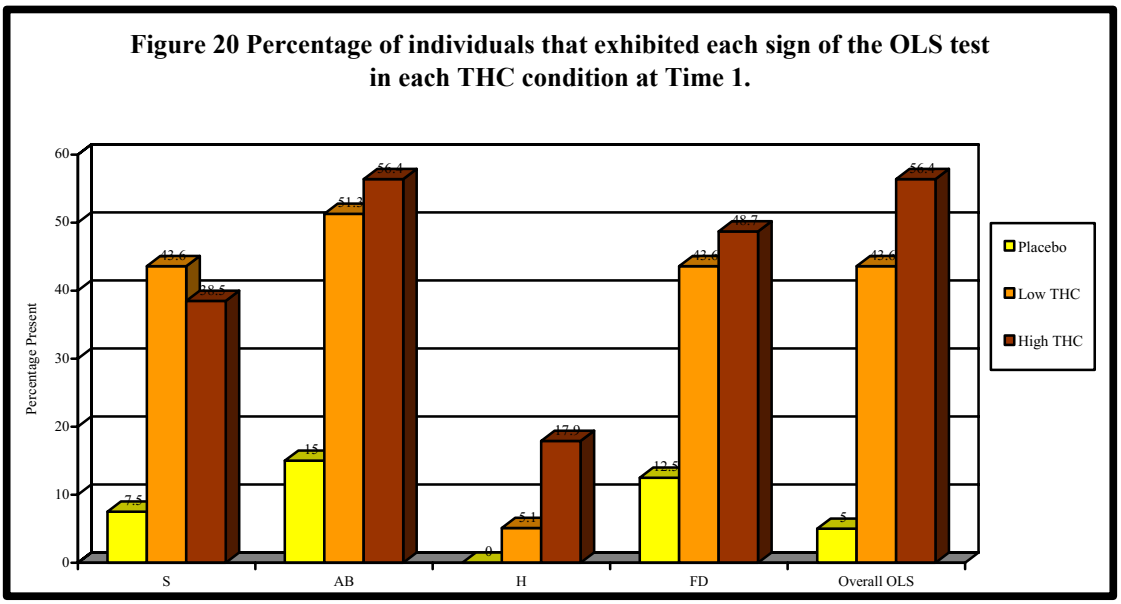
3. One Leg Stand

There were four signs scored in the One Leg Stand (OLS) to determine impairment. These signs included:

1. Swaying while balancing on one leg (S)
2. Uses arms to maintain balance (AB)
3. Hopping during test to maintain balance (H)
4. Puts raised foot down (FD)

Figure 20 outlines the percentage of individuals that exhibited each sign in each condition.

Figure 20 Percentage of individuals that exhibited each sign of the OLS test in each THC condition at Time 1.



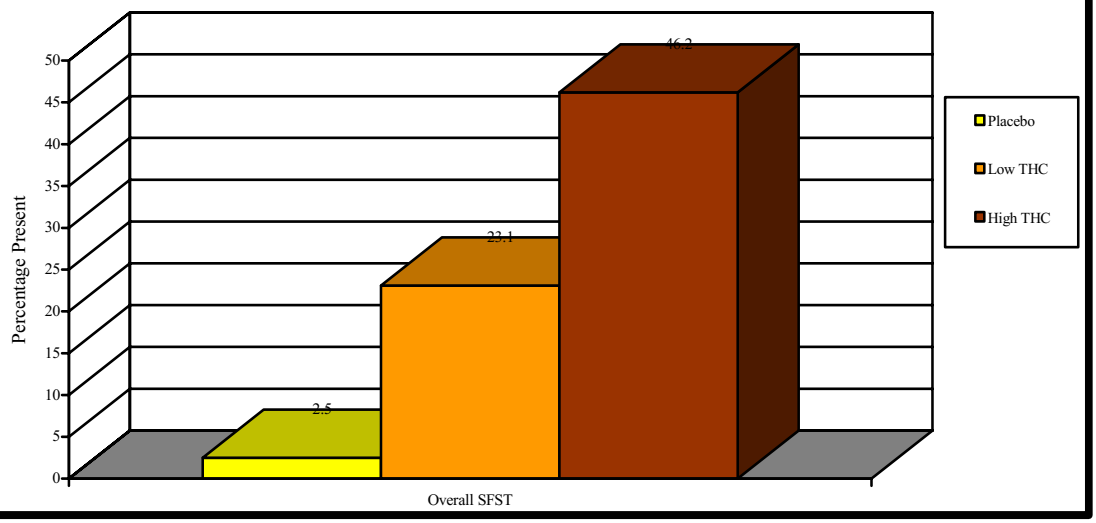
Chi-square tests between each sign and the level of THC demonstrated that all signs were significantly related to the level of THC (S, $\chi2=14.5$, df=2, $p<.005$; AB, $\chi2=16.7$, df=2, $p<.001$; H, $\chi2=9.5$, df=2, $p<.01$; and FD, $\chi2=13.4$, df=2, $p<.005$). Overall OLS performance was also related to the level of THC ($\chi2=25.0$, df=2, $p<.001$). All relationships were positive ($\rho=.3$, $p<.005$; $\rho=.3$, $p<.001$; $\rho=.3$, $p<.005$; $\rho=.3$, $p<.005$ respectively) suggesting that as the level of THC increases, so does the likelihood that these signs will be observed during the administration of the OLS, and that the individual will be classified as impaired on the OLS test ($\rho=.4$, $p<.001$).

Overall SFST Battery Performance

Overall performance was examined by combining the results obtained on three of the sobriety tests administered. These tests comprise the SFST battery and include the HGN, WAT and the OLS test. Participants classified as impaired on two or more of the tests were classified as impaired on overall SFST battery performance.

Figure 21 outlines the percentage of individuals that were classified as impaired on overall SFST battery performance in each condition.

Figure 21 Percentage of individuals classified as impaired on the SFST in each THC condition at Time 1.



A chi-square test for overall SFST battery performance and level of THC showed that SFST battery impairment was related to the level of THC ($\chi 2=20.8$, df=2, $p<.001$). This relationship was statistically significant and positive, ($\rho=.4$, $p<.001$), suggesting that as the level of THC increases, so does the probability that administering the SFSTs will assess an individual as impaired to a degree equivalent to a BAC above .10%.

The sign HMJ was examined to determine whether scoring this sign in the HGN test has any effect on overall SFST battery classifications. A change in the percentage of individuals classified as impaired on overall SFST battery performance was reported after taking into consideration the presence of HMJ (see Figure 22).

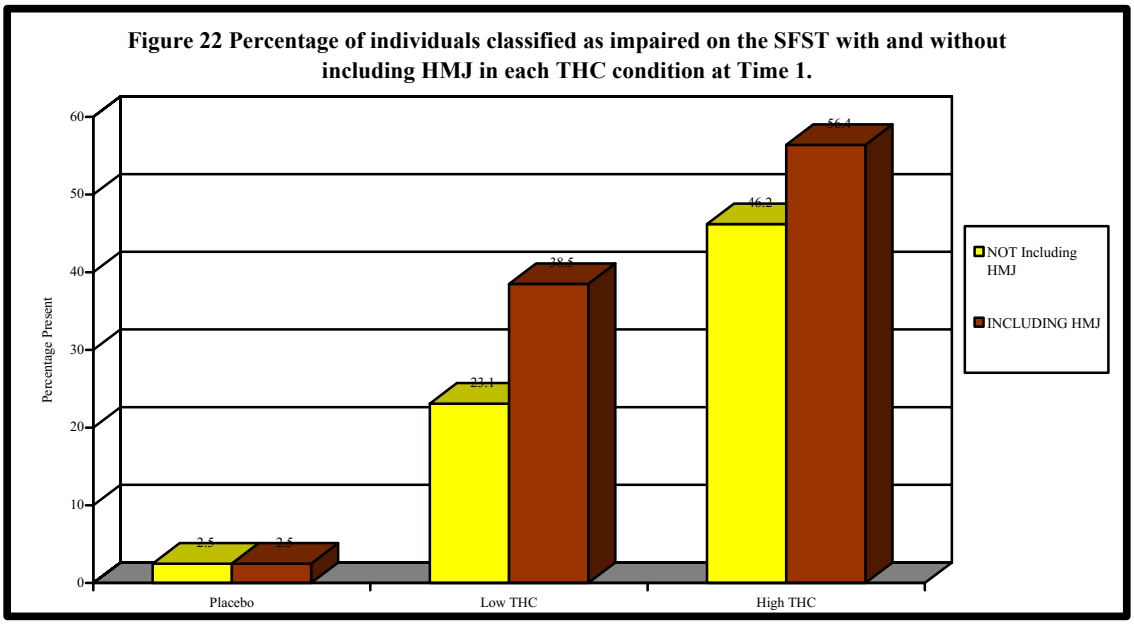


Figure 22 Percentage of individuals classified as impaired on the SFST with and without including HMJ in each THC condition at Time 1.

The percentage of individuals classified as impaired on overall performance on the SFST battery increased drastically when HMJ was taken into account. The placebo session was not effected by the introduction of the HMJ, suggesting that scoring HMJ as a sign of impairment increases the probability of detecting impaired participants in low or high THC conditions, but not in placebo. A chi-square test revealed that overall SFST battery performance and the level of THC was still related after including HMJ in the scoring procedure of the HGN test ($\chi 2=30.6$, df=2, $p<.001$). The relationship remained positive but slightly stronger than when HMJ was not included ($\rho=.5$, $p<.001$).

Additional Sobriety Tests

The additional two sobriety tests were taken form the Drug Evaluation and Classification Program (DEC).

Romberg Balance

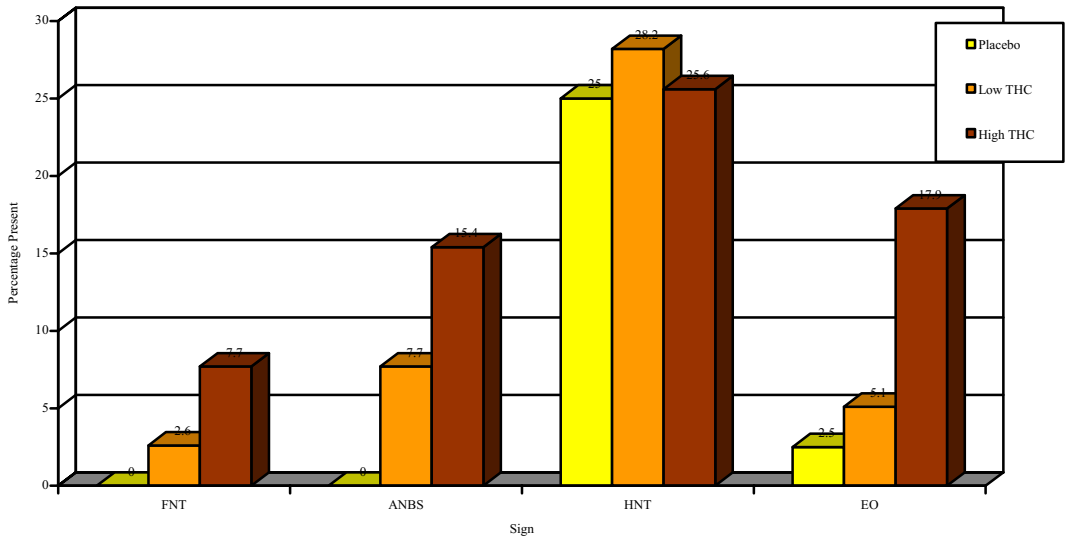
Four signs were scored in the Romberg Balance (RB) test to determine impairment. These signs include:

1. Feet not together (FNT)
2. Arms not by side (ANBS)
3. Head not tilted as demonstrated (HNT)

4. Eyes not closed (EO)

Figure 23 outlines the percentage of individuals that exhibited each sign for each THC condition.

Figure 23 Percentage of individuals exhibiting each sign of the RB test for each THC condition at Time 1.



Chi-square tests revealed that the ANBS and EO was related to the level of THC ($\chi 2=6.6$, df=2, $p<.05$; $\chi 2=6.9$, df=2, $p<.05$ respectively). These relationships were positive and statistically significant ($\rho=.2$, $p<.05$; $\rho=.2$, $p<.05$ respectively) suggesting that as the level of THC increases so does the likelihood that participants will not keep arms by their side and not close their eyes during the RB test.

Finger to Nose

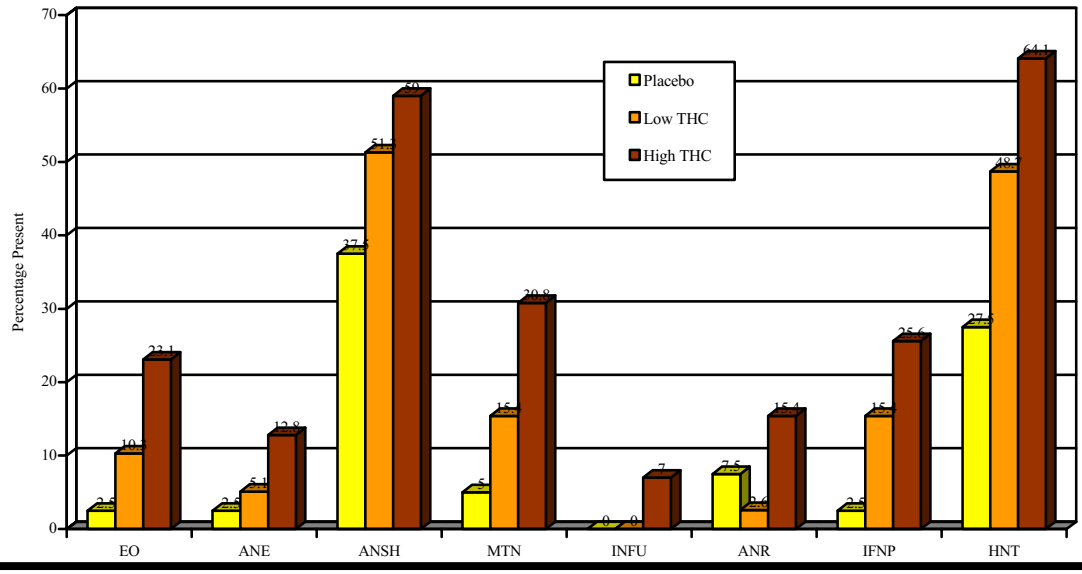
Seven signs were scored in the Finger to Nose (FTN) test to determine impairment. These signs included:

1. Eyes not closed (EO)
2. Arms not fully extended (ANE)
3. Arms not level with shoulders (ANSH)
4. Head not tilted as demonstrated (HNT)
5. Index fingers not pointed/ Index finger not used to touch nose (IFN)
6. Arms not returned to original position after touching nose (ANR)

7. Tip of nose not touched (MTN)

Figure 24 outlines the displays the percentage of participants that exhibited each sign in each condition.

Figure 24 Percentage of individuals that exhibited each sign of the FTN test in each THC condition at Time 1



Chi-squared tests between each sign and levels of THC showed that the four signs EO, MTN, IFNP, and HNT, were significantly related to the level of THC ($\chi 2=8.1$, df=2, $p<.05$; $\chi 2=9.4$, df=2, $p<.01$; $\chi 2=8.6$, df=2, $p<.05$; $\chi 2=10.7$, df=2, $p<.01$ respectively). These relationships were positive and significant ($\rho=.3$, $p<.005$; $\rho=.3$, $p<.01$; $\rho=.3$, $p<.005$; $\rho=.3$, $p<.005$ respectively). This suggests that the likelihood of individuals having difficulties with the instruction to use their index finger to touch the tip of their nose, is increased with increasing levels of THC. Individuals are also more likely to forget to close their eyes and tilt their head as demonstrated by the investigator during the instruction stage of the RB.

These results suggest that many signs scored and used in the detection of impairment caused by cannabis, are related to the level of THC at 5 minutes after smoking cannabis. This indicates that the presence of many signs during sobriety test performance may be indicative of the level of impaired performance. The results indicate that the most effective test of impairment associated with THC is the OLS, where all scored signs

were related to the level of THC. The HGN test on the other hand, was the test least related to the level of THC at Time 1. In addition, the introduction of scoring HMJ in the HGN, added to the accuracy of the HGN test, as well as to the SFSTs. This indicates that HMJ adds to the effectiveness of sobriety tests to detect impaired performance specific to low or high THC conditions.

Sobriety Performance TIME 2

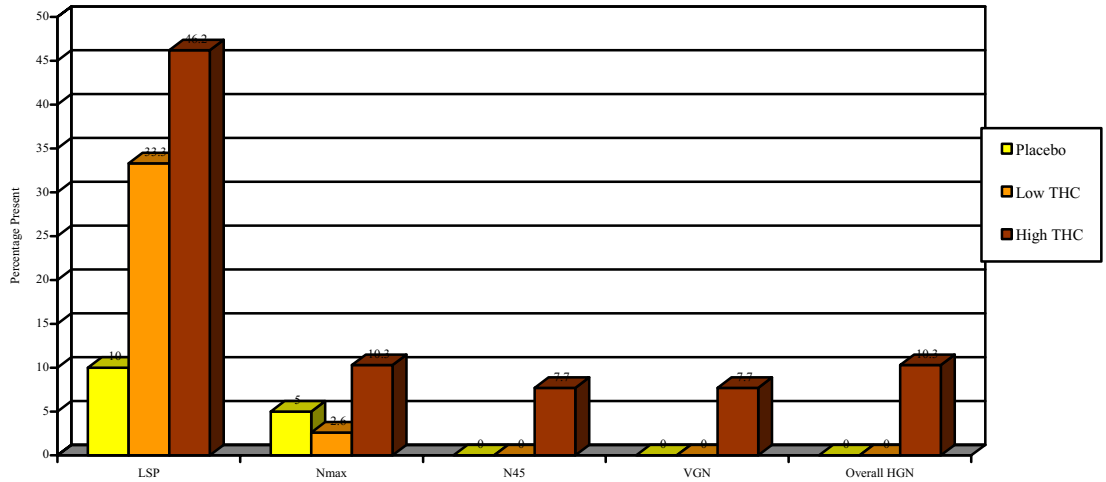
The sobriety tests performed at Time 2 are representative of performance scored at 55 minutes after the consumption of cannabis.

SFSTs

1. HGN

Figure 25 shows the number of individuals that exhibited each sign for the HGN test, for each condition.

Figure 25 Percentage of individuals exhibiting each sign of the HGN test in each THC condition at Time 2.



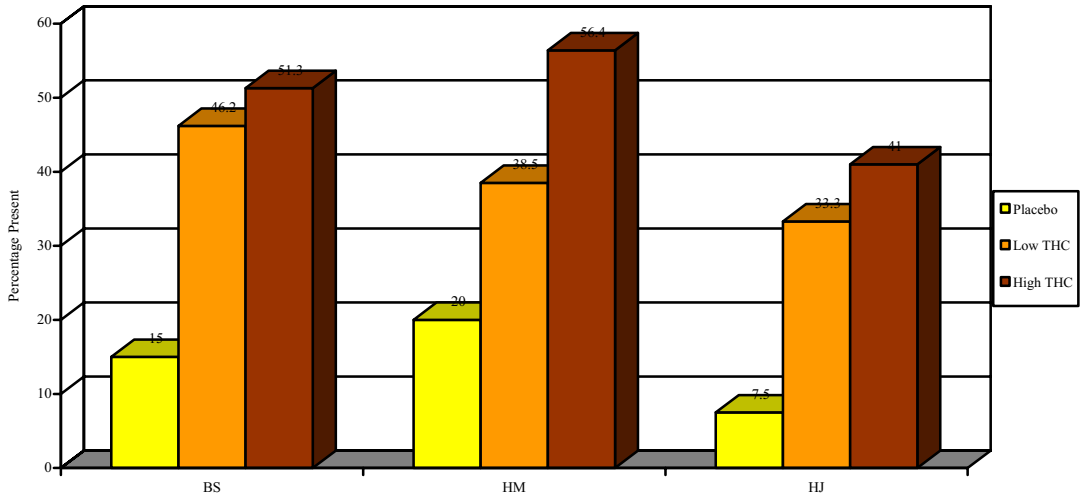
Chi-square tests were performed on each sign and level of THC. The results showed that LSP was significantly related to the level of THC ($\chi 2=12.7$, df=2, $p<.005$). The relationship was positive ($\rho=.3$, $p<.001$). Overall HGN impairment was also significantly related to the level of THC ($\chi 2=12.4$, df=2, $p<.005$) where the relationship was positive ($\rho=.3$, $p<.005$). These results suggest that as the level of THC increases so

does the likelihood that LSP will be observed during the administration of the HGN test as well as impairment on the HGN test overall.

New Signs for HGN test

Figure 26 shows the percentage of BS, HM and HJ observed during the HGN test during each THC condition.

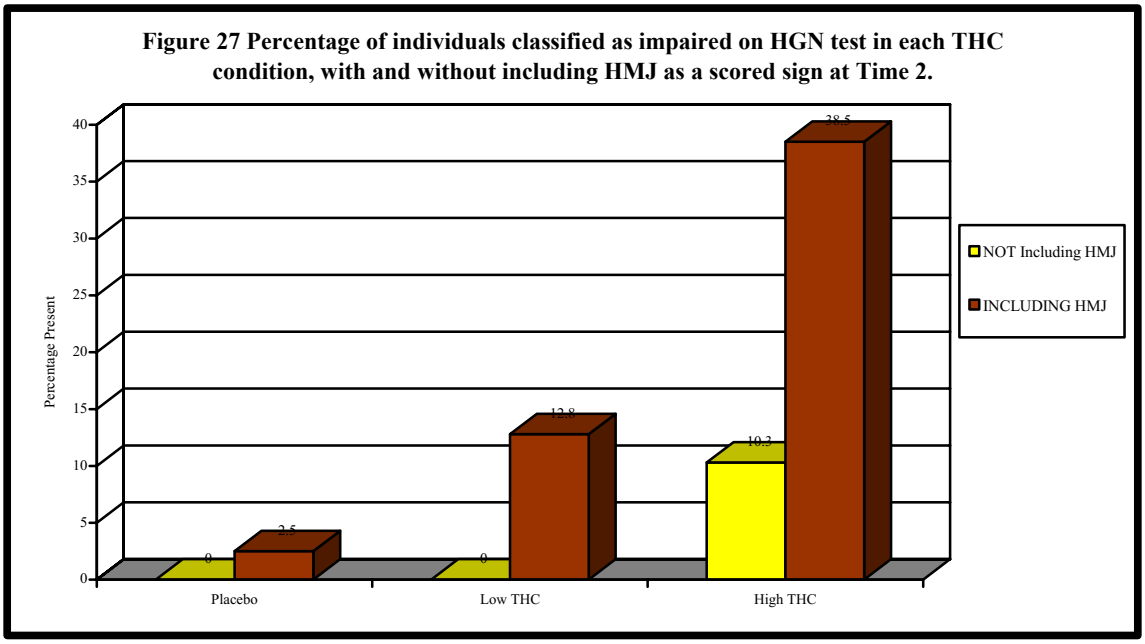
Figure 26 Percentage of individuals exhibiting each new sign during the HGN test in each THC condition at Time 2.



Chi-squared tests revealed that again all three signs were significantly related to the dose of THC (BS: $\chi 2=13.1$, df=2, $p<.005$; HM: $\chi 2=11.1$, df=2, $p<.005$; HJ: $\chi 2=12.4$, df=2 $p<.005$). All relationships were statistically significant ($\rho=.3$, $p<.005$; $\rho=.3$, $p<.005$; $\rho=.3$, $p<.005$ respectively). HM was again the sign that was observed in most participants. This suggests that as the level of THC increases so does the likelihood that these signs will be observed during the administration of the HGN test.

Including the sign HMJ as a scored sign in the HGN test increased the number of individuals classified as impaired. See Figure 27.

Figure 27 Percentage of individuals classified as impaired on HGN test in each THC condition, with and without including HMJ as a scored sign at Time 2.

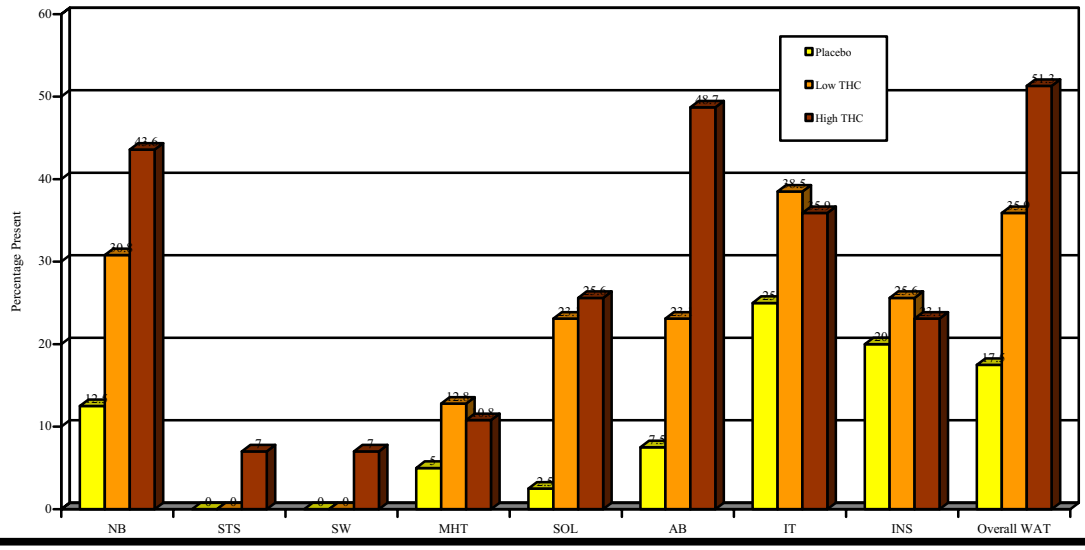


Chi-square tests showed that the relationship between the dose of THC and impairment on the HGN test after including HMJ is strengthened ($\chi 2=18.4$, df=2, $p<.001$; $\rho=.4$, $p<.001$). Figure 27 clearly represents the increase in the percentage of individuals classified as impaired. As the dose of THC increases, so does the likelihood that an individual will be classified as impaired when taking into account HMJ. The presence of 2.5% of participants classified as impaired in the placebo session is in fact indicative of only one subject, therefore 2.5% may not be a significant error considering the large changes that were observed across the low and high THC conditions.

2. Walk and Turn

Figure 28 shows the number of individuals that exhibited each sign during the WAT test, for each condition.

Figure 28 Percentage of individuals exhibiting each sign during the WAT test in each THC condition at Time 2.

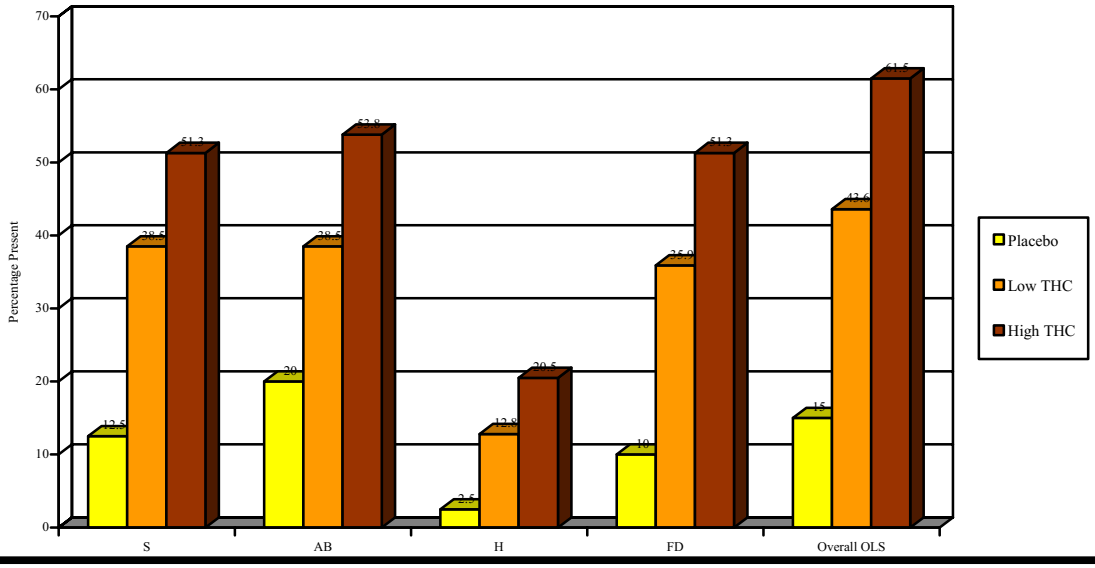


Chi-square tests revealed that the signs: NB, SOL, AB and overall WAT impairment were significantly related to the dose of THC. All of these signs were positively correlated with the dose of THC ($\chi 2=9.4$, df=2, $p<.01$, $\rho=.3$, $p<.005$; $\chi 2=9.1$, df=2, $p<.05$, $\rho=.3$, $p<.01$; $\chi 2=17.6$, df=2, $p<.001$, $\rho=.4$, $p<.001$; $\chi 2=10.0$, df=2, $p<.01$, $\rho=.3$, $p<.005$ respectively). This suggests that as the level of THC increases so does the likelihood that an individual will be classified as impaired on the WAT test. Specifically, after the administration of THC, the statistically significant signs will be observed during the administration of the WAT performance .

3. One Leg Stand

Figure 29 shows the percentage of participants exhibiting each sign scored in the OLS test.

Figure 29 Percentage of individuals exhibiting each sign during the OLS test in each THC condition at Time 2.

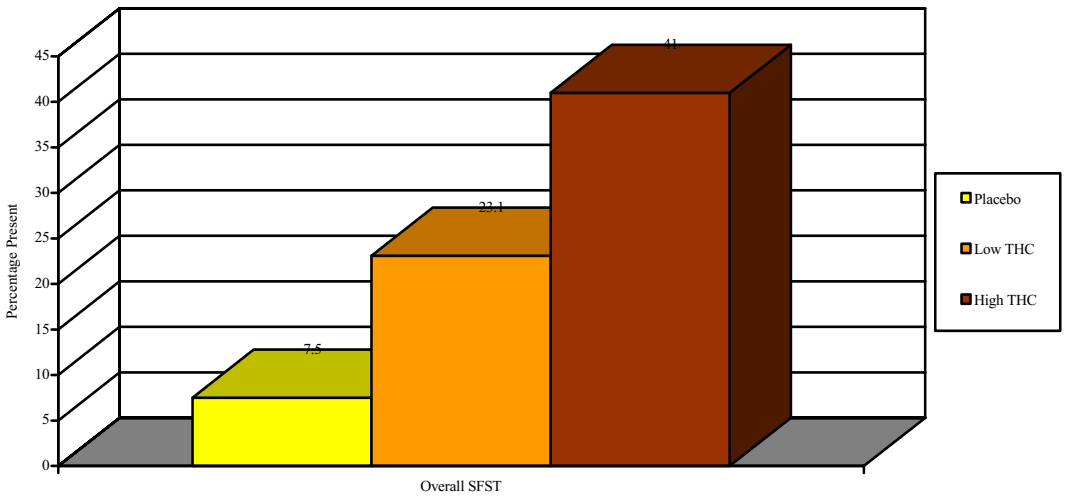


Chi-square tests indicated that all the signs of the OLS were significantly related to the dose of THC (S: $\chi 2=13.8$, df=2, $p<.005$; AB: $\chi 2=9.7$, df=2, $p<.01$; H: $\chi 2=6.2$, df=2, $p<.05$; FD: $\chi 2=15.8$, df=2, $p<.001$). Each sign was significantly correlated with the level of THC ($\rho=.3$, $p<.001$; $\rho=.3$, $p<.005$; $\rho=.2$, $p<.05$; $\rho=.4$, $p<.001$ respectively). These results suggest that as the level of THC increases so does the likelihood that all signs of the OLS will be observed during performance. In addition, overall OLS impairment was also related and significantly correlated with the level of THC ($\chi 2=18.2$, df=2, $p<.001$, $\rho=.4$, $p<.001$) .

Overall SFST Battery Performance

Overall SFST battery performance was examined by adding scores on the three tests HGN, WAT and OLS. Figure 30 outlines the percentage of participants classified as impaired on overall performance (impairment on two or more of the three tests).

Figure 30 Percentage of individuals classified as impaired on the SFST in each THC condition at Time 2.



A chi-square test for overall SFST battery performance and the level of THC showed that SFST battery impairment was significantly related to THC condition ($\chi 2=12.3$, df=2, $p<.005$). This relationship was positive ($\rho=.3$, $p<.001$). This result suggests that as the dose of THC increases so does the probability that the SFSTs test will classify impairment to a level equivalent to a BAC above .10% at 55 minutes after smoking cannabis.

Including the HMJ, as a scored sign in the HGN, improved the percentage of individuals classified as impaired on overall SFST battery performance (see Figure 31). The placebo session was again, unaffected by the introduction of HMJ. Without the introduction of HMJ, 7.5% of individuals were classified as impaired in the placebo session, suggesting that percentage changes in the low and high condition after the introduction of the HMJ, are specific to the administration of THC. In addition, a chi-squared test indicated that the introduction of HMJ slightly increased the strength and significance level of the relationship between overall SFST battery performance and the level of THC ($\chi 2=16.7$, df=2, $p<.001$, $\rho=.4$, $p<.001$).

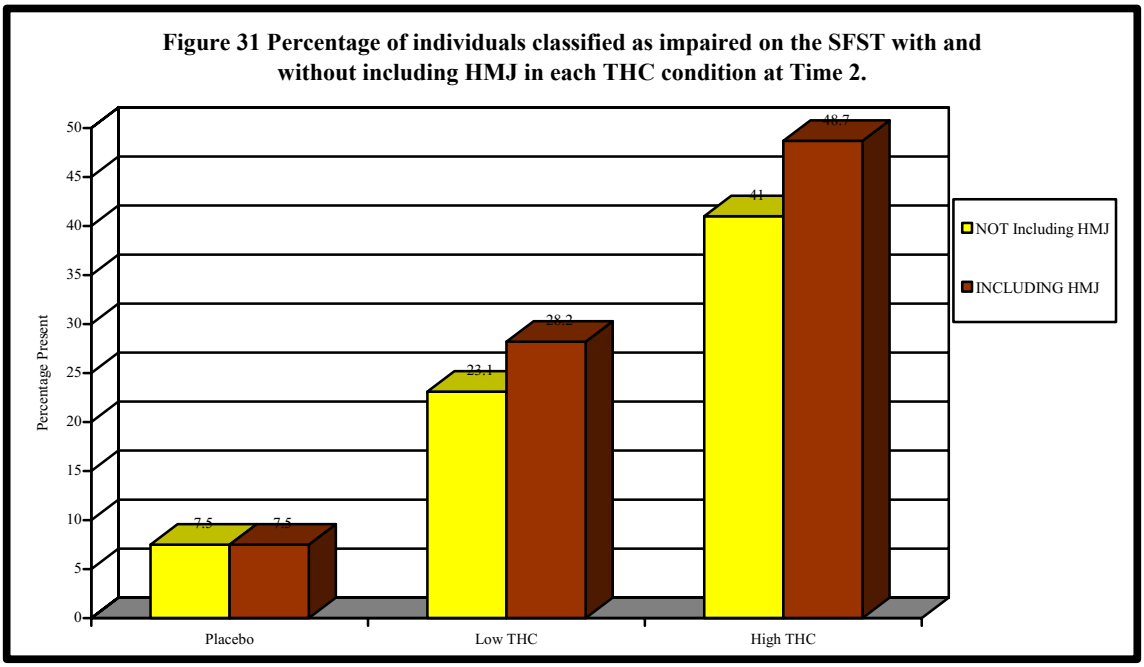


Figure 31 Percentage of individuals classified as impaired on the SFST with and without including HMJ in each THC condition at Time 2.

Additional Sobriety Tests

Romberg Balance

Figure 32 shows the number of times a sign in the RB was observed in each THC condition.

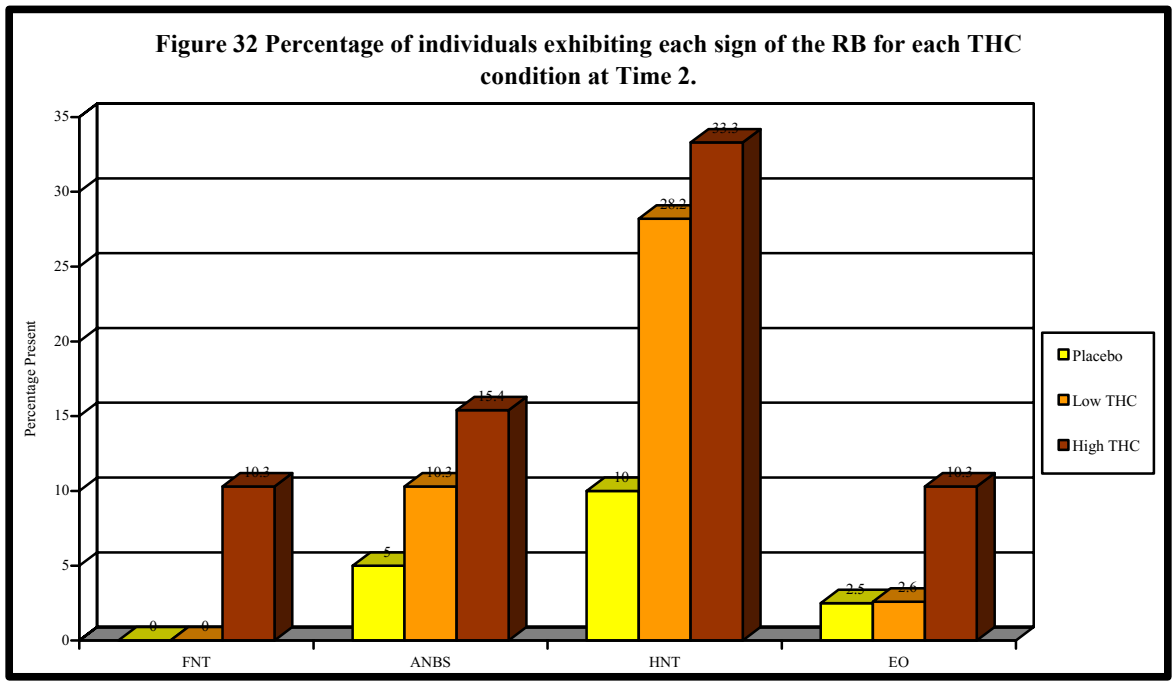


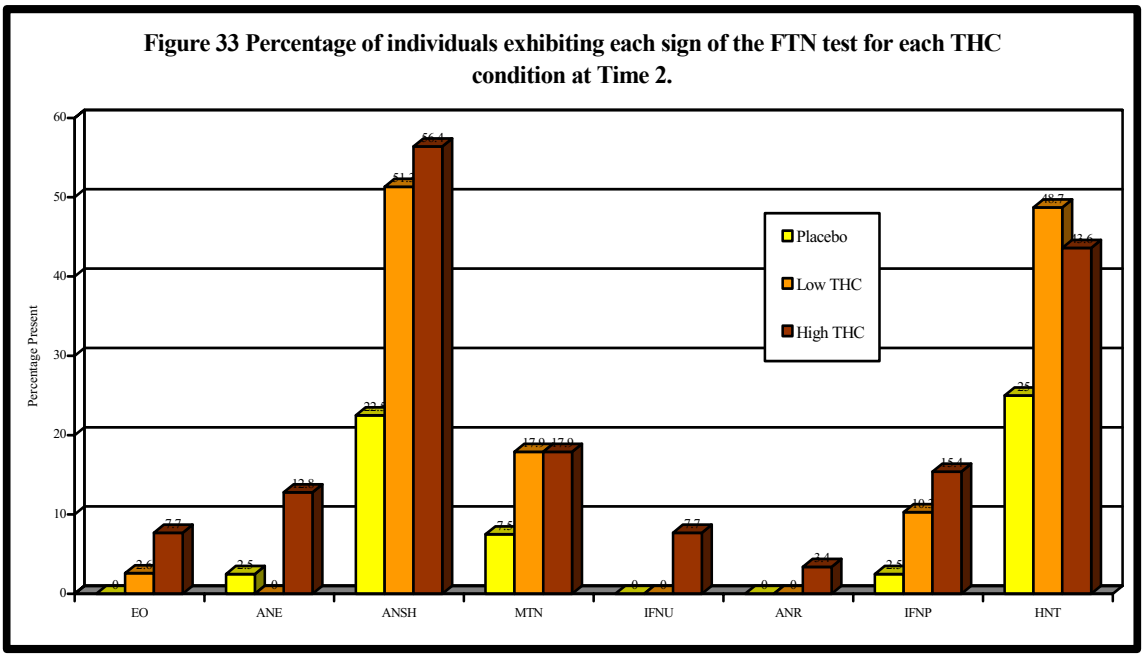
Figure 32 Percentage of individuals exhibiting each sign of the RB for each THC condition at Time 2.

Chi-squared tests revealed that the signs FNT and HNT were significantly related to the dose of THC ($\chi 2=8.4$, df=2, $p<.05$; $\chi 2=6.6$, df=2, $p<.05$ respectively). Both relationships were positive suggesting that as the dose of THC increases so does the likelihood that these signs will be observed during the administration of the RB test ($\rho=.2$, $p<.05$; $\rho=.2$, $p<.05$).

Finger to Nose

The percentage of participants exhibiting each sign of the FTN test in each THC condition is outlined in figure 33.

Figure 33 Percentage of individuals exhibiting each sign of the FTN test for each THC condition at Time 2.



Chi-square tests indicated that only two of the eight signs of the FTN test were significantly related to THC condition (ANSH: $\chi 2=10.8$, df=2, $p<.01$; ANR: $\chi 2=8.4$, df=2, $p<.05$). These signs were positively correlated with the dose of THC, revealing that as the level of THC increases so does the likelihood that these signs will be observed during the administration of the FTN test ($\rho=.3$, $p<.005$; $\rho=.2$, $p<.05$ respectively).

These results suggest that many signs observed in the sobriety tests administered in the present study are related to the level of THC. Specifically, the OLS test again appeared to be the most effective test in detecting impairment 55 minutes after smoking cannabis, as all signs were related to the level of THC. In addition, the results suggest that

introducing HMJ in the scoring procedure of the HGN test increases the chance of classifying a participant in the low or high THC condition as impaired, on the HGN test and on overall SFST battery performance.

Sobriety Performance TIME 3

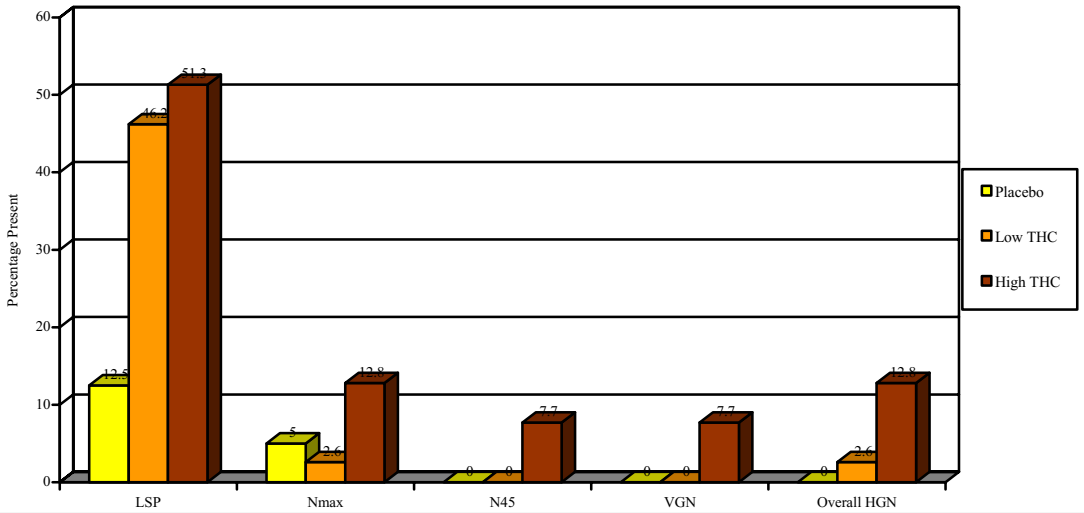
The sobriety tests performed at Time 3 are representative of performance scored 105 minutes after the consumption of cannabis.

SFSTs

1. HGN

Figure 34 shows the percentage of individuals exhibiting each sign of the HGN test in each THC condition.

Figure 34 Percentage of individuals exhibiting each sign of the HGN test in each THC condition at Time 3.

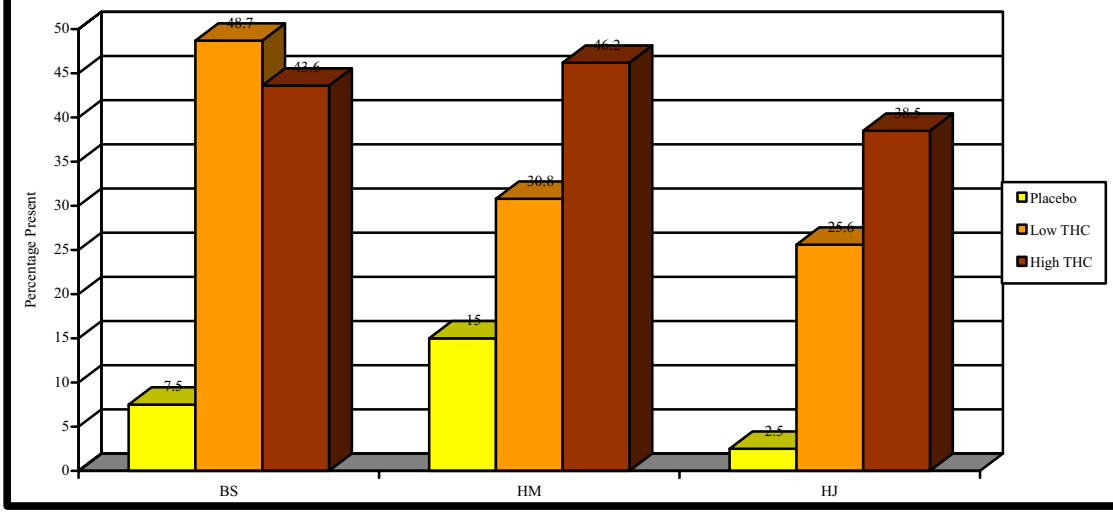


Chi-square tests demonstrated that, as in Time 2, LSP was significantly related to the level of THC ($\chi 2=15.2$, df=2, $p<.005$). This relationship was positive ($\rho=.3$, $p<.001$). Overall HGN impairment was related to the level of THC and this relationship was significant ($\chi 2=7.5$, df=2, $p<.05$, $\rho=.2$, $p<.01$). These results suggest that as the level of THC increases, so does the presence of overall HGN impairment, specifically, the presence of LSP.

New Signs for HGN test

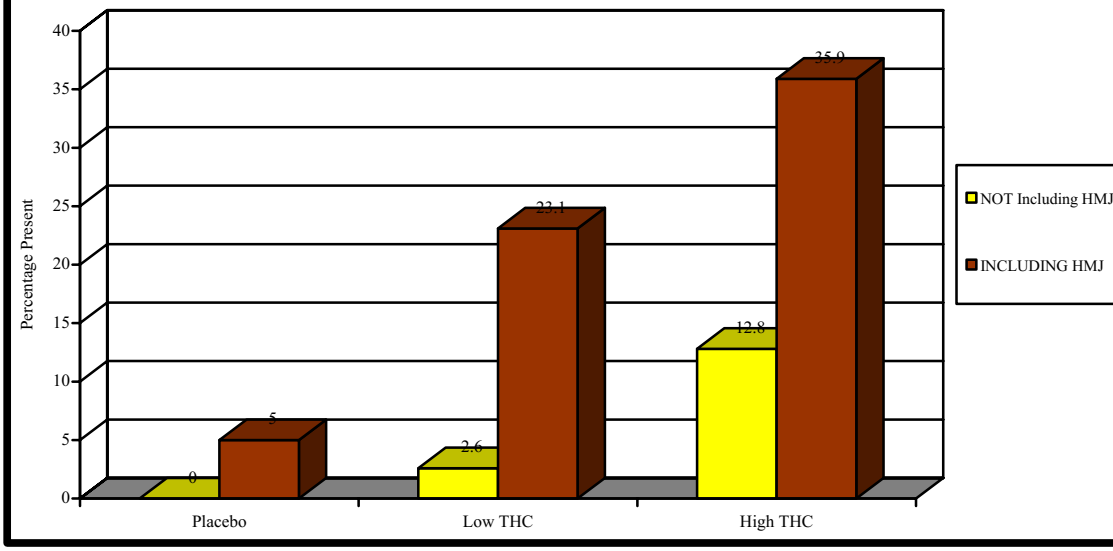
The percentage of participants exhibiting the new signs in each THC condition is outlined in Figure 35.

Figure 35 Percentage of individuals exhibiting each new sign of the HGN test for each THC condition at Time 3.



Results indicated that the signs HM and HJ were significantly related to the dose of THC ($\chi 2=9.0$, df=2, $p<.05$; $\chi 2=15.3$, df=2, $p<.001$ respectively). Both relationships were positive ($\rho=.3$, $p<.005$; $\rho=.4$, $p<.001$ respectively). Including HMJ as a scored sign in the HGN test increased the percentage of individuals classified as impaired on the HGN test. See Figure 36.

Figure 36 Percentage of individuals classified as impaired on the HGN with and without scoring HMJ as a new sign at Time 3.

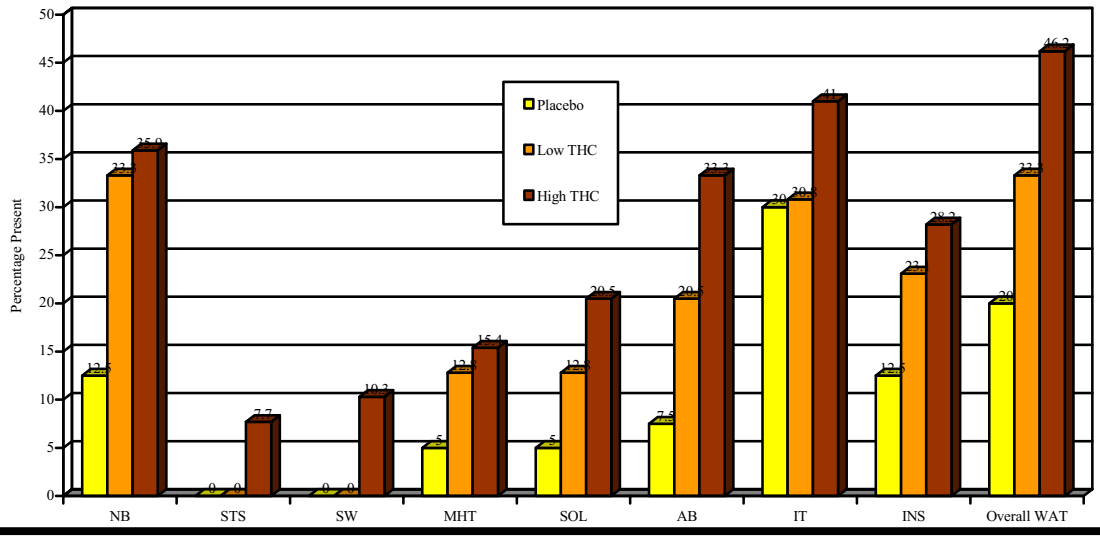


A chi-square test indicated that HGN impairment when HMJ was included was more significantly related to the dose of THC dose than when it was not included ($\chi 2=11.414$, df=2, $p<.005$). The relationship was also larger in magnitude ($\rho=.310$, $p<.005$) than when it was not included. These results suggest that including HMJ as a scored sign adds to the sensitivity of detecting impairment.

2. Walk and Turn

Figure 37 outlines the percentages of individuals showing each sign of the WAT test.

Figure 37 Percentage of individuals exhibiting each sign of the WAT test in each THC condition at Time 3.

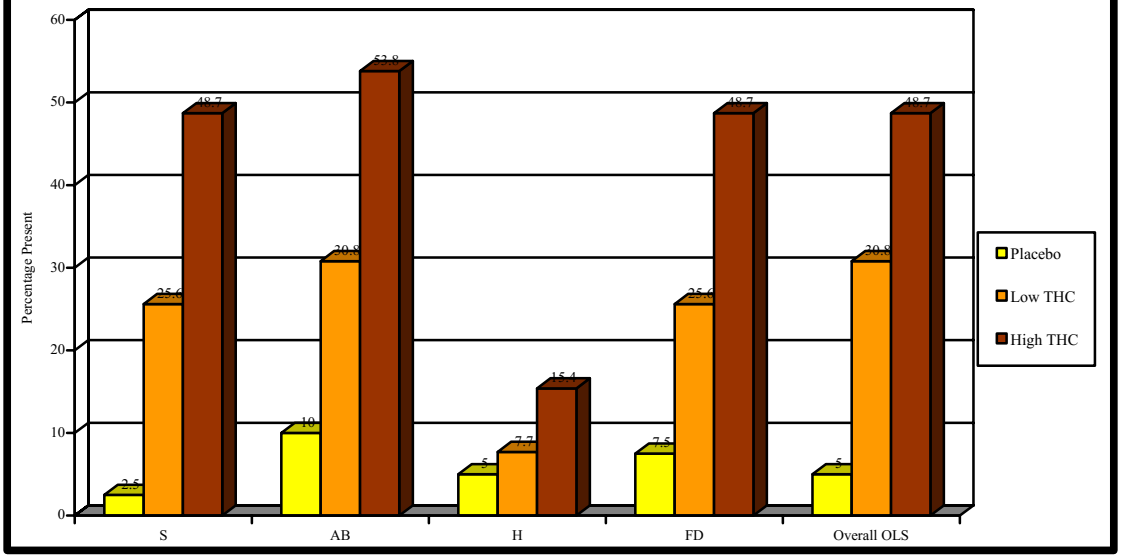


Results indicated that the three signs; NB, SW and AB, were significantly related to the dose of THC ($\chi 2=6.6$, df=2, $p<.05$; $\chi 2=8.4$, df=2, $p<.05$; $\chi 2=8.1$, df=2, $p<.05$ respectively). These relationships were positive ($\rho=.2$, $p<.05$; $\rho=.2$, $p<.05$; $\rho=.3$, $p<.005$ respectively). Overall WAT impairment was also related to the dose of THC ($\chi 2=6.1$, df=2, $p<.05$, $\rho=.2$, $p<.05$). These results suggest that as the level of THC increases, so does the likelihood that these signs will be observed during the administration of the WAT test and that individuals will be classified as impaired on overall WAT performance.

3. One Leg Stand

Figure 38 shows the presence of each sign of the OLS for each THC condition.

Figure 38 Percentage of individuals exhibiting each sign of the OLS in each THC condition at Time 3.

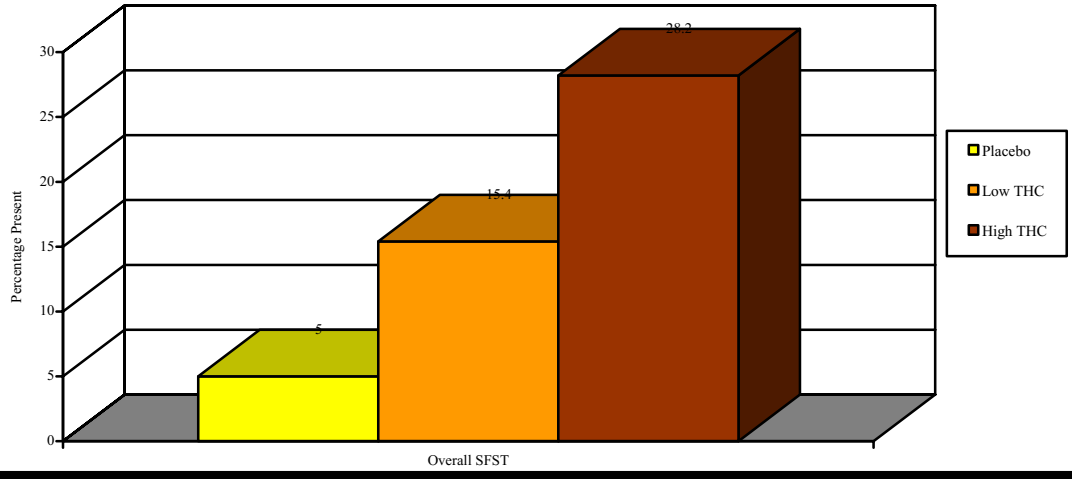


Chi-square tests revealed that almost all signs of the OLS, with the exception of the sign H, were significantly related to the dose of THC. These relationships were positive (S: $\chi 2=22.2$, df=2, $p<.001$, $\rho=.4$, $p<.001$; AB: $\chi 2=17.6$, df=2, $p<.001$, $\rho=.4$, $p<.001$; FD: $\chi 2=17.0$, df=2, $p<.001$, $\rho=.4$, $p<.001$). Overall OLS impairment was again significantly and positively related to the dose of THC ($\chi 2=19.0$, df=2, $p<.001$, $\rho=.4$, $p<.001$). These results indicate that performance on the OLS test is likely to indicate that an individual is impaired as the level of THC increases.

Overall SFST Battery Performance

Figure 39 outlines the percentage of participants classified as impaired on overall SFST battery performance (impairment on two or more of three tests: HGN, WAT, OLS).

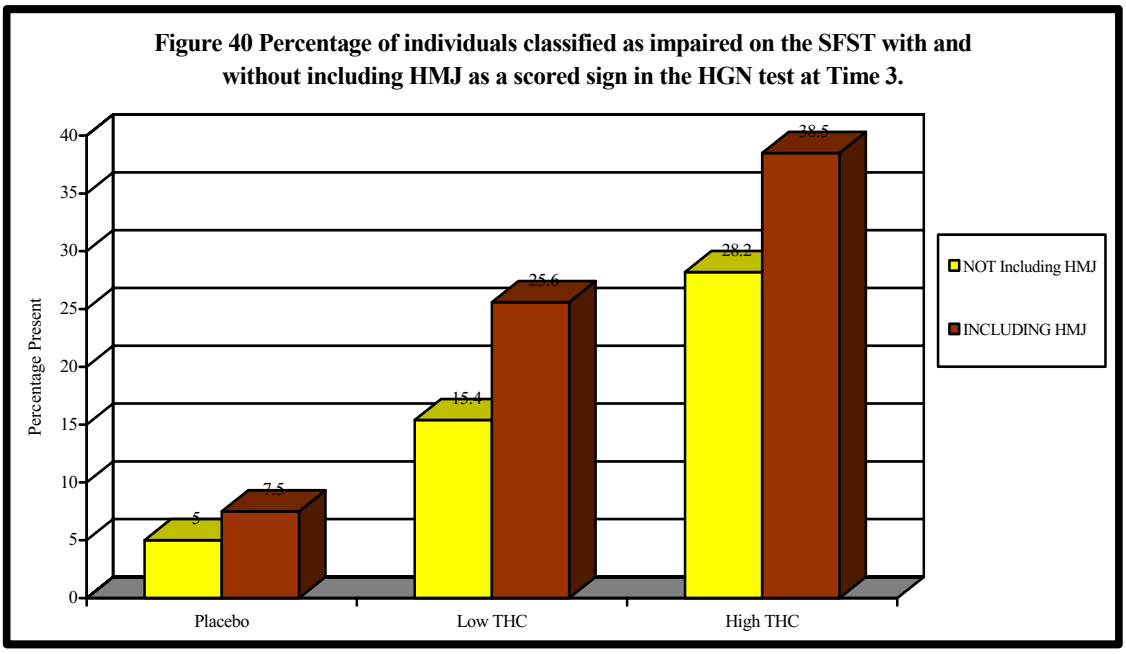
Figure 39 Percentage of individuals classified as impaired on the SFST in each THC condition at Time 3.



A chi-square test for overall SFST battery performance and the level of THC indicated that SFST battery impairment was significantly related to THC condition ($\chi 2=7.9$, df=2, $p<.05$). This relationship was positive ($\rho=.3$, $p<.01$). This suggests that as the level of THC increases so does the probability that the SFSTs test will indicate that an individual is impaired to a level equivalent to a BAC above .10%, at 105 minutes after smoking cannabis.

Scoring the sign HMJ in the HGN test, improved the percentage of individuals classified as impaired on overall SFST battery performance (see Figure 40). The placebo session was slightly affected by the introduction of HMJ, although again it should be explained that the 2.5% difference is indicative of one subject. In addition, a chi-square test revealed that the introduction of HMJ increased the strength and significance level of the relationship between SFST battery performance and the level of THC level ($\chi 2=10.6$, df=2, $p<.01$, $\rho=.3$, $p<.005$).

Figure 40 Percentage of individuals classified as impaired on the SFST with and without including HMJ as a scored sign in the HGN test at Time 3.

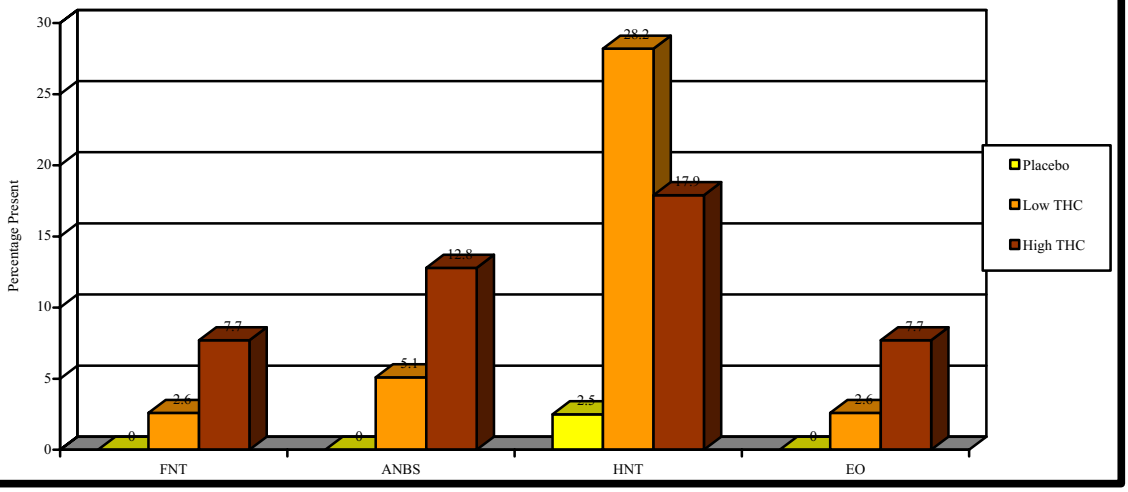


Additional Sobriety Tests

Romberg Balance

Figure 41 shows the prevalence of each sign of the RB in each THC condition.

Figure 41 Percentage of individuals exhibiting each sign of the RB test for each condition at Time 3.

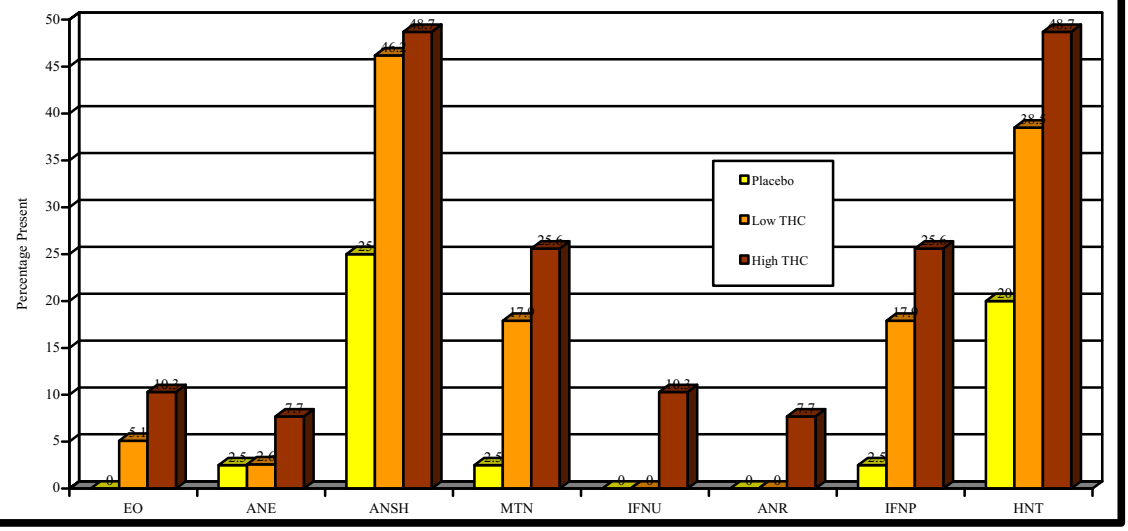


Chi-squared tests revealed that none of the signs in RB test were related to the dose of THC. This suggests that signs exhibited during each condition occur independent or irrespective of the dose of THC.

Finger to Nose

Figure 42 shows the number of individuals showing each sign of the FTN test for each THC condition.

Figure 42 Percentage of individuals exhibiting each sign in the FTN test for each THC condition at Time 3.



Results indicated that four signs were related to the dose of THC. These signs included: MTN ($\chi 2=8.5$, df=2, $p<.05$); IFNU ($\chi 2=8.4$, df=2, $p<.05$); IFNP ($\chi 2=8.5$, df=2, $p<.05$);

and HNT ($\chi 2=7.313$, df=2, $p<.05$). All relationship were positive ($\rho=.3$, $p<.005$; $\rho=.2$, $p<.05$; $\rho=.3$, $p<.005$; $\rho=.2$, $p<.01$, respectively). These findings suggest that as the level of THC increases, so does the likelihood that these signs will be observed during the administration of the FTN test.

These results demonstrate that the number of signs related to the level of THC decreased slightly in Time 3, compared to Time 1 and Time 2. However, the OLS test was again the most effective test of impairment, as almost all signs were related to the level of THC at all times. In addition, the results suggest that introducing HMJ as a scored sign in the HGN test increases the chances of classifying individuals in the low or high THC condition as impaired, on the HGN test and on overall SFSTs, at 105 minutes after smoking cannabis.

8.4.2 Cannabis Dose, Sobriety Test Performance and Frequency of Cannabis Use

Chi-square tests were computed to examine whether there is a difference in sobriety test performance between non-regular and regular cannabis users under each THC condition. The results indicated that a number of statistical differences in performance exist between regular and non-regular users. Specifically, the percentage of individuals exhibiting signs of the sobriety tests were different across the two groups. The statistics that will be reported are the relationships between the sign observed and level of THC that were significant for one group but not the other. This will highlight the major differences between both groups and allow for comparison to the differences identified in the driving task.

Sobriety Performance at TIME 1

SFSTs

1. HGN

At Time 1 none of the signs were significantly different between regular and non-regular users. There were however significant differences between non-regular users and regular users for the 'new' signs in the HGN test. The sign BS was significantly

related to the level of THC ($\chi 2=10.5$, $p<.01$) for non-regular users but not for regular users. This relationship was positive for non-regular users ($r=.4$, $p<.005$). HJ was also significantly related to the level of THC for non-regular users ($\chi 2=16.2$, $p<.001$) but not for regular users. This relationship was positive for non-regular users ($r=.5$, $p<.001$). HM however was significantly related to the level of THC for both non-regular users ($\chi 2=14.7$, $p<.005$, $r=.5$, $p<.001$) and regular users ($\chi 2=8.8$, $p<.05$, $r=.4$, $p<.005$). In addition, overall performance on the HGN test when scoring HMJ, was significantly related to the level of THC for both non-regular and regular users ($\chi 2=7.7$, $p<.05$ and $\chi 2=8.7$, $p<.05$), in which the relationship was significantly positive for both groups ($r=.3$, $p<.05$ and $r=.3$, $p<.01$ respectively). The strongest relationship was between the dose of THC and the signs HM and HJ.

2. Walk and Turn

NB and SOL and overall WAT impairment was significantly related to the level of THC for non-regular users ($\chi 2=11.7$, $p<.005$, $r=.5$, $p<.001$; $\chi 2=18.7$, $p<.001$, $r=.6$, $p<.001$ and $\chi 2=9.0$, $p<.05$, $r=.4$, $p<.005$ respectively) but not for regular users. AB on the other hand was significantly related to the level of THC for regular users ($\chi 2=6.0$, $p=.05$, $r=.3$, $p<.05$), but not for non-regular users. SOL had the strongest relationship with the level of THC.

3. One Leg Stand

H and FD, were significantly related to the level of THC for non-regular users ($\chi 2=8.6$, $p<.05$, $r=.3$, $p<.01$ and $\chi 2=11.7$, $p<.005$, $r=.5$, $p<.005$ respectively) but not for regular users. For both non-regular and regular users, there was a significant relationship between the level of THC and the sign AB (non-regular users: $\chi 2=7.9$, $p<.05$, $r=.4$, $p<.05$; regular users: $\chi 2=9.1$, $p<.05$, $r=.3$, $p<.01$) and overall OLS impairment (non-regular users: $\chi 2=16.7$, $p<.001$, $r=.6$, $p<.001$; regular users: $\chi 2=10.2$, $p<.01$, $r=.3$, $p<.01$). FD and overall OLS impairment showed the strongest relationship with the level of THC.

Overall SFST Battery Performance

Overall SFST battery performance was significantly related to the level of THC ($\chi 2=7.3$, $p<.05$ and $\chi 2=14.8$, $p<.005$) for both regular and non-regular users. This

relationship was positive in both cases (r=.3, p<.01 and r=.5, p<.001), but higher in magnitude for non-regular users. Overall performance on the SFSTs (including HMJ as a scored sign in the HGN test) was also significantly related to the level of THC for regular users ($\chi 2$=11.7, p<.005, r=.4, p<.005) and non-regular users ($\chi 2$=20.1, p<.001, r=.6, p<.001). The relationship between the level of THC and SFST battery performance was strongest when HMJ was included as a scored sign.

Additional Sobriety Tests

Romberg Balance

In the RB test, only one sign was significantly different for both groups. For regular users, EO was significantly related to the level of THC ($\chi 2$=11.1, p<.005), but not for non-regular users. This relationship was significantly positive for non-regular users (r=.4, p<.005).

Finger to Nose

ANR was significantly related to level of THC ($\chi 2$=6.4, p<.05) for non-regular users, and this relationship was positive (r=.3, p<.05), but was not significant for regular users. IFNP and HNT was significantly related to the level of THC for regular users ($\chi 2$=11.1, p<.005, r=.4, p<.005 and $\chi 2$=8.4, p<.05, r=.4, p<.005 respectively).

In summary, at Time 1, non-regular users were more impaired on the SFSTs and the additional sobriety tests compared to regular users. This impairment was most obvious in the HGN test and the WAT test.

Sobriety Performance at TIME 2

SFSTs

1. HGN

N45 and VGN were significantly related to the level of THC for non-regular users but not for regular users ($\chi 2$=6.4, df=2, p<.05, ρ=.3, p<.05 and $\chi 2$=6.4, df=2, p<.05, ρ=.3, p<.05 respectively). Overall HGN impairment was also related to level of THC for

non-regular users but not for regular users ($\chi 2=6.4$, df=2, $p<.05$, $\rho=.3$, $p<.05$). LSP was related to the dose of THC for non-regular users ($\chi 2=7.0$, df=2, $p<.05$, $\rho=.3$, $p<.05$) and regular users ($\chi 2=6.6$, df=2, $p<.05$, $\rho=.3$, $p<.05$). The 'new' signs HM and HJ were significantly related to level of THC for non-regular users only ($\chi 2=11.3$, df=2, $p<.005$, $\rho=.5$, $p<.005$ and $\chi 2=10.5$, df=2, $p<.05$, $\rho=.4$, $p<.005$ respectively). There was a significant relationship between level of THC and BS and overall HGN impairment including HMJ for non-regular users ($\chi 2=7.6$, df=2, $p<.05$, $\rho=.3$, $p<.05$ and $\chi 2=10.5$, df=2, $p<.005$, $\rho=.4$, $p<.005$ respectively) and regular users ($\chi 2=7.3$, df=2, $p<.05$, $\rho=.4$, $p<.01$ and $\chi 2=8.3$, df=2, $p<.05$, $\rho=.4$, $p<.005$ respectively). All relationships were significantly positive, but the highest correlation was between HM and HJ and the dose of THC (this was also reported at Time 1).

2. Walk and Turn

Four signs were significantly related to level of THC for non-regular users only. These signs included; NB ($\chi 2=7.5$, df=2, $p<.05$, $\rho=.4$, $p<.01$); STS ($\chi 2=6.4$, df=2, $p<.05$, $\rho=.3$, $p<.05$); SW ($\chi 2=6.4$, df=2, $p<.05$, $\rho=.3$, $p<.05$); and SOL ($\chi 2=10.5$, df=2, $p<.01$, $\rho=.4$, $p<.005$). Overall WAT impairment was also significantly related to level of THC for non-regular users only ($\chi 2=7.5$, df=2, $p<.05$, $\rho=.4$, $p<.01$), whereas AB was significant for both groups (non-regular: $\chi 2=10.5$, df=2, $p<.01$, $\rho=.4$, $p<.005$, regular: $\chi 2=7.5$, df=2, $p<.05$, $\rho=.3$, $p<.01$). All relationships were positive but the strongest association was between AB and the dose of THC.

3. One Leg Stand

All signs of the OLS including overall OLS impairment were significantly related to level of THC for non-regular users only; S ($\chi 2=11.7$, df=2, $p<.005$, $\rho=.5$, $p<.001$); AB ($\chi 2=13.6$, df=2, $p<.01$, $\rho=.5$, $p<.001$); H ($\chi 2=8.2$, df=2, $p<.05$, $\rho=.4$, $p<.005$); FD ($\chi 2=12.0$, df=2, $p<.005$, $\rho=.5$, $p<.001$); overall OLS ($\chi 2=16.2$, df=2, $p<.001$, $\rho=.5$, $p<.001$). All of these relationships, with the exception of H were stronger than those observed in the other sobriety tests.

Overall SFST Battery Performance

Overall SFST battery impairment was significantly related to the dose of THC for both non-regular users and regular users ($\chi 2=6.4$, df=2, $p<.05$, $\rho=.3$, $p<.05$ and $\chi 2=6.4$, df=2,

$p<.05$, $\rho=.3$, $p<.05$ respectively). After including HMJ as a scored sign in the HGN, overall SFST battery impairment remained significantly related to the level of THC for both non-regular users ($\chi2=9.7$, $df=2$, $p<.01$, $\rho=.4$, $p<.005$) and regular users ($\chi2=7.5$, $df=2$, $p<.05$, $\rho=.3$, $p<.01$). Both relationships had a higher correlation when HMJ was included as a scored sign.

Additional Sobriety Tests

Romberg Balance

Again only one sign was significantly different between regular users and non-regular users and this sign was different to the sign that was significantly different between both groups at Time 1 (EO). At Time 2 FNT was significantly related to the level of THC for non-regular users but not for regular users ($\chi2=6.4$, $df=2$, $p<.05$, $\rho=.3$, $p<.05$). No signs were significantly related to the level of THC for regular users.

Finger to Nose

Five signs were significantly related to the level of THC for non-regular users only; ANE ($\chi2=6.4$, $df=2$, $p<.05$, $\rho=.3$, $p<.05$); ANSH ($\chi2=8.9$, $df=2$, $p<.05$, $\rho=.4$, $p<.01$); IFNU ($\chi2=6.4$, $df=2$, $p<.05$, $\rho=.3$, $p<.05$); ANR ($\chi2=8.6$, $df=2$, $p<.05$, $\rho=.3$, $p<.05$); HNT ($\chi2=12.0$, $df=2$, $p<.005$, $\rho=.4$, $p<.005$). HNT had the strongest relationship with the level of THC. No signs were significantly related to the level of THC for regular users.

In summary, at Time 2, non-regular users were more impaired on the SFSTs and the additional sobriety tests compared to regular users. This impairment was obvious in all the tests that comprise the SFSTs and the FTN test.

Sobriety Performance at TIME 3

SFSTs

1. HGN

N45 and VGN were significantly related to the level of THC for non-regular users but not for regular users ($\chi2$=6.4, df=2, p<.05, ρ=.3, p<.05 and $\chi2$=6.4, df=2, p<.05, ρ=.3, p<.05 respectively). Overall HGN impairment was also related to the level of THC for non-regular users but not for regular users ($\chi2$=6.4, df=2, p<.05, ρ=.3, p<.05). LSP was related to the dose of THC for both non-regular users ($\chi2$=8.0, df=2, p<.05, ρ=.4, p<.01) and regular users ($\chi2$=8.2, df=2, p<.05, ρ=.3, p<.05). HM and HJ were again significantly related to the level of THC for non-regular users only ($\chi2$=8.9, df=2, p<.05, ρ=.4, p<.01; and $\chi2$=9.9, df=2, p<.01, ρ=.4, p<.005 respectively). BS was also significant for non-regular users only ($\chi2$=15.9, df=2, p<.001, ρ=.5, p<.001). All relationships were significantly positive, but the strongest correlation was between the level of THC and the signs HJ and BS.

2. Walk and Turn

Four signs were significantly related to level of THC for non-regular users only; NB ($\chi2$=10.3, df=2, p<.01, ρ=.4, p<.005); STS ($\chi2$=6.4, df=2, p<.05, ρ=.3, p<.05); SW ($\chi2$=6.4, df=2, p<.05, ρ=.3, p<.05); and AB ($\chi2$=7.1, df=2, p<.05, ρ=.4, p<.05). Overall WAT impairment was also significantly related to level of THC for non-regular users only ($\chi2$=9.8, df=2, p<.01, ρ=.4, p<.005). These relationships were positive for non-regular users.

3. One Leg Stand

FD as well as overall OLS impairment was significantly related to the level of THC for non-regular users only ($\chi2$=12.1, df=2, p<.005, ρ=.5, p<.001; and $\chi2$=15.8, df=2, p<.001, ρ=.5, p<.001 respectively). S and AB were related to the dose of THC for non-regular users ($\chi2$=13.6, df=2, p<.005, ρ=.5, p<.001 and $\chi2$=9.8, df=2, p<.01, ρ=.4, p<.005 respectively) and for regular users ($\chi2$=10.4, df=2, p<.01, ρ=.4, p<.005 and $\chi2$=9.1, df=2, p<.05, ρ=.4, p<.005 respectively). All relationships were significant and positive, where the relationship between overall OLS impairment and the level of THC had the highest correlation.

Overall SFST Battery Performance

The relationship between overall SFST battery performance and the dose of THC was significant only for non-regular users ($\chi2$=12.4, df=2, p<.005, ρ=.5, p<.001). This was

also the case for overall SFSTs when HMJ was scored in the HGN test ($\chi 2=15.6$, df=2, $p<.001$, $\rho=.5$, $p<.05$). Both relationships were positive for non-regular users.

Additional Sobriety Tests

Romberg Balance

FNT and EO were significantly related to the level of THC for non-regular users only ($\chi 2=6.4$, df=2, $p<.05$, $\rho=.3$, $p<.05$ and $\chi 2=6.4$, df=2, $p<.05$, $\rho=.3$, $p<.05$ respectively). These relationships were positive for non-regular users.

Finger to Nose

Five signs were significantly related to the level of THC for non-regular users but not for regular users; ANE ($\chi 2=6.4$, df=2, $p<.05$, $\rho=.3$, $p<.05$); MTN ($\chi 2=6.2$, df=2, $p<.05$, $\rho=.3$, $p<.05$); IFNU ($\chi 2=8.6$, df=2, $p<.05$, $\rho=.3$, $p<.05$); ANR ($\chi 2=6.4$, df=2, $p<.05$, $\rho=.3$, $p<.05$); and IFNP ($\chi 2=6.9$, df=2, $p<.05$, $\rho=.4$, $p<.01$). All relationships were positive for non-regular users.

In summary, at Time 3, non-regular users were more impaired on the SFSTs and the additional sobriety tests compared to regular users. This impairment was obvious in the HGN test, the WAT test and the FTN test.

8.5 Cannabis dose, sobriety test performance and driving performance

8.5.1 Cannabis Dose and Patterns in Performance

This section examines whether a relationship between driving ability and sobriety test performance exists. In order to examine this, it is necessary to determine at which time driving ability was impaired and then which signs of the sobriety tests were significantly related to THC condition.

The results from the driving simulator task indicated that at Time 2, the driving variables, 'straddling the barrier line' and 'straddling the solid line', were significantly related to the level of THC. These results suggest that at approximately 80 minutes

after smoking cannabis, driving ability is impaired, with the higher the level of THC, the higher the likelihood that an individual will have difficulty maintaining a lane in traffic.

Sobriety tests were administered three times, but the times relevant to our analysis are those administered prior and subsequent to driving at Time 2. The sobriety tests of importance are therefore sobriety test administered at Time 2 and at Time 3. Table 12 outlines the variables for the driving task and sobriety tests that were significantly related to THC condition.

Table 12 Driving variables and sobriety test signs significantly related to level of THC.

TIME AFTER CANNABIS CONSUMPTION	**5 mins**	**30 mins**	**50 mins**	**80 mins**	**105 mins**
		T1		**T2**	
DRIVING SIMULATOR:					
Straddled the solid line		**p=.09**		**p<.05**	
Straddled barrier line		**p=.08**		**p<.001**	
	T1		**T2**		**T3**
HGN:					
Lack of Smooth Pursuit	ns		**p<.001**		**p<.005**
Nyst. At Max. Dev.	ns		ns		ns
Nyst. At 45 D	ns		ns		ns
VGN	ns		ns		ns
HGN Impairment	ns		**p<.05**		**p<.05**
NEW SIGNS:					
Swaying	**p<.005**		**p<.005**		ns
Head Moves	**p<.001**		**p<.005**		**p<.05**
Head Jerks	**p<.001**		**p<.005**		**p<.001**
HGN Imp. Incl. Head Moves	**p<.001**		**p<.001**		**p<.005**
WALK AND TURN:					
No Balance	**p<.05**		**p<.01**		**p<.05**
Starts too Soon	ns		ns		ns
Pause While Walking	ns		ns		**p<.05**
Misses Heel to Toe	**p<.05**		ns		ns
Steps Off the Line	**p<.005**		**p<.05**		ns
Arms Used to Balance	**p<.05**		**p<.001**		**p<.05**
Improper Turn	ns		ns		ns
Incorrect no. of Steps	ns		ns		ns
W+T Impairment	**p<.001**		**p<.01**		**p<.05**
ONE LEG STAND:					
Swaying	**p<.005**		**p<.005**		**p<.001**
Arms Used to Balance	**p<.001**		**p<.01**		**p<.001**
Hopping	**p<.01**		**p<.05**		ns
Foot Down	**p<.005**		**p<.001**		**p<.001**
OLS Impairment	**p<.001**		**p<.001**		**p<.001**
ROMBERG BALANCE:					
Feet Not Together	ns		**p<.05**		ns
Arms Not By Side	**p<.05**		ns		ns
Head Not Tilted	ns		ns		ns
Eyes Open	**p<.05**		ns		ns
FINGER TO NOSE:					
Eyes Open	**p<.05**		ns		ns
Arms Not Fully Extended	ns		ns		ns
Arms Not Shoulder Height	ns		**p<.01**		ns
Index Missed Tip of Nose	**p<.01**		ns		**p<.05**
Finger Other Than Index Used	ns		ns		**p<.05**
Arms Not Returned	ns		**p<.05**		ns
Index Not Pointed	**p<.05**		ns		**p<.05**
Head Not Tilted Correct	**p<.01**		ns		**p<.05**
OVERALL SFSTs:					
SFST Battery Impairment	**p<.001**		**p<.005**		**p<.05**
SFSTs Imp. Inc. Head Moves	**p<.001**		**p<.001**		**p<.01**

Table 12 summarises the signs that were significantly related to the level of THC when driving ability was impaired. LSP in the HGN test was significant at Time 2 and Time 3 but not at Time 1. At Time 2 and at Time 3 HGN impairment was also significant. In terms of the 'new' signs in the HGN test, all signs were significantly related to the level of THC at all times, with the exception of S which was not significant at Time 3. The sign HJ became more significant from Time 2 to Time 3, indicating that it may be a good predictor of impaired driving performance. In addition, including HMJ in the scoring procedure of the HGN test strengthened the significance of the relationship between HGN and the dose of THC at both Time 2 ($p<.05$ when HMJ was not scored compared to $p<.001$ when HMJ was scored) and Time 3 ($p<.05$ when HMJ was not scored compared to $p<.005$ when HMJ was scored).

For the WAT test the signs that appear to be related to driving ability are NB and AB. These signs were significantly related to the level of THC at both Time 2 and Time 3. These signs as well as overall WAT impairment appear to be related to driving ability. The signs that appear to be unrelated to driving ability are STS, MHT, IT and INS. STS, MHT, IT and INS were not related to the level of THC at Time 2 or Time 3. It appears that the presence of these signs during the WAT test is not necessarily an indication of impaired driving ability (at least that measured in the present study). NB, SW, SOL, AB and overall WAT were only significant at Time 2 or Time 3 alone.

The OLS was the sobriety test best related to driving ability. The signs scored in the OLS test were significant at all times, with the exception of H at Time 3. The signs S, AB and FD had a strong relationship with the level of THC at Time 2 and Time 3. Overall OLS impairment was also related to the level of THC at Time 2 and Time 3, when the dose of THC significantly impaired driving ability. These results suggest that if during administration of the OLS test all signs are observed, it is likely that driving ability is impaired.

The RB test was unrelated to driving ability. When driving ability was impaired, only FNT at Time 2 was related to the level of THC.

The FTN test was also unrelated to impaired driving ability, as the signs significantly related to the level of THC was different at each time. Signs significantly related to the

level of THC where significant at either one time only and this varied between Time 1, Time 2 and Time 3. When driving was impaired, the signs significantly related to the level of THC at Time 2 were not significantly related to the level of THC at Time 3 and visa versa.

Overall SFST battery impairment, when the HGN, WAT and OLS were added, were related to driving ability. At Time 2 and Time 3, there was a significant relationship with the dose of THC and sobriety test performance. Including HMJ in the HGN increased the strength of this relationship at both Time 2 and Time 3. These results suggest the SFST battery is likely to detect impaired driving associated with cannabis, although including the HMJ as a scored sign in the HGN test will improve its accuracy to do so.

8.5.2 Cannabis Dose, Patterns in Performance and Frequency of Cannabis Use

Differences in performance on the sobriety tests, for non-regular users and regular users, was examined. For each group, impaired driving ability was compared to the signs of the sobriety tests that were significantly related to level of THC.

Non-Regular Users Compared to Regular Users

The results from the driving simulator task indicated that at Time 1, there was a significant relationship between dose of THC and the variable 'car rolling' in both groups, although the relationship was different for each group. For non-regular users the number of times car rolling occurred increased with the level of THC. For regular users the number of times car rolling occurred decreased as the level of THC increased. This result indicates that car rolling was impaired for non-regular users but not for regular users.

RT for an emergency stop increased for non-regular users as the level of THC increased when compared to regular users at Time 1. This demonstrates that THC impairs responses to emergency situations more so in non-regular users than in regular users.

At Time 2 non-regular users had significantly more collisions than regular users as level of THC increased, indicating that non-regular users were more impaired by THC than regular users. Finally at Time 2, after an emergency stop, the distance between the vehicle and the object was greater for non-regular users than regular users, indicating that non-regular users were more impaired on this variable compared to regular users.

These results clearly demonstrate that non-regular users are more impaired on driving variables with increasing levels of THC, compared to regular users. This difference is present at both 30 minutes and 80 minutes after the administration of cannabis. In summary, the data indicates that non-regular users are more likely to cause accidents in emergency situations, compared to regular users. Since the group severely impaired by THC is the non-regular users group it is important to establish which signs of the sobriety tests, for this group, were significantly related to the dose of THC administered. All sobriety test performances (Time 1, Time 2 and Time 3) are relevant as differences in driving ability between non-regular and regular users were recorded at both Time 1 and at Time 2 of the driving task.

Table 13 outlines the variables for the driving task and sobriety tests that were significantly related to the level of THC for non-regular users.

Table 13 Summary of significant relationships between level of THC and driving and sobriety signs.

TIME AFTER CANNABIS CONSUMPTION	5 mins	30 mins	50 mins	80 mins	105 mins
		Time 1		**Time 2**	
DRIVING SIMULATOR:					
Increased no. of Car rolling		**p<.05**			
Increased RT in Emergency		**p<.05**			
Increased no. of Collisions				**p<.05**	
Increased Distance b/w object				**p<.05**	
	Time 1		**Time 2**		**Time 3**
HGN:					
Lack of Smooth Pursuit	ns		**p<.05 (B)**		**p<.05 (B)**
Nyst. At Max. Dev.	ns		ns		ns
Nyst. At 45 D	ns		**p<.05 ***		**p<.05 ***
VGN	ns		**p<.05 ***		**p<.05 ***
HGN Impairment	ns		**p<.05 ***		**p<.05 ***
NEW SIGNS:					
Swaying	**p<.01 ***		**p<.05 (B)**		**p<.001 ***
Head Moves	**p<.005(B)**		**p<.005 ***		**p<.05 ***
Head Jerks	**p<.001 ***		**p<.005 ***		**p<.01 ***
HGN Imp. Incl. Head Moves	**p<.05 (B)**		**p<.005(B)**		
WALK AND TURN:					
No Balance	**p<.001 ***		**p<.05 ***		**p<.01 ***
Starts too Soon	ns		**p<.05 ***		**p<.05 ***
Pause While Walking	ns		**p<.05 ***		**p<.05 ***
Misses Heel to Toe	ns		ns		ns
Steps Off the Line	**p<.001 ***		**p<.01 ***		ns
Arms Used to Balance	**p=.05 #**		**p<.01 (B)**		**p<.05 ***
Improper Turn	ns		ns		ns
Incorrect no. of Steps	ns		ns		ns
W+T Impairment	**p<.05 ***		**p<.05 ***		**p<.01 ***
ONE LEG STAND:					
Swaying	ns		**p<.005 ***		**p<.001(B)**
Arms Used to Balance	**p<.05 (B)**		**p<.01 ***		**p<.01 (B)**
Hopping	**p<.05 ***		**p<.05 ***		ns
Foot Down	**p<.005 ***		**p<.005 ***		**p<.005 ***
OLS Impairment	**p<.001(B)**		**p<.001 ***		**p<.001 ***
OVERALL SFSTs:					
SFST Battery Impairment	**p<.005(B)**		**p<.05 (B)**		**p<.005 ***
SFSTs Imp. Inc. Head Moves	**p<.001(B)**		**p<.01 (B)**		**p<.001 ***
ROMBERG BALANCE:					
Feet Not Together	ns		**p<.05 ***		**p<.05 ***
Arms Not By Side	ns		ns		ns
Head Not Tilted	ns		ns		ns
Eyes Open	**p<.005 #**		ns		**p<.05 ***
FINGER TO NOSE:					
Eyes Open	ns		ns		ns
Arms Not Fully Extended	ns		**p<.05 ***		**p<.05 ***
Arms Not Shoulder Height	ns		**p<.05 ***		ns
Index Missed Tip of Nose	ns		ns		**p<.05 ***
Finger Other Than Index Used	ns		**p<.05 ***		**p<.05 ***
Arms Not Returned	**p<.05 ***		**p<.05 ***		**p<.05 ***
Index Not Pointed	**p<.005 #**		ns		**p<.05 ***
Head Not Tilted Correct	**p<.005 #**		**p<.005 ***		ns

*** denotes that the relationship was significant only for non-regular users**
 # denotes that the relationship was significant only for regular users
(B) denotes that the relationship was significant for regular users also

Table 13 reports the signs that were significantly related to the dose of THC when driving was impaired in non-regular users. In the HGN test, LSP was significantly related to the dose of THC. Unlike when all participants were examined as one group, for non-regular users when driving was impaired, there was a significant relationship between level of THC and N45 and VGN. Overall HGN impairment was also related to driving impairment. With respect to the 'new' signs, all were significantly related to level of THC, where the relationship was more pronounced at Time 2 and Time 3 for the signs S and HJ. A stronger relationships was observed between the HGN test and the level of THC at all sobriety testing times when HMJ was scored as a sign when compared to when it was not. This suggests that the ability to detect driving impairment when using the HGN is improved after taking into consideration the presence of HMJ.

For the WAT test the most consistent signs were NB, AB and overall WAT impairment. MHT, IT and INS were unrelated to driving impairment. This was also observed when non-regular users and regular users were analysed as one group.

The OLS test is the better test for detecting driving impairment. All signs were significantly related to level of THC at the times when driving ability was impaired. The strength of these relationships were improved than when compared to many signs observed in the other sobriety tests.

Overall SFST battery impairment (when HGN, WAT and OLS were added) was significantly related to level of THC for non-regular users. Overall SFSTs including HMJ (in the HGN test) was also related to driving impairment, in which significant relationships are stronger than when HMJ was not included (in the HGN test). These results suggest that including HMJ as a scored sign in the HGN test improves the ability to detect impaired driving ability with the SFSTs, particularly in non-regular users.

The RB test was unrelated to driving impairment (this was also reported when non-regular and regular users were analysed as one group). However, the signs FNT and EO were significantly related to the level of THC at different times.

Finally, for the FTN test, the signs that appear most related to driving impairment in non-regular users are the ANE, IFNU, ANR, and HNT. These results suggest that these

signs are likely to be observed during the administration of the FTN when driving ability is impaired, particularly in non-regular users.

8.6 Efficiency of the Standard Field Sobriety Test to predict driving ability

In order to establish the sensitivity of the sobriety tests to predict driving impairment, discriminant analysis was calculated using overall SFST battery performance and all sobriety tests that comprise the SFSTs (HGN, WAT and OLS). Driving impairment was scored for each individual as either 'impaired' or 'not impaired'. A score between 0 and 75 constituted 'not impaired' on driving and a score of 76 and above constituted 'impaired' on driving (calculated using scores obtained on all 36 variables). This scoring procedure was taken from the Cybercar technical manual ("pass" or "fail" on driving test, calculated using averaged scores from driver training sessions). The discriminant analysis calculated how often the sobriety tests correctly classified participants as either impaired or not impaired on driving. The analysis also calculated which test alone was the best predictor of driving impairment.

Each experimental session comprised the administration of the sobriety tests (Time 1), the driving task (Time 1), the sobriety tests again (Time 2), the driving task again (Time 2) and a final sobriety tests (Time 3). Driving performance at Time 1 was analysed with sobriety test performance at Time 1 and at Time 2. Driving performance at Time 2 was analysed with sobriety test performance at Time 2 and at Time 3.

<u>Driving Impairment at TIME 1</u>

Driving impairment at Time 1 is a measure of the number of participants impaired by the level of THC 30 minutes after smoking cannabis.

Low THC Condition

A discriminant analysis indicated that the sobriety tests administered at Time 1 correctly classified participants, as either impaired or not impaired on the driving task administered at Time 1, in 69.2% of cases. However only 50% of the participants that were impaired were correctly identified as impaired, and 89.5% of participants not impaired were correctly identified as not impaired. The best single predictor of driving

ability (at low levels of THC) was the WAT test. A discriminant analysis calculating performance on the SFSTs indicated that including the sign HMJ is a better predictor of driving ability, than when not including HMJ. These results suggest that sobriety tests administered at 5 minutes after smoking low doses of cannabis correctly classify driving ability (at 30 minutes) in 69.2% of cases.

A discriminant analysis indicated that sobriety tests administered at Time 2 correctly classified participants as either impaired or not impaired on the driving task administered at Time 1 in 64.2% of cases. This percentage includes 70% of impaired participants correctly identified as impaired and 57.9% of participants not impaired correctly identified as not impaired. The best single predictor of driving ability (at low levels of THC) was the WAT test. Including the sign HMJ in the administration of the SFSTs did not improve the ability to correctly classify driving impairment. These results suggest that sobriety tests administered at 50 minutes after smoking low levels of THC identifies impaired driving (at 30 minutes) in 64.2% of the cases assessed.

High THC Condition

Results indicated that sobriety tests administered at Time 1 correctly classified participants driving ability at Time 1 in 68.4% of cases. Of the participants who were in impaired, 63.6% were correctly identified as impaired, and of those who were not impaired, 75% were correctly identified as not impaired. The best single predictor of driving ability (at high levels of THC) was the OLS test. Results also indicated that including HMJ did not improve the accuracy of the SFSTs. These results suggest that sobriety tests administered at 5 minutes after smoking high levels of THC accurately determines driving ability (at 30 minutes) 68.4% of the time.

Results indicated that sobriety tests administered at Time 2 correctly classified participants as impaired or not impaired on the driving task at Time 1 in 63.2% of cases. Of the participants impaired on the driving task 63.6% were correctly identified as impaired, and of the participants not impaired on the driving task 62.5% were correctly identified as not impaired. The best single predictor of driving ability (at high levels of THC) was once again the OLS test. Including the sign HMJ in the scoring procedure of the HGN test did not improve the accuracy of the SFSTs to predict driving ability.

These results suggest that sobriety tests administered at 50 minutes after smoking high levels of cannabis successfully predict driving ability (at 30 minutes) 63.2% of the time.

Driving Impairment at TIME 2

Driving impairment at Time 2 is measure of the number of individuals impaired by the level of THC 80 minutes after smoking cannabis.

Low THC Condition

A discriminant analysis calculated using the sobriety tests administered at Time 2 correctly classified driving ability at Time 2 in 71.8% of cases. However 88.5% of participants who were impaired on the driving task were correctly identified as impaired, but only 38.5% of participants not impaired on the driving task were correctly identified as not impaired. The best single predictor of driving ability (at low levels of THC) was overall SFSTs, followed by the WAT test. Including the sign HMJ did not improve the accuracy of the SFSTs to predict driving ability. These results suggest that sobriety tests administered at 50 minutes after smoking low levels of THC accurately predict driving ability (at 80 minutes) in 71.8% of cases.

Results indicated that sobriety tests administered at Time 3 correctly classified driving ability at Time 2 in 66.7% of cases. All participants impaired on the driving task were correctly identified as impaired but none of the participants not impaired on the driving task were correctly identified as not impaired. The best predictor of driving ability (at to low levels of THC) was the WAT test. The results also demonstrated that including the sign HMJ improves the accuracy to predict driving impairment than when HMJ is not included. These findings suggest that sobriety tests administered at 105 minutes after smoking low levels of THC successfully predict driving ability (at 80 minutes) in 66.7% of cases.

High THC Condition

A discriminant analysis indicated that sobriety tests administered at Time 2 correctly classified driving ability at Time 2 in 65.8% of cases. Specifically, 92% of impaired participants were correctly identified as impaired, but only 15.4% of participants not impaired were correctly identified as not impaired. The best single predictor of driving

ability (at high levels of THC) was the OLS test. Including HMJ in the SFSTs was again a better predictor of driving ability, when compared to not including HMJ. These results suggest that sobriety tests administered at 50 minutes after the smoking of high levels of THC successfully predict driving impairment (at 80 minutes) in 65.8% of cases.

Finally, the results indicated that sobriety tests administered at Time 3 correctly classified driving ability at Time 2 in 76.3% of cases. Specifically, 84% of participants impaired on the driving task were correctly identified as impaired, and 61.5% of those not impaired were correctly identified as not impaired. The best single predictor of driving ability (at high levels of THC) was again the OLS test. Including HMJ improved the accuracy to predict driving impairment when compared to not including HMJ. These findings suggest that sobriety tests administered at 105 minutes after the smoking of high levels of THC successfully predict driving impairment (at 80 minutes) in 76.3% of cases.

There is some variability in the accuracy of the sobriety tests to predict driving impairment. From the results on the driving task at Time 2 and the sobriety tests administered at Time 2 and at Time 3, the sobriety tests are moderately good predictors of driving ability. Specifically, in some cases all participants impaired on the driving task were correctly classified as impaired. In addition, the WAT test was the best predictor of driving impairment when low levels of THC are administered, whereas the OLS test was the best predictor when high levels of THC were administered. Finally, including HMJ as a scored sign in the SFSTs improved the accuracy of the SFSTs to predict driving ability after the consumption of high levels of THC.

8.7 Summary of results: Level of THC in blood, driving performance and sobriety test performance

Figure 43 outlines the levels of THC in blood after the consumption of low and high dose cannabis cigarettes. In addition, Figure 43 outlines the results of the administration of the sobriety tests and performance on the driving simulator task.

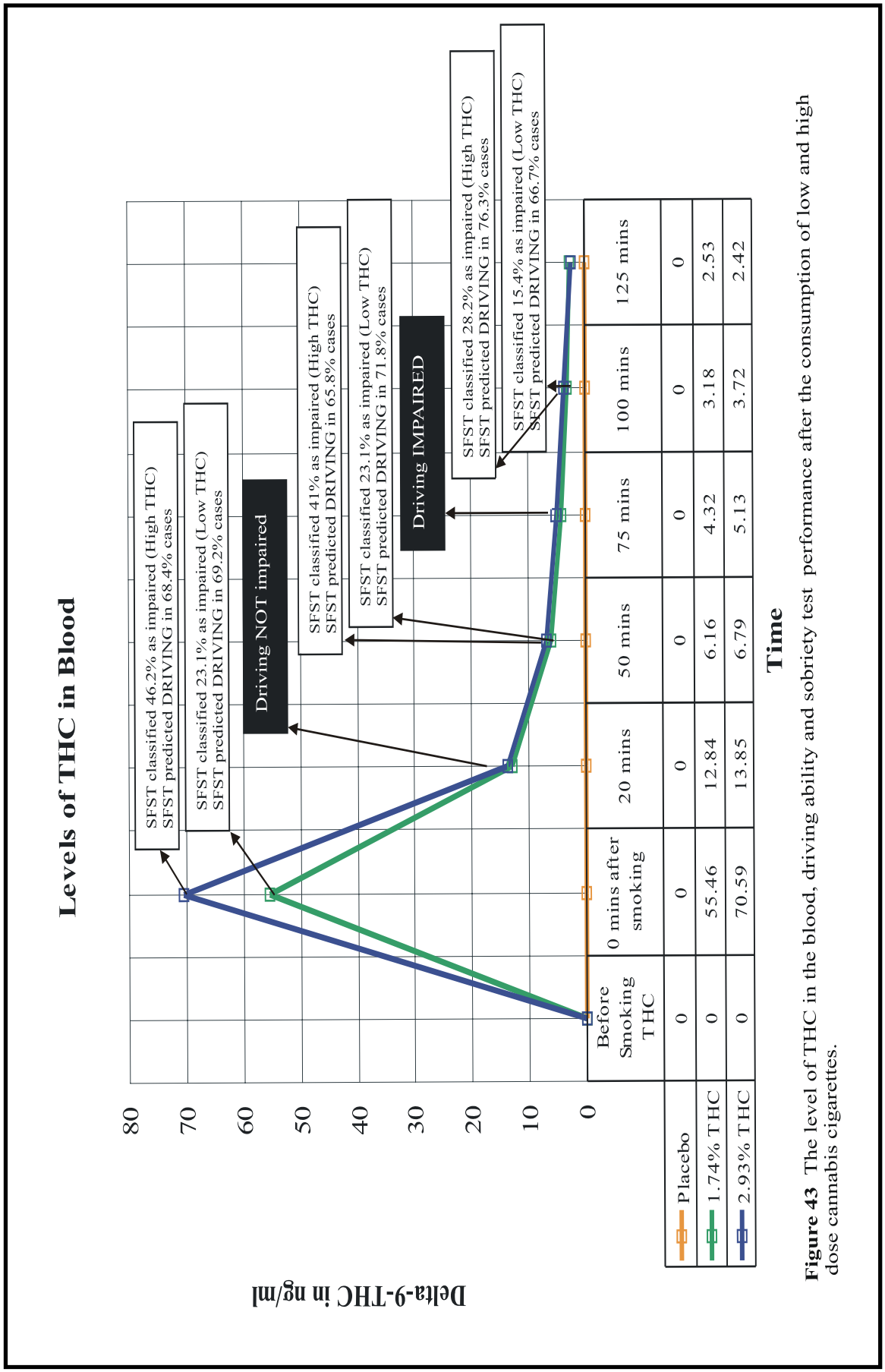


Figure 43 The level of THC in the blood, driving ability and sobriety test performance after the consumption of low and high dose cannabis cigarettes.

Results from the driving task indicated that between 20 and 50 minutes after the consumption of cannabis, driving ability was not significantly impaired by increasing levels of THC. At this point the level of THC in blood varied between 6 and 13 ng/ml. Between 75 and 100 minutes however, driving ability was significantly impaired by increasing levels of THC. At this point the level of THC in blood had dropped to between 3 and 5 ng/ml. It may be assumed that with higher levels of THC in blood, there would be an increased probability that driving ability will be impaired, but this was not observed in the present study. As the level of THC in blood dropped to levels below 6 ng/ml (75 minutes after smoking), driving impairment was observed.

Results from the sobriety tests revealed that the highest number of participants were classified as impaired at 5 minutes after the consumption of high dose cannabis. This percentage decreased as the time after the consumption of cannabis increased. At all times the percentage of individuals classified as impaired was higher in the high THC condition compared to the low THC condition. The sobriety tests classified participants as impaired more often when the level of THC in blood was higher. These results indicate that there is a positive relationship between the sobriety tests and the level of THC in blood.

From analysis of the driving data, it was reported that as the level of THC in the blood decreases, the level of driving impairment increases. It was also reported that as the level of THC in blood decreases so does the percentage of participants classified as impaired by the sobriety tests. These results demonstrate that sobriety tests are better predictors of the level of THC in blood as opposed to actual driving ability. However, statistical analyses revealed that the sensitivity of the sobriety tests to predict driving ability increases as the level of THC in blood decreases. Sobriety tests were most sensitive in correctly classifying driving ability when levels of THC in blood were as low as 2 ng/ml. When the level of THC in blood was between 6 and 70 ng/ml, low correct classification rates were more often due to the false classification of participants as impaired who were not actually impaired. These results suggest that the data from sobriety test administration resemble the recent consumption of cannabis irrespective of driving ability. When the level of THC in blood drops to under 6ng/ml, the sobriety tests are accurate in predicting driving ability 76.3% of the time, which is considerably better than chance.

8.8 Summary of results: Frequency of cannabis use: Level of THC in blood, driving performance and sobriety test performance

Figure 44 displays the differences in the level of THC in the blood after the consumption of low and high dose cannabis for regular cannabis users and non-regular cannabis users. Figure 44 also displays the major differences in performance on the driving task and sobriety tests between the two groups.

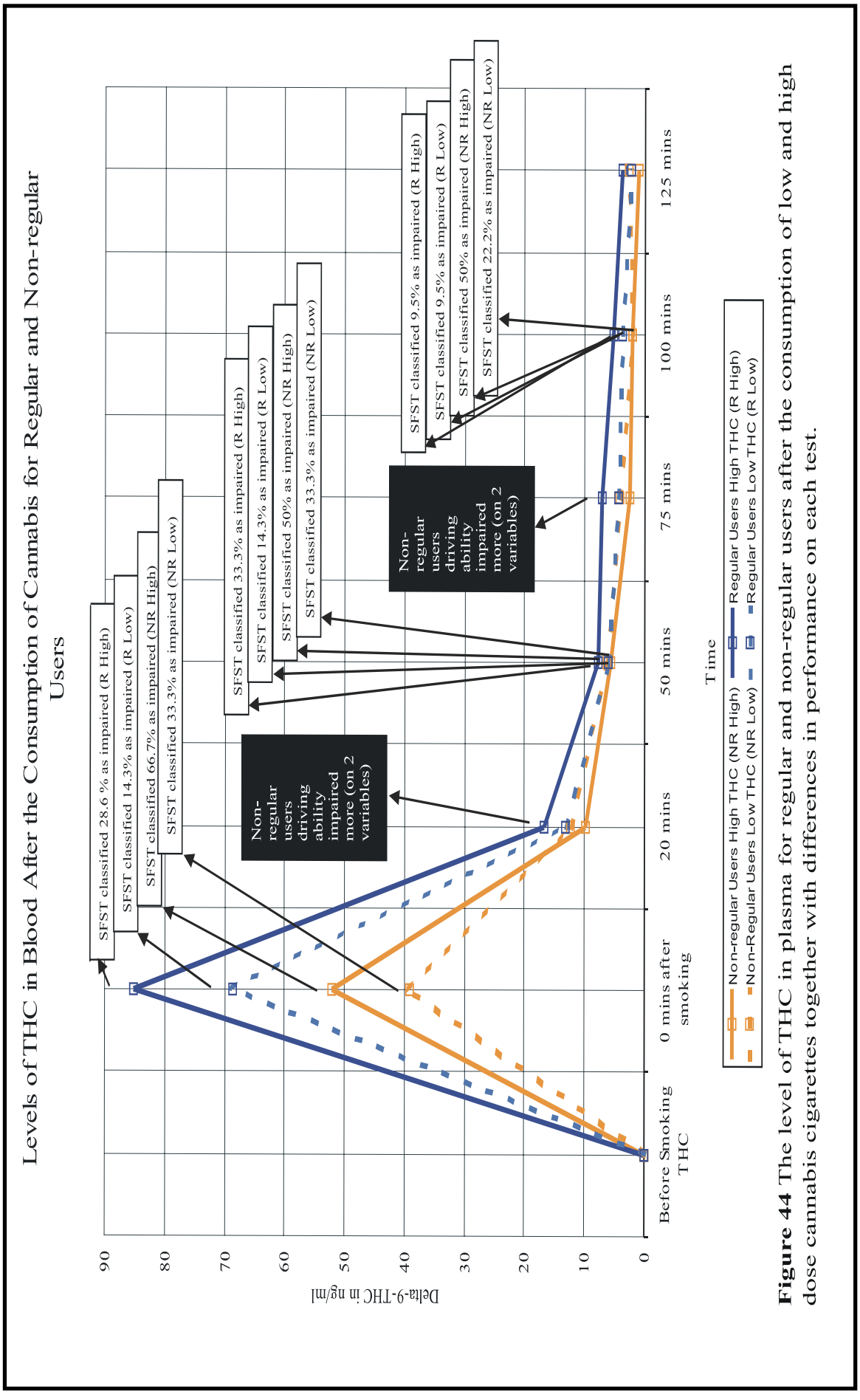


Figure 44 The level of THC in plasma for regular and non-regular users after the consumption of low and high dose cannabis cigarettes together with differences in performance on each test.

Results from the driving task indicated that non-regular users were significantly more impaired on two driving variables than regular users, between 20 and 50 minutes after smoking cannabis. These variables included 'car rolling' and 'RT in an emergency situation'. At this time, the level of THC in blood was between 6 and 12 ng/ml in non-regular users and between 6 and 16 ng/ml in regular users. Non-regular users were also significantly more impaired on the driving task (on two variables) than regular users between 75 and 100 minutes after the consumption of cannabis. Specifically the two variables impaired included 'number of collisions' and 'distance between object in an emergency situation'. At this time, the level of THC in blood was between 2 and 4 ng/ml in non-regular users, and between 5 and 7 ng/ml in regular users. These results suggest that the significant difference in driving impairment between both groups is not necessarily associated with high levels of THC in blood. If this was true, it would be expected that non-regular users, who were more impaired on the driving task, would have higher levels of THC in blood compared to regular users, however the opposite was observed (regular users had higher levels of THC in blood).

Results from the sobriety tests indicated that the highest number of participants classified as impaired (66.7%) was 5 minutes after the consumption of cannabis, and comprised non-regular users. At this time, the level of THC in blood in non-regular users was 52 ng/ml. In comparison, the level of THC in blood in regular users was 85 ng/ml, where only 28.6% of regular users were classified as impaired. In all cases, the percentage of participants classified as impaired was higher in non-regular users compared to regular users, in both the low and high THC condition. In addition, the level of THC in blood was lower in non-regular users compared to regular users, in both the low and high THC condition. It appears that the level of THC in blood is not related to sobriety test performance when the frequency of cannabis use is taken into consideration. Regular users appear to have a higher tolerance level to the psychological and physiological effects of THC and this is reflected in their performance on the sobriety tests (lower percentage of regular users classified as impaired compared to non-regular users).

From the driving data it was reported that non-regular users are more impaired on the driving task after the consumption of low or high dose of THC, compared to regular users. It was also reported that a higher percentage of non-regular users were classified

as impaired after the consumption of THC, compared to regular users. In addition, the percentage of individuals classified as impaired decreased as the level of THC in blood decreased, for both groups. These findings suggest that sobriety tests reflect the level of THC in blood, however if this was true, we would expect that a higher percentage of regular users would have been classified as impaired since the level of THC in their blood was higher compared to non-regular users. This was not observed, therefore the difference in the percentage of individuals classified as impaired is likely to be a result of the difference in driving ability between both groups. Sobriety test performance therefore reflects the difference in driving performance between regular and non-regular users, irrespective of the level of THC in blood.

Chapter Nine: Discussion

Chapter nine discusses the major results of the present study in the context of past research.

9.1 Cannabis dose and intoxication ratings

The results of the present study indicated that the perceived effects of the cannabis cigarettes administered were indicative of the perceived strength of cannabis usually smoked by cannabis users ("street cannabis"). The level of psychological and physiological effects produced by the cannabis cigarettes administered was also consistent with the typical effects experienced after smoking "street cannabis". Therefore it was concluded that the level of THC in the cigarettes used in the present study were similar to the level of THC used in previous cannabis research that administered cannabis of "street" strength.

The self-report strength of the placebo cannabis cigarettes used in the present study was described as very low, consistent with the actual content of THC in the cigarette. The self-report strength of the 1.74% THC cannabis cigarette was described as containing low or moderate levels of THC and the 2.93% THC cannabis cigarette was described as containing a fairly high level of THC.

There were some differences between the perceived strength of each cannabis cigarettes between non-regular cannabis users and regular cannabis users. Non-regular users reported to consume cannabis that is more likely to have the same THC content as the low cannabis cigarette administered in the present study. In contrast, regular users reported that the perceived effects of the high THC cigarette had the same THC content as the cannabis that they would usually smoke.

From these results it is hypothesised that differences in performance, between regular users and non-regular users, particularly in the high THC condition, would be observed because of the differences in perceived effects of cannabis. In other words, the perception that the high THC dose induced minimal psychological and physical changes

may be due to an increased tolerance to the drug by regular users. This hypothesis is consistent with the comments made by Ramaekers et al. (2000), who reported that regular users may have a higher tolerance to the effects of THC, in which the impairing effects of THC are more effectively compensated for by regular cannabis users than by non-regular cannabis users. A difference in performance between regular and non-regular users was observed for driving ability and sobriety test performance (discussed in 9.2 and 9.3).

The results of the present study indicated that the psychological and physiological effects produced by the cannabis cigarettes were indicative of the THC content of the cigarette. In the placebo session the majority of participants reported no subjective intoxication, in the low THC session most participants reported that the effects were similar to those usually experienced, and in the high THC condition the majority of participants stated that the effects were either the same or slightly different. These typical effects of THC described by participants included red eyes, increased heart rate, decreased motivation, increased relaxation, time distortion, the feeling of heavy limbs, and the most frequent, uncontrollable laughter.

There were differences in the description of the psychological and physiological effects produced by the low and high THC cigarette between regular and non-regular cannabis users. Generally most non-regular users reported that the low THC cigarette produced a similar level of intoxication as the cannabis usually smoked, whereas regular cannabis users reported that the high THC cigarette produced a similar intoxication as the cannabis usually smoked. Again, it was expected that differences in performance would be observed for regular and non-regular users and this was reported for driving ability and sobriety test performance (discussed in 9.2 and 9.3). Once again this result is consistent with comments made by Ramaekers, et al. (2000).

The use of the Intoxication Rating Questionnaire made it possible to establish that the cannabis cigarettes used in the study were of equivalent or similar strength to “street cannabis”. The use of the questionnaire also made it possible to establish that regular cannabis users experience psychological and physiological changes associated with THC intoxication to a lesser extent when compared to non-regular users. It is possible that the levels of THC administered in the present study, and perhaps even past

research, are not the typical dose consumed by regular users. If this is true, it is likely that the impairment observed in regular users reported in these studies, underestimates the impairing effects of cannabis on regular users in a real-life driving situation. For instance, for regular users who typically consume a larger amount and/or a higher concentration of cannabis, the degree of psychological and physiological changes would be greater. The result is likely to be a higher degree of impairment than that reported in the present study.

9.2 Cannabis dose and driving performance

The present study found that cannabis significantly impaired some aspects of driving ability. Specifically, the inability to maintain a steady position within a traffic lane is increased with increasing levels of THC.

Data from the driving simulator indicated that the mean number of times 'straddling the barrier line' and 'straddling a solid line' occurred, increased with the level of THC, particularly at 80 minutes after smoking cannabis. This suggests that the higher the THC content of the cigarette, the more likely an individual will drive with two or more wheels of a vehicle over an unbroken line marked out for traffic moving in the same direction, and over a solid line marked out for traffic moving in the opposite direction. This indicates that THC modifies the ability to maintain focused on a task that requires continuous attention as well as the ability to maintain a specific position (balance/steady position of steering wheel/vehicle). This type of impairment is likely to result in dangerous driving, as well as increase the risk of an accident, particularly in situations where attention is required for more than 15 minutes of driving (minimum length of the driving task used in this study).

These findings are consistent with previous research that has revealed 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). Research examining the actions of THC on cannabinoid

receptors in the brain has shown that THC interferes with the normal functioning of the cerebellum, the region most responsible for balance, posture and the coordination of movement. THC interferes with the communication between the cerebellum and motor cortex, where the cerebellum compares actual movements with intended movements and then signals the motor cortex to make any necessary adjustments. 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 the WAT and OLS sobriety test performances (discussed in 9.3).

Large statistically significant differences were observed in the impairment of driving performance caused by THC for regular cannabis users compared to non-regular cannabis users. These differences revealed that the driving ability of non-regular users was impaired by cannabis relative to that of regular users. Non-regular users had slower RTs to emergency situations in which this impairment was observed at 30 minutes after the smoking of cannabis. This result is consistent with those of Rafaelson, et al. (1973) who reported an increased latency when stopping and starting. Caswell (1979), Smiley et al. (1981) and Barnett et al. (1985) also found that high doses of THC slowed RT to subsidiary tasks. Robbe (1995) indicated that even though reported effects of THC do not seem to be severe, in emergency situations this impairment may be detrimental. In contrast, Stein et al. (1983) who used a task that ran for the same duration as the present study, observed no impairment on the subsidiary task. This contradiction may be due to the fact that the impairment observed in the present study occurred 30 minutes after smoking cannabis.

Eighty minutes after smoking, non-regular users had more collisions than regular users, and when stopping to avoid hitting an object in a emergency situation, the distance between vehicle and object was less than the distance between vehicle and object observed for regular users. The effect of THC on performance in non-regular users is consistent with the effects of THC on driving ability observed by Hansteen et al. (1976) and Smiley et al. (1981), in which the administration of THC increased the number of obstacles hit on a driving course. This supports that proposition that THC increases the time required to process information and to respond to an obstacle and/or emergency

situation, resulting in a decrease in the distance between the vehicle and the obstacle or contact with the obstacle itself.

The differences observed between regular and non-regular users are consistent with those reported by Ramaekers et al. (2000) and Lamers and Ramaekers (2000), in which driving impairment due to cannabis consumption was less severe in individuals who were experienced with cannabis and who therefore have a higher tolerance to cannabis, compared to non-regular users. Claims that regular users have a higher tolerance to the effects associated with cannabis should be made with caution (as mentioned in 9.1) as regular users typically consume a larger amount of cannabis to experience the same psychological and physiological effects as non-regular users in this study. Klonoff (1974) also acknowledged that there may be qualitative differences between the impairment shown by cannabis in different individuals.

In addition to the differences in performance between regular and non-regular cannabis users on the driving task, the time at which impairment in non-regular users was observed is inconsistent with the findings of Berghaus et al. (1995). Driving impairment was observed in non-regular users at 80 minutes after the consumption of cannabis, whereas Berghaus et al. (1995) reports that optimal impairment occurs between 40 minutes and 1 hour after smoking cannabis. It is possible that this discrepancy is primarily due to the fact that impairment in the driving task was observed in non-regular users only. Non-regular users in the present study reported that the high THC cannabis cigarette produced more intensified psychological and physiological effects compared to cannabis typically smoked. The impairment observed may therefore may have continued for many hours after the consumption of cannabis.

In conclusion, the impairing effects of THC in non-regular cannabis users suggests that THC impairs car control (more collisions) and RT to emergency situations (slower reaction time, increased stopping distance and more collisions). It is therefore hypothesised that intoxicated non-regular users would be more impaired on tests that claim to detect driving impairment caused by drugs, than intoxicated regular users. Along these lines sobriety tests will detect more signs during performance in non-regular users compared to regular users and this hypothesis was supported (discussed in 9.3).

9.3 Cannabis dose and sobriety test performance

The results of the present study found that cannabis impairs performance on sobriety tests. Specifically, the higher the THC content of the cannabis cigarette smoked, the more likely the sobriety tests will classify an individual as impaired to a degree equivalent to a BAC above .10%.

The HGN test was not related to the dose of THC at 5 minutes after smoking cannabis. However, at 55 minutes after smoking and at 105 minutes after smoking, HGN impairment was related to the dose of THC. Specifically, the sign LSP (Lack of Smooth Pursuit) was more likely to occur with higher levels of THC. These findings suggest that LSP may be observed 55 to 105 minutes after smoking a cigarette with a high THC content. At this time 'dumped' THC re-enters the blood stream (elimination phase) (Chesher, 1997). It is acknowledged that generally nystagmus is also observed when a lack of smooth pursuit is observed. It is therefore possible that nystagmus was indeed present but too slight to be detected. In addition, it is possible that a drug other than cannabis induced the LSP observed, since blood samples were not tested for any substance other than THC (discussed in Chapter 10). The observation of LSP in the THC conditions is inconsistent with some research that has reported that nystagmus does not occur after the consumption of THC (Page, 1995). Research by Adler and Burns (1994) however reported the presence of LSP after marijuana smoking. This sign was present in 60% of individuals arrested for drug use and whose specimen tested positive for marijuana (as well as other substances). Adler and Burns (1994) also reported that 66% of these individuals exhibited HGN at maximum deviation. Assuming that the LSP and HGN at maximum deviation observed were associated solely with the presence of marijuana, the data is consistent with the findings of the present study.

The sign HMJ (Head Movements/Jerks), which was recorded when the participant was unable to keep their head still while following a moving stimulus, was present in the highest percentage of individuals compared to any other sign of the sobriety tests used, at 5 minutes and at 55 minutes after smoking cannabis. These results are consistent with the notion that THC impairs the ability to maintain a specific position discussed in

previous research (discussed in driving 9.3.2). The introduction of HMJ as a scored sign in the HGN improved the efficiency of the HGN to detect impairment caused by THC. The results indicated that scoring HMJ improved the strength and significance level of the relationship between HGN and the level of THC. This suggests that the inclusion of HMJ increases the likelihood that the HGN will indicate whether an individual is impaired after smoking cannabis containing either low or high levels of THC. Since the SFST battery has not been validated for the detection of drugs, it is important to acknowledge the advantages of adding new signs that contribute to the accuracy of the SFSTs to detect impairment associated with the consumption of cannabis. Ultimately, these findings should be replicated, nevertheless, departments using or considering the use of such sobriety tests should consider the inclusion of the sign HMJ, as it appears to facilitate the detection of impairment caused by the level of THC equivalent to that in street cannabis.

The WAT test was related to the dose of THC in all administrations of the sobriety test. The signs that were observed at all times were NB (No Balance) and AB (Arms used to Balance). At 5 minutes, 55 minutes and 105 minutes after smoking cannabis containing either low or high THC content, balance was significantly impaired. These findings suggest that the administration of THC impairs the ability to maintain balance, as well as to focus attention. Overall impairment on the WAT was related to the dose of THC, so that individuals were more likely to be classified as impaired (equivalent to a BAC above .10%) after smoking low or high THC cannabis cigarettes. It is important to acknowledge that three signs of the WAT test were unrelated to the level of THC at all administrations of the sobriety test. The three signs included MHT (Misses Heel to Toe), IT (improper Turn) and INS (Incorrect Number of Steps). These signs appeared almost as often in the placebo session as they did in the THC conditions and are therefore likely to be observed irrespective of drug consumption. It is somewhat problematic to classify an individual as impaired by THC on the basis of the presence of these three signs alone. However, it is not clear, from past research, whether MHT, IT and INS are observed in placebo and alcohol conditions alike. It is possible that the high incidence of false positives reported in previous research is the result of the scoring of signs that are unrelated to alcohol and/or drug use. This is an issue that should be addressed by future research because further research may indicate that the signs should be excluded from the scoring procedures of the SFST battery.

In the present study the OLS was by far the best test of impairment associated with the administration of THC compared to any other sobriety test. Overall performance on this test was significantly related to the level of THC at all testing times, as were all the signs of this test, with the exception of the sign H (Hopping) at Time 3. These relationships may be hypothesised because of the large degree of steadiness and balance required to perform well on this test. Although some participants may not have very good balance to begin with, the type of impairment observed after smoking cannabis was very severe, so that in almost all cases all signs of this test were observed more than once. These findings suggest that an individual is most likely to perform badly on the OLS compared to any of the other sobriety tests after cannabis administration. If these findings are replicated, impairment on this test should therefore take priority over performance on the other tests when the aim is to detect THC. This opinion is inconsistent with the comments made by FIT administrators in Jackson et al.'s (2000) study, who indicated that 'the OLS appears too sensitive for determining drug use, as the majority of suspects fail this test'. The findings of the present study suggest that it is possible that a number of drug-impaired drivers tested in Jackson et al.'s study were wrongfully released (not impaired) on the basis of failing only the OLS.

The HGN, WAT and OLS test reveal that the administration of THC impaired the execution of fine movements. The ability to smoothly follow a moving stimulus, maintain a steady upright position when walking along a designated straight line (while touching heel to toe), and maintaining balance on one leg without swaying or hoping, constitute the execution of fine movements. The main aim of these tests (apart from the HGN) is to assess the ability to maintain a required position as well as to follow specific instructions. This not only requires balance, but also continuous attention, in which the individual must constantly make an effort to focus on the task at hand. After the consumption of THC, participants showed difficulties performing basic tasks such as, keeping their head still when instructed, keeping their arms by their side when walking a straight line and keeping their arms by their side and body still when instructed to stand on one leg. The SFST battery comprises the performance on all three tests.

Overall SFST battery performance was calculated by combining the results obtained on the HGN, WAT and OLS test, so that impairment on two or more of these tests

constituted impairment on the SFSTs. The results of the present study indicated that the SFST battery was related to the level of THC at all times. These results suggest that the SFST battery is a moderately good predictor of impairment caused by low and high doses of cannabis. The SFSTs detected impairment in 46.2% of cases at Time 1, 41% of cases at Time 2, but in only 28.2% of cases at Time 3 (in the high THC condition). This finding is at the low range of accuracy in predicting intoxication, with previous research reporting sobriety testing to be successful in detecting impairment caused by drugs in up to 94% of cases (173 Case Study, 1986). However the results are consistent with the data of the Johns Hopkins Study (1984) (55% of all intoxicated participants were classified as impaired). Previous research also demonstrates that the DEC program has an optimal ability to predict impairment caused by cannabis when 28 variables are used (Heishman et al., 1996). Although the Johns Hopkins study and the 173 case study implemented the DECP sobriety testing method, which includes a more extensive testing procedure (12 steps that also include the SFSTs), in the absence of research on the SFSTs alone and drugs, the percentage comparisons are included to demonstrate and compare the validity of using SFSTs alone to test for drug impairment. The SFSTs used in this study consisted of 16 variables. Perhaps if the SFSTs included the investigation of more signs, the percentage of individuals correctly classified as impaired in the THC conditions may have increased. Including HMJ as a scored sign in the HGN increased the percentage of individuals correctly classified as impaired in the THC conditions in the present study.

Including HMJ (Head Movements/Jerks) as a scored sign in the HGN test increased the efficiency of the SFSTs to detect impairment caused by cannabis. The results indicated that after including HMJ, both the strength and the level of significance of the relationship between THC and the SFSTs was improved. The most interesting finding was that after including HMJ, individuals in the placebo condition were not misclassified. This implies that HMJ is specific to THC intoxication and will therefore only effect classifications on impairment in cases where THC is involved. Training manuals on the SFSTs do suggest that an individual's head may not keep still during HGN performance, but it is not a scored sign, therefore it is unlikely to effect the final classification of impairment. The present study indicates that HMJ occurs often enough to be added to the scoring procedure of the SFSTs and doing so will improve the ability of the SFSTs to detect impairment caused by THC.

The additional two sobriety tests examined in the present study were the RB test and FTN test. Both these tests appeared unrelated to the level of THC. In some of the participant performances, however, the level of THC was related to the sign observed. In the RB test, the sign related to the level of THC differed from Time 1 to Time 2, and at Time 3 no signs were related to the level of THC. These results suggest that there are no consistent patterns between the presence of signs in the RB test and cannabis intoxication. Similar results were obtained for the FTN test, in which signs were related to the level of THC in some sobriety performances but not others, and the significant signs changed from Time 1 to Time 3. There were no consistent patterns in the presence of signs in the FTN test and cannabis intoxication. The administration of THC does not impair performance on the RB and FTN in the same way that it does tests comprising the SFST battery. These results are inconsistent with the finding of Heishman (NIDA notes, 1996) who reported that as the dose of THC administered increased, subjects performed 2.5 times more errors when attempting to touch their nose. Since the DEC program includes the scoring of the RB and FTN test, it is likely that these two tests are the cause of false positives or misses reported in past research. However, the administration of THC appears to primarily impair balance, therefore future research should focus on balance during performance in the RB and the FTN test. If this is done some significant patterns between signs of the RB and FTN test and the level of THC may be observed.

The results of the present study also indicated that differences in performance between regular cannabis users and non-regular cannabis users exist. Non-regular users performed worse on most sobriety tests in the low and high THC conditions, compared to regular users. This was revealed by the large number of significant relationships between signs and level of THC for non-regular users.

With respect to the HGN test, the most interesting finding was the significant relationship between the level of THC and N45 (Nystagmus at 45 degrees) and VGN (Vertical Gaze Nystagmus), in non-regular users. The reason that these relationships were significant for non-regular users only is unclear, but it is hypothesised that it may involve the different tolerance levels to THC across the two groups. Since non-regular users are less experienced with the drug and also claim that the effects of the high THC

cannabis were stronger than cannabis that they usually smoke, it is not surprising that the impairment of some signs were magnified in non-regular users.

Other signs that were significantly related to level of THC in non-regular users but not regular users varied from HJ (head Jerks) in the HGN test, to NB (No Balance) in the WAT test, to almost all signs of the OLS test. Again, even in non-regular users alone, the OLS appeared to be the best test for impairment. Some signs of the OLS were also significantly related to the dose of THC for regular users, which indicates that the OLS is likely to detect impairment in both groups. The results on the OLS for non-regular users also indicate that the stronger the impairment, the more signs observed in the OLS test.

Unfortunately, past research on the validity of the SFSTs and DEC program has not investigated differences in performance on sobriety tests between regular and non-regular cannabis users. The present study shows that the frequency of cannabis use is likely to influence performance on sobriety tests. Therefore this variable should be further examined when administering and scoring sobriety tests.

In conclusion, the results of the present study suggest that the SFST battery classifies individuals as impaired after the consumption of THC in up to 46.2% of cases. Including HMJ (head Movements/Jerks) as a scored sign in the HGN improves this efficiency by an additional 10.2%. In addition, the OLS test is the best test of impairment associated with cannabis. Finally, of the correlation coefficients reported for each sign and the overall sobriety test score for each test with the level of THC, the strongest correlation was $\rho=.5$ (detailed in 8.4). This indicates that even the strongest relationships were only moderate in magnitude and that there is a possibility of improving the accuracy of sobriety tests with the introduction of more accurate signs and tests of impairment.

9.4 Efficiency of the Standard Field Sobriety Test to predict driving ability

A greater number of signs were observed during the administration of the sobriety tests when driving ability was impaired by THC, than when driving was not impaired by

THC. These results indicate that as the level of THC increases, so does both the degree of driving impairment, and the number of participants classified as impaired on SFSTs.

Sobriety test performances when THC impaired driving ability were examined. Driving ability was impaired 80 minutes after the consumption of cannabis, therefore the sobriety test performances of interest were those administered at Time 2 and at Time 3.

The driving variables impaired by THC were 'straddling barrier lines' and 'straddling solid lines'. This suggests that attention and balance were impaired (discussed in driving 9.2), where the maintenance of the steady position of the vehicle's steering wheel is impaired (2 or more wheels of the vehicle move out of the designated traffic lane). The sobriety test performances at Time 2 and Time 3 reflect this type of impairment, in which the signs primarily involving balance, such as NB (No Balance) in the WAT test and all signs of the OLS test, were significantly related to level of THC. In addition, the new sign HMJ (Head Movements/Jerks) was also related to the level of THC when driving ability was impaired. The RB test and the FTN test were unrelated to driving performance at all times (discussed in 9.3).

The results also indicate that non-regular cannabis users are more impaired on the driving task and the SFSTs than regular cannabis users by low and high doses of THC. Non-regular users performed significantly worse than regular users during both driving performances, with RT to emergency situations and number of collisions increasing with the level of THC administered. It was hypothesised that sobriety test performance will reflect the difference in driving impairment caused by THC, in both groups. This hypothesis was supported with more signs significantly related to the level of THC in non-regular users, than in regular users, at all times. The most interesting difference was the significant relationship between N45 (Nystagmus at 45 degrees) and VGN (Vertical Gaze Nystagmus) and level of THC at Time 2 and Time 3. Other significant signs varied from HJ (Head Jerks) in the HGN and NB (No Balance) in the WAT test, to almost all signs of the OLS test. The signs that were significantly related to THC dose, when driving was impaired in non-regular users, once again, involved attention and balance.

Finally, using the SFSTs, the percentage of non-regular users classified as impaired was higher than the percentage of regular users classified as impaired (e.g., high THC condition, at Time 1, 66.7% compared to 28.6%). The SFSTs appears to reflect the difference in driving impairment, caused by low and high levels of THC, for both groups. Including HMJ (Head Movements/Jerks) in the scoring procedure of the HGN test significantly increased the percentage of participants scored as impaired from 66.7% to 72.2% in non-regular users and 28.6% to 42.9% in regular users. Including HMJ in the HGN test improves the relationship between the SFSTs and driving impairment related to increasing levels of THC.

It is acknowledged that SFSTs are not primarily 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 therefore is that the drug present is impairing driving, but this may not necessarily be the case. It is therefore important and also the aim of the Victorian legislation, to distinguish between the presence of a drug and the presence of impairment. The sobriety tests are administered in Victoria to drivers suspected of being impaired/who may pose a danger on the road, therefore it is logical to assume that it is driving ability that we aim to assess with these tests. In order to statistically examine whether sobriety tests predicted driving impairment, discriminant function analysis was performed. In this case, whether a participant is a regular or non-regular cannabis user is irrelevant, as the SFSTs should correctly identify impairment irrespective of participant characteristics or the level of THC. Overall SFST battery performance and the tests that comprise the SFSTs were examined (as these tests were related to THC dose at all times, and are the tests used by Victoria Police). The results of the present study indicate that sobriety tests administered at 5 minutes after the smoking of low dose cannabis correctly classified 69.2% of participants as either impaired or not impaired on driving at 30 minutes after the consumption of cannabis. Five minutes after smoking high dose cannabis, the sobriety tests correctly classified 63.6% of the participants. When driving was most impaired (80 minutes after smoking cannabis), the sobriety tests also predicted impairment; the sobriety tests administered at 50 minutes after smoking cannabis correctly classified 71.8% of participants when low dose cannabis had been consumed and 65.8% of participants when high dose cannabis had been consumed. Sobriety tests administered at 105 minutes after smoking low dose THC correctly identified driving as either

impaired or not impaired in 66.7% of the participants. At 105 minutes after the consumption of high dose THC, sobriety tests correctly classified 76.3% of drivers as either impaired or not impaired on driving. These results suggest that the sobriety tests used in the present study predicted driving impairment, caused by low and high levels of THC, considerably better than chance.

The best predictor of driving ability, after the consumption of low dose cannabis, was the WAT test. When high doses of cannabis had been consumed, the best predictor of driving ability was the OLS test. These results suggest that THC impairs both balance and attention, and tests that assess these abilities are the best predictors of driving impairment caused by cannabis.

In some cases, particularly when high dose cannabis was consumed, the SFST battery assessment that included the 'new' sign HMJ (Head Movements/Jerks) was a better predictor of driving impairment 80 minutes after smoking cannabis (driving significantly impaired), than when not including HMJ. This finding supports previous recommendations reported in police sobriety test manuals, that assessing whether one is able to keep their head in a specific position, can improve the efficiency of the SFSTs to detect impairment associated with THC.

The high correct classification rate of the tests was at times due to a high percentage of impaired individuals being scored as impaired. For instance, the sobriety tests administered at Time 2 (after the consumption of low dose cannabis) correctly identified all impaired individuals as impaired. At this time, the sobriety tests incorrectly classified as impaired a large number of participants who were not impaired on driving. These results reveal that a greater number of signs present during the administration of sobriety tests, may not be an indication of driving ability, but rather an indication of the recent consumption of THC. This suggests that the sobriety tests not only reflect impairment on driving, but also reflect the consumption of low or high levels of THC even when driving is not impaired.

The results of the present study demonstrate how accurately the SFSTs can detect driving impairment. The results also describe the relationship between THC and driving ability. Specifically, when driving was significantly impaired (80 minutes after

smoking) up to 92% of impaired participants were correctly classified as impaired by THC. This finding is consistent with past SFST battery and DEC validation studies, although these studies did not test driving ability, but rather assumed that it was impaired, by assuming the substance impairing sobriety test performance also impairs driving. It is recommended that the findings of the present study be used as a preliminary guide to determine how low and high levels of THC impair both driving ability and sobriety test performance. Nevertheless, this study was an essential first step in determining the accuracy of sobriety tests to predict driving impairment, and how this accuracy may be improved.

In summary, departments or organisations using or considering the use of sobriety tests can be assured that the SFSTs assess both the impairment in driving due to THC and THC consumption considerably better than chance. However, in order to improve the accuracy of the SFSTs, administrators should consider the inclusion of the sign HMJ (Head Movements/Jerks) in the scoring of the HGN.

9.5 Level of THC in blood and performance

THC in blood peaked to 55 ng/ml after the consumption of a 1.74% THC (low) cannabis cigarette, and 70 ng/ml after the consumption of a 2.93% THC (high) cigarette. The peak level of THC in blood referred to in this section was obtained after the cessation of smoking cannabis, not during the smoking procedure. Regular and non-regular cannabis users recorded significantly different peak levels immediately after smoking the different doses of cannabis. Regular users recorded a peak THC level of 68 ng/ml after the consumption of the low THC cigarette and a peak THC level of 85 ng/ml after the consumption of the high THC cigarette. Non-regular users recorded a peak level of 39 ng/ml in the low THC condition and 52 ng/ml in the high THC condition. These results are consistent with previous research indicating that the level of THC in the plasma can peak up to 130 ng/ml (equivalent to 81 ng/ml in blood (Giroud, et al., 2001)) after the consumption of a 3.55% THC cigarette and up to 75 ng/ml (equivalent to 47 ng/ml in blood (Giroud et al., 2001)) after the consumption of a 1.75% THC cigarette (after the cessation of smoking) (Cone & Huestis, 1993). The differences in the peak level of THC between regular users and non-regular users can be attributed to the greater experience in smoking cannabis in regular users. 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 an entire 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).

After the initial peak in THC level, the level of THC dropped dramatically to a level of 12 ng/ml in the low THC condition and to a level of 13 ng/ml in the high THC condition (20 minutes after smoking). For non-regular users alone, THC dropped to 12 ng/ml in the low THC condition and to 9 ng/ml in the high THC condition. For regular users, the level of THC dropped to 13 ng/ml in the low THC condition and to 16 ng/ml in the high THC condition. Again the differences in the level of THC in blood between both groups are most likely to be explained by the difference in the length of time that the THC smoke was inhaled and held in the lungs.

The level of THC in blood continued to drop to a level as low as 2 ng/ml (final blood sample, 125 minutes after smoking). An interesting finding was that in both the low and high THC condition, the rate at which the level of THC dropped from the sample taken 20 minutes after smoking to the sample taken 125 minutes after smoking, was almost identical. THC dropped at a steady rate of approximately 1 to 2 ng/ml every 25 minutes. This steady drop was observed in both regular and non-regular users. These findings are consistent with previous research (Cone & Huestis, 1993; Chesher, 1997).

Driving ability was impaired when the level of THC in blood was between 3 and 5 ng/ml. This finding is consistent with previous research that has reported driving ability is maximally impaired by marijuana when THC blood levels drop to 13 ng/ml (Berghaus et al., 1995; Cone & Huestis, 1993, using whole blood to plasma multiplication factor 1.6 (Giroud et al., 2001)). In the present study, the variables 'straddling the barrier line' and 'straddling the solid line' were impaired when the blood THC levels were between 3 and 5 ng/ml. These findings suggest that tracking, attention, and balance (maintaining a balanced/steady position of the steering wheel/vehicle) is impaired by lower levels of THC. 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 levels of THC in plasma drop to below 13 ng/ml ((equivalent to approximately 8 ng/ml in whole blood (Giroud et al., 2001) 1 hour after the beginning of smoking; elimination phase in the actions of THC), consistent with the findings of the present study. The negative relationship between driving and THC blood levels may be due to participants experiencing initial magnified symptoms associated with smoking cannabis (a subjective effect is experienced after 1 or 2 inhalations (Berghaus, et al., 1995)), so that in response they over compensate for the effects of the drug. During the elimination phase of THC in blood, these obvious symptoms are not as magnified, and participants may therefore decide it is no longer necessary to compensate. Therefore the impairing effects of THC become more prominent in tests that assess performance. This is one theory that could be addressed in future research with the administration of several subjective effects questionnaires throughout a treatment session. An alternative explanation for this negative relationship between THC blood levels and impaired performance is that the level of THC in the blood is not necessarily the level of THC present in the brain, in which high levels in the brain would be associated with increased impairment. Like in the case with benzodiazapines, in which impairment is maximum 1 hour after peak plasma levels, maximum impairment associated with THC may occur once peak drug plasma levels have plateaued (Petroulias, 2001; Rush & Griffiths, 1996). This is one issue that could be addressed with future research.

Non-regular users performed worse on the driving task than regular users. When this occurred, THC blood levels in non-regular users were between 2 and 12 ng/ml. Previous research has not reported that THC levels as low as 2 ng/ml impair driving ability. This may have been due to a difference in the participant sample tested. The present study included non-regular cannabis users, where at all times, the THC blood levels were between 1 and 7 ng/ml lower, compared to regular users. It appears, therefore, 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). If this is the true, it is also likely that regular users require higher doses, or stronger levels of THC to experience the same effects as non-regular users. After the consumption of higher and stronger doses of THC, regular users may exhibit the same impairment as that observed in non-regular users.

The percentage of individuals classified as impaired on the SFSTs decreased as THC blood levels decreased. The highest percentage of individuals classified as impaired on the SFSTs was observed in the high THC condition, immediately after the cessation of smoking, with the level of THC in the blood was 70 ng/ml. These findings suggest that sobriety tests are related to levels of THC in the blood. However, the number of individuals classified as impaired when THC levels dropped to between 2 and 6 ng/ml (elimination phase), was higher for the high THC condition compared to the low THC condition. The difference in THC blood levels between both conditions at this time was approximately only 1 ng/ml. It is unclear why a higher number of individuals were classified as impaired in the high THC session when THC levels were almost identical to the low THC session. It is possible that other cannabinoids in the blood, that were not measured in the present study, may be present in higher numbers in the high THC condition compared to the low THC condition. For instance, there may exist a relationship between the metabolite THC-COOH and performance. Robbe and O'Hanlon (1993) suggest that based on previous research demonstrating that peak and time integrated THC-COOH concentrations are proportional to administrated THC doses, and peak THC-COOH concentration coincide in time with subjective 'highs', an epiphenomenal correlation between THC-COOH and performance may exist (Robbe & O'Hanlon, 1993). This correlation may explain the difference in performance on the sobriety tests and the driving task between both conditions in the current study. Correlational analysis in the study by Robbe and O'Hanlon (1993) however indicated that no strong relationships between THC-COOH and performance exist and it is not possible to conclude anything about a driver's impairment based on levels of THC-COOH in plasma. In contrast, Kruger and Vollrath (2000) reported that THC-COOH decreased speed and improved the maintenance of the lateral position of the vehicle.

The percentage of individuals classified as impaired on the SFSTs decreased as THC blood levels decreased for both non-regular and regular cannabis users. However, sobriety tests classified a higher percentage of non-regular users as impaired at all times, compared to regular users. The level of THC at these times was always lower in non-regular users by between 20 and 30 ng/ml for the blood sample taken immediately after the cessation of smoking (peak levels), and between 2 and 12 ng/ml for the remaining blood samples. Once again, it appears that regular users have a higher tolerance to the psychological and physiological effects of cannabis, so that they are able to compensate

for the impairing effects (Robbe & O'Hanlon, 1993). If this is the case, it is also likely that regular users require higher doses, or stronger levels of THC in order to experience the same impairing effects as non-regular users.

In conclusion, there is a positive relationship between THC blood level and sobriety testing, in which higher levels of THC in blood are associated with increased sensitivity of the sobriety tests in classifying impairment. On the other hand, THC blood level is negatively correlated with driving ability, so that a decrease in the level of THC in blood predicts a greater driving impairment. It is suggested that no specific level of THC in blood should be regarded as having the most impairing effects on performance. The present study also suggests that regular users, who are more tolerant to the effects of marijuana, are able to perform better on many tasks than non-regular users, even when their THC blood levels are higher. In addition, the present data do not indicate that THC does not impair driving ability for regular users. Regular users are more likely to consume larger amounts of cannabis and cannabis of higher strength, than those administered in the present study. Therefore, the consumption of larger amounts of cannabis or higher strength cannabis (compared to present study) by regular users may result in a change in performance similar to that observed in the present study in non-regular users.

9.6 Summary of findings

The main finding of the project was that smoking cannabis containing either 1.74% THC or 2.93% THC significantly impaired driving ability and sobriety test performance. At this time, the level of THC in blood varied between 3 and 5 ng/ml. In addition, sobriety tests, specifically those that comprise the SFSTs, predict driving ability caused by these levels of cannabis considerably better than chance (76.3%). The SFST battery is improved when HMJ (Head Movements/Jerks) is scored in the HGN. Finally, cannabis cigarettes containing either 1.74% or 2.93 % THC impair non-regular cannabis users more severely than regular cannabis users and this is reflected in both their driving performance and sobriety test performance. At this time, THC blood levels are higher in regular users compared to non-regular users.

In conclusion, the SFSTs as a test battery is a moderately good predictor of driving impairment and the recent consumption of cannabis. In the absence of reliable and accurate physical tests of THC blood levels and driving ability, the SFSTs can provide relevant information concerning drug intoxication and driver fitness. In addition driver characteristics such as frequency of cannabis use may hinder the ability to successfully detect cannabis intoxication or recent cannabis use with the SFSTs. However if the individual is also impaired on driving, the SFSTs will demonstrate this, irrespective of THC blood levels.

Chapter Ten: Summary of Limitations

The present study examined the efficacy of the SFSTs to detect impairment after the administration of three different doses of marijuana (placebo, low and high dose). SFST battery results were compared to performance on a driving task to establish whether SFST battery performance is related or can predict quality of driving (impaired or not impaired). The sample tested comprised 40 participants (14 female, 26 male) aged between 21 and 35 years. These participants were also divided into two groups; regular cannabis users and non-regular cannabis users. Regular users comprised 22 participants and non-regular users comprised 18 participants.

The results indicated that cannabis significantly impaired driving ability. Specifically, the inability to maintain a steady position within a traffic lane is increased with increasing level of THC. This was evident in the significant relationship between THC dose and two variables of the driving simulator; 'straddling the barrier line' and 'straddling a solid line'. Errors increased with the level of THC, especially 80 minutes after smoking cannabis. This suggests that the higher the THC content of the cigarette, the more likely an individual will drive with two or more wheels of a vehicle over an unbroken line marked out for traffic moving in the same direction, and over a solid line marked out for traffic moving in the opposite direction.

The present study was randomised, counter-balanced, double blind, and used a repeated measures design. These measures were taken to ensure that the project was conducted using the best design possible, nevertheless, some limitations are acknowledged. These limitations are acknowledged in terms of interpreting the results of the study and to facilitate future work in the area.

The sample in the present study comprised 40 participants (14 female, 26 male). The sample was ample to test several relationships between THC and many performance variables, however it was not large enough to test for sex differences. It is possible that high p values (not significant differences) observed, when testing possible differences between males and females, were indicative of the absence of a difference in performance between both sexes. It would be best to replicate the study with a larger

sample size of equal number of males and females to assess whether sex differences exist, and if so the nature and specificity of such differences.

Participants tested in the present study were screened for past and present drug use using a medical questionnaire and medical examination. No blood or urine samples were taken from participants to scientifically test for past and present drug use. It is possible that participants may have misinformed investigators on past and present drug use fearing possible prosecution, scrutiny or exclusion from the study. Therefore, we cannot be certain that the participants tested in this study were drug free. This was also the case during the testing sessions. All blood samples taken during each testing session were screened only for THC, including the baseline sample. Therefore, it cannot be certain that the participants were drug free at the beginning of each testing session. For financial reasons, the blood samples taken in this study were analysed for THC only. Where financially possible, future research should take a blood or urine sample during the medical examination and have it screened for all major drugs. The presence of any drug in this sample should result in the exclusion of the participant from the study, or if sample size permits a specific analysis according to drug type. Similarly, the baseline sample in the experimental sessions should be screened for all drugs. The presence of any drug in this sample should result in the exclusion of the test results from the data, or possibly the analysis of the test results under a different category.

In addition, with reference to the sample tested in this study, results from the Frequency of Cannabis Use questionnaire and Intoxication Rating questionnaire indicated that the sample comprised 18 non-regular cannabis users and 22 regular cannabis users. Non-regular cannabis users described the high THC dose cigarettes as being much stronger than cannabis usually smoked, whereas regular cannabis users described the high THC dose cigarettes as being weaker or similar to cannabis usually smoked. These results suggest that the greater performance decrements observed in non-regular users compared to regular users is likely to be the result of the extent to which each group was experiencing "typical" marijuana effects. Regular users may not have achieved their typical "high" and their performance on all tests may be an under representation of how cannabis may typically effect their performance. Future research should consider the smoking of cannabis until a "desired high" is achieved or a "typical high" is achieved. This may better represent the effects of cannabis in regular cannabis, where it is likely

that more decrements will be observed. It should be noted however, that it is also likely that regular users in the present study performed better than non-regular users simply because of their tolerance and experience with the effects of cannabis on performance.

With reference to the smoking procedure utilised in the present study, a total of 8 inhalations of the allocated marijuana cigarette was used. The procedure was a systematic scientific controlled process similar to that used by Cone and Huestis (1993). How much of the cigarette was actually smoked after 8 inhalation was not measured in the present study. There may have been a difference in the amount of cannabis cigarette remaining, after the completion of 8 inhalations, between regular and non-regular cannabis users. Any difference found may have explained the difference in the level of THC in blood between both groups.

Finally, the present study describes the effects of cannabis on driving behaviour. Driving behaviour was measured using the Cybercar driving simulator, in which a total of 36 out of 126 variables were included in the analysis. It is acknowledged that driving simulator tests are not equal to real-life driving, and that the driving simulator used in the present study has in the past been used in an industry setting as a training tool in driver education programs. Nevertheless, the simulator does test similar driving variables as those tested in past simulator studies and the impairment associated with cannabis observed on the Cybercar is consistent with some previous drugs and driving research. Ideally, a closed course driving test with and without traffic, such as that utilised by Robbe (1993), should be incorporated in studies that aim to test the effects of any drug on driving behaviour. However, many ethical and legal constraints prevent this from being possible. Nevertheless, the simulator used in the present study did measure many skills closely related to real life driving (steering, braking, etc.) and the results from the simulator showed that THC impairs similar driving variables as those reported in previous driving research.

Chapter Eleven: Implications and Future Research

11.1 Implications of the present study

The findings of the present study demonstrated that the Standardised Field Sobriety Tests (SFSTs) was related to the level of THC. The higher the level of THC administered to participants, the higher the number of participants classified as impaired on the SFSTs. The current project is the first to study the effects of marijuana 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 the SFSTs together with a driving task has demonstrated that performance on the SFSTs is significantly related to driving ability. The SFST battery was able to successfully predict driving impairment significantly better than chance in 73% of cases. These results suggest that the SFSTs can be used as a means of testing for driving impairment caused by marijuana. In cases where simple roadside specimen tests for marijuana are absent, such as breathe analysis instruments used to test for the presence of alcohol in drivers, the SFST battery provides essential information on one's ability to perform tasks, such as driving safely.

The present study provides essential information on how accurately the SFSTs assess driving impairment caused by marijuana. 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, in the OLS all four possible signs (errors) were related to THC dose at almost all testing times (with the exception of Hopping in Time 3). 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 is often the best predictor of impairment caused by marijuana. In addition, in the WAT test, the presence of two or more signs (errors) also constitutes a classification of "impaired" on this test. The IT (Improper Turn) sign and the MHT (Misses Heel to Toe) sign of the

WAT test were not related to THC dose at any time during testing. Therefore if both IT and MHT are the only two 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 THC dose and driving impairment.

In addition, the present study identified a new sign to be scored in the HGN test of the SFSTs. This sign was labeled HMJ (Head Movements/Jerks). The scoring of this sign increased the number of participants classified as impaired after the administration of THC and was also the best predictor of driving impairment in cases where high THC was administered. 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 who will be correctly classified as impaired and prosecuted.

Finally, the research also demonstrated that the relationship between levels of THC in blood and impairment is not a linear one. The research demonstrates that when THC levels drop to approximately 3 and 5 ng/ml, driving is maximally 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 drivers 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.

11.2 Future Research

The present study should be replicated using a larger sample size and an equal number of males and females in order to validate the findings and test for any sex differences.

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 two most popular drugs (in terms of prevalence in road accidents and deaths), alcohol and marijuana, alone and in combination on SFSTs and driving performance.

Future research would provide invaluable information on the best ways to administer and interpret SFST battery data for law enforcement agencies currently using or considering the use of the SFSTs, to detect drug impaired drivers in the absence of physical drug detection devices.

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Appendices

Appendix A Information Sheet and Consent Form

B.S.I. PROTOCOL
SHEET

INFORMED CONSENT FORM

AN EVALUATION OF THE EFFICIENCY OF SOBRIETY TESTING IN DETECTING THC.

This is a joint project between Swinburne University and Vicroads

Dr. Con Stough

Dr Pradeep Nathan

Katherine Papafotiou

Brain Sciences Institute

Swinburne University of Technology

PARTICIPANT'S NAME:	
SUBJECT CODE	***CODE*** _ _

We are conducting research to examine the relationship between different levels of THC and performance on the Standardised Field Sobriety Test (SFSTs). This project is being undertaken to provide more information on the effects of THC on performance and assess the efficiency of sobriety tests in detecting THC 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. Papafotiou as part of her Ph.D. research, as well as collaboration between the Brain Sciences Institute and Vicroads.

If you agree to participate in this study you will take part in four sessions. In the first session you will be asked to complete a Cannabis Use questionnaire, Personality questionnaire, Driving Attitudes questionnaire and a Basic Medical Examination. This should take approximately 2 hours. The second, third and fourth sessions will be experimental where you will be administered three different doses of THC (1.78% of THC, 3.42% of THC or placebo: no THC) in cigarette form and then be asked to perform a Standardised Field Sobriety test (SFSTs) and a Driving Simulator Test (DS). The SFSTs involves a number of tests that involve balance and motor coordination including the Horizontal Gaze Nystagmus, the Walk and Turn and the One Leg Stand. The DS is a computerised driving task where you will be required to drive through

several scenarios that appear on a screen in front of you. These tests will take approximately 20 minutes each to complete. Blood samples and saliva samples will be taken throughout the study. One blood sample will be taken before you even begin the study to screen for any current use of alcohol, THC or amphetamines (first session). Once testing begins, one blood sample and saliva sample will be taken before THC administration, and then six more at 10 mins, 25 mins, 60 mins, 85 mins, 120 mins and 145 mins. The SFSTs will be performed after the samples taken at 10 mins, 60 mins and 120 mins. The DS will be performed after the samples taken at 35 mins and 85 mins.

The administration of THC will be carried out using cigarettes containing either 0%, 1.78% or 3.42% of THC. In the three sessions, you will be administered one of the following:

i) a 0% of THC cigarette (placebo)
ii) a 1.75% of THC cigarette or
iii) a 3.55% of THC cigarette

Neither you or the experimenters will know the THC content to be administered to you at any particular session. On the sessions that you will receive 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 (THC administration) session will take approximately 3 hours to complete.

You must also agree not to drive or ride to any of the sessions, and you also cannot drive or ride for at least 12 hours after each session and we will also be asking you not to consume alcohol or any other medication for at least 24 hours after each session. We will provide transport to take you home. Taxi vouchers will be provided for those who require them.

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 12 hours after the administration of THC, and that you do not consume alcohol or any other medications for at least 24 hours after the administration of THC.

You will also be video taped while performing the SFSTs. This footage may be used in training sessions for the SFSTs to Police Officers and/or other professionals, only if you provide your consent after having reviewed the footage yourself (see attached SFSTs 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 THC* can be directed to Dr Con Stough, Brain Sciences Institute (ph: 9214 8167 email: cstough@mind.scan.swin.edu.au).

In the event of any complaint about the way you have been treated during the study, or a query that Dr 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

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 where I may be administered cigarettes containing THC they may contain 1.78% or 3.47% of THC.

I agree that for the sessions in which I may possibly be administered 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 will not drive or ride for at least 12 hours after I have been administered THC and I agree not to consume any alcohol or other medication for at least 24 hours after I have been administered THC.

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 PRINCIPALINVESTIGATOR/S.....
……..…
……
……
…….

SIGNATURE.....….....DATE....…….....

SIGNATURE.....….....DATE.....……..

B.S.I. PROTOCOL SHEET

SFSTs FOOTAGE CONSENT FORM (b)

AN EVALUATION OF THE EFFICIENCY OF SOBRIETY TESTING IN DETECTING THC.

Katherine Papafotiou
Dr. Con Stough
Brain Sciences Institute
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 SFSTs. This video footage may be shown in training sessions on the SFSTs 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 SFSTs.

NAME OF PARTICIPANT
……

SIGNATURE……...DATE……

NAME OF PRINCIPAL INVESTIGATOR/S
……
……
……

SIGNATURE……..DATE…….

SIGNATURE…….…….....DATE……

Appendix B Patient Medical Questionnaire

PATIENT QUESTIONAIRE

Name: _____ D.O.B.:_____
Address:_____Date:_____
_____ Phone:_____

Instructions: These questions are designed to help us understand any medical problems that you may have. All information given will be treated in the strictest confidence. Please tick all relevant boxes. Please ask for assistance if you unsure about any of the questions.

Medical History:
Are you allergic to anything that you know of?

Medications?	☐Yes	☐No
Foods?	☐Yes	☐No
Surgical Tapes?	☐Yes	☐No
Any other substances?	☐Yes	☐No

If yes, please give details: _____
_____
_____

Do you take any medications (prescription or over-the-counter)? ☐Yes ☐No
If yes, please fill in the details in the table below:

Name of medication	Dose	Number of times taken each day	Date of commencement

Do you have any of the following problems?

Heart Problems?	☐Yes	☐No
High or low pressure?	☐Yes	☐No
Respiratory problems?	☐Yes	☐No
Stomach or intestinal problems?	☐Yes	☐No
Liver problems?	☐Yes	☐No
Kidney or urinary problems?	☐Yes	☐No
Diabetes?	☐Yes	☐No
Anaemia or blood disorders?	☐Yes	☐No
Epilepsy or fitting?	☐Yes	☐No
Eyesight problems or colour blindness?	☐Yes	☐No
Cancer?	☐Yes	☐No
Skin disorders?	☐Yes	☐No
Anxiety or depression?	☐Yes	☐No
Any other psychological problem?	☐Yes	☐No

If you answered YES to any of the questions above, please give details:

_____
_____
_____

Have you ever had any operations? ☐Yes ☐No
If yes, please give details:

_____
_____
_____

When did you last consult a doctor? And for what reason?

_____
_____
_____

Do you follow any special diet? ☐Yes ☐No
If yes, what type?_____

How much alcohol do you drink?
Number of glasses?_____/day Type_____
Number of glasses?_____/week Type_____
Do you smoke? ☐Yes ☐No Number of cigarettes/day?_____
Do you drink coffee? ☐Yes ☐No Number of cups/day?_____

Do you use glasses? ☐Yes ☐No
Do you use contact lenses? ☐Yes ☐No
Do you use a hearing aid? ☐Yes ☐No
Do you use any other type of prosthesis? ☐Yes ☐No

Additional questions for **FEMALES ONLY**:
Are you or could you be pregnant? ☐Yes ☐No
Are you breastfeeding ☐Yes ☐No
Are your periods regular? ☐Yes ☐No
Last period ended? (date) _____
Do you take the contraceptive pill? ☐Yes ☐No
Brand name?_____

Appendix C Medical Examination Sheet

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:_____

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	☐	☐		_____
Extremeties	☐	☐		_____
Skin	☐	☐		_____
Other (specify)	☐	☐		_____

Baseline Obs: BP Standing_____ BP sitting_____
Pulse _____ T° _____
Height _____ Weight _____

Urinalysis _____

Comments: _____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Signature:_____

Appendix D Demographics Questionnaire

Demographics Questionnaire

Name: _____ **Subject Code:**_____

Age: _____

Sex: _____

Marital Status: _____

Education Level: (eg. 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 E Frequency of Cannabis Use Questionnaire

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? (eg. 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? (eg. two cigarettes/one pipe/etc.)

_____

What are the general effects of cannabis on you?

_____

_____

_____

_____

_____

Appendix F Subject Codes and Treatment Details

Subject No.	Session 1	Session 2	Session 3
1	a	b	c
2	b	c	a
3	c	a	b
4	a	b	c
5	b	c	a
6	c	a	b
7	a	b	c
8	b	c	a
9	c	a	b
10	a	b	c
11	b	c	a
12	c	a	b
14	a	b	c
15	b	c	a
16	c	a	b
17	a	b	c
18	b	c	a
19	c	a	b
20	a	b	c
21	b	c	a
22	c	a	b
23	a	b	c
24	b	c	a
25	c	a	b
26	a	b	c
27	b	c	a
28	c	a	b
29	a	b	c
30	b	c	a
31	c	a	b
32	a	b	c
33	b	c	a
34	c	a	b
35	a	b	c
36	b	c	a
37	c	a	b
38	a	b	c
39	b	c	a
40	c	a	b

Key:
a= Placebo
b= Low THC
c= High THC

Appendix G Intoxication Rating Questionnaire

PARTICIPANT RATING OF INTOXICATION

How do you feel you performed on the FIRST Sobriety Test?

How do you feel you performed on the SECOND Sobriety Test?

How do you feel you performed on the FINAL Sobriety Test?

How do you feel you performed on the FIRST DRIVING SIMULATOR task?

How do you feel you performed on the SECOND DRIVING SIMULATOR task?

How do you compare the **strength** of the marijuana cigarette you smoked **today** with marijuana that you **usually** smoke? (circle response)

Much Stronger…....A Little Stronger.……..The Same.…....A Little Weaker…..…Much Weaker

How do you compare the **effects** of the marijuana cigarette you smoked **today**, on your mental and physical abilities, with marijuana that you **usually** smoke? (circle response)

Very Different Effects……..A Few Different Effects…..…The Same…..….No Effects at All

What are the effects in either case? (which are different? which are the same? which are not present?)

_____

_____

_____

_____

_____

_____

_____

Appendix H Standard Field Sobriety Test Score Sheet

Physical Impairment Test - Performance Record, Page 1

Horizontal Gaze Nystagmus

DRAFT

	Yes	No
Suspect wearing contact lenses		
Pupil size equal		

	Yes	No
Eye tracking normal		
Eye disorder observed		

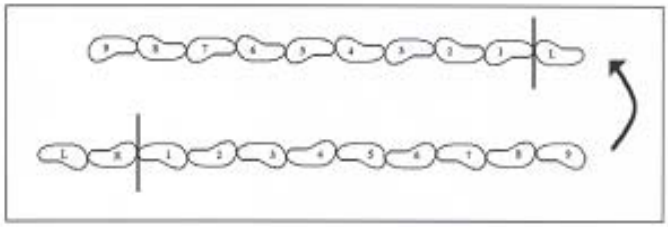
Signs Observed	Left Eye	Right Eye
Eye does not pursue smoothly		
Distinct nystagmus at maximum deviation		
Nystagmus onset before 45 degrees		

Other	

Walk and Turn Test

Instruction Stage

Cannot Keep Balance	
Starts to Soon	



Walking Stage

Signs Observed	First Nine Steps	Second Nine Steps
Stops walking		
Misses heel to toe		
Steps off line		
Raises arms		
Actual steps taken		

Improper Turn (describe)	
Cannot Perform Test (explain)	
Other	

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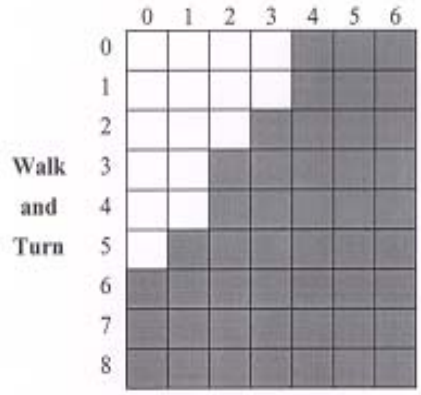
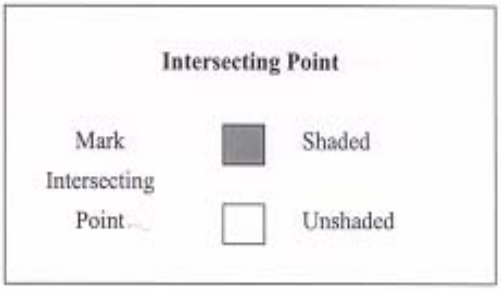
Physical Impairment Test - Performance Record, Page 2

Interpretation Table

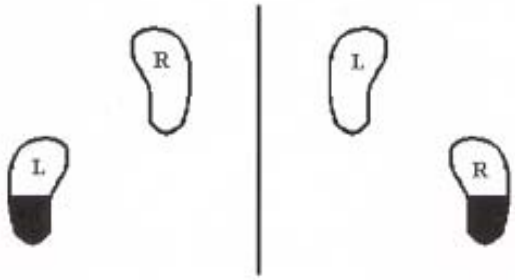
DRAFT

Nystagmus





One Leg Stand Test



Signs Observed	Left Leg	Right Leg
Sways while balancing		
Uses arms to balance		
Hopping		
Puts foot down		

Other	
Type of Footwear	

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Appendix I Blood Data for each subject and at each time point

Subject No.	Before smoking	0 mins after smoking	20 mins after smoking	50 mins after smoking	75 mins after smoking	100 mins after smoking	125 mins after smoking
PLACEBO							
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0
MEAN	0	0	0	0	0	0	0
(SD)	(0)	(0)	(0)	(0)	(0)	(0)	(0)

Subject No.	Before smoking	0 mins after smoking	20 mins after smoking	50 mins after smoking	75 mins after smoking	100 mins after smoking	125 mins after smoking
LOW THC							
1	0	28.1	3.9	3.3	2.5	0	0
2	0	73.2	16.2	9.8	6.4	5.8	0
3	.	.	.	.	.	.	
4	0	0	.	.	.	.	
5	0	194.4	42.3	17.9	14.1	9.9	8.3
6	0	11.9	.	0	2.5	2	2
7	0	43.9	7.2	4.1	0	0	0
8	0	127	26.1	11.4	6.7	6	3.9
9	0	58.4	10.3	6.8	5	3.3	2.5
10	0	87.2	15.6	6.3	5.6	5.1	3.8
11	0	19.3	.	.	.		2.6
12	0	16.2	3.9	2.1	0	0	0
13	0	101	14.7	8.9	6.3	5.3	4.9
14	0	58	11.6	5	4.6	0	2.8
15	0	.	.	.	.	.	
16	0	16.6	2.8	0	0	0	0
17	0	49.6	19.4	6.3	6	4	3.7
18	0	111	22.3	11.7	6.3	2.7	2
19	.	.	.	.	.	.	
20	0	23.3	3.5	0	0	0	0
21	0	28.4	3.7	0	0	0	0
22	0	17.2	11	5.6	0	0	0
23	0	19.9	5.9	6.8	5.6	0	3.2
24	0	144.7	12.3	9.1	6.6	5.8	0
25	0	92.7	10.9	6.3	4.9	4.1	0
26	0	82.2	25	10.8	8.5	6	5.1
27	0	51.2	23.3	12.4	10.6	8.5	9.5
28	0	61.2	.	.	.	.	
29	0	33.8	5.5	0	0	2.2	0
30	0	43.3	3	2	3.1	4.3	5
31	0	63.2	6.5	5	3.2	4.6	3.1
32	0	39.5	12.5	6.6	4.8	3.8	2.5
33	0	.	.	.	.	.	
34	0	0	2	0	0	0	0
35	0	44.7	15.8	9.2	4.6	4.9	3.9
36	0	29.8	.	.	.	.	
37	0	105	27.4	18.1	11.2	6.9	7.2
38	0	14.6	2.7	0	0	0	0
39	0	45.4	17.4	4.5	2.7	0	2.6
40	0	60.7	13.8	7.1	6.6	6.4	4.8
MEAN (SD)	0 (0)	55.46 (43.03)	12.85 (9.37)	6.16 (4.94)	4.33 (3.66)	3.18 (2.94)	2.53 (2.61)

Subject No.	Before smoking	0 mins after smoking	20 mins after smoking	50 mins after smoking	75 mins after smoking	100 mins after smoking	125 mins after smoking
HIGH THC							
1	0	54.4	6.1	3.8	0	0	0
2	0	132.5	14.6	.	.	.	
3	0	2	.	.	.	.	
4	.	.	.	.	.	.	
5	0	187.2	39.7	17.5	14.2	11.1	8.5
6	0	35.9	10.6	0	4.8	2	2.9
7	0	57.6	13.8	6.6	5.6	4.1	2.8
8	0	139	40.8	22.6	18	13.5	8.7
9	0	32.4	7.3	3.8	2.3	2.1	0
10	0	115.7	19.1	10.5	8.8	8.5	5
11	0	164.6	27.9	5.3	.	.	
12	0	46.2	2.3	0	0	0	0
13	0	47.8	8.4	4.7	2.1	0	0
14	0	110	14	6.5	2.9	2.7	0
15	.	.	.	.	.	.	
16	0	13.3	0	0	.	.	
17	0	101	.	14.5	.	.	
18	0	136	27.9	17.4	9.1	8.6	5.3
19	0	0	.	.	.	.	
20	0	47.5	7.6	4.2	2.3	2.1	0
21	0	8.2	0	0	0	0	0
22	0	7.1	0	0	0	0	0
23	0	86.1	6.7	10.3	3.5	3.8	2.2
24	0	228.8	31.8	13.4	.	.	
25	0	114.7	14.5	.	10.4	.	
26	0	96.9	19.6	10.2	7.2	5.6	4.3
27	.	.	.	.	.	.	
28	0	3.3	.	.	.	.	
29	0	43.9	7.8	4.6	8.2	0	
30	0	41.9	10.5	4.5	4.1	5.2	6.1
31	0	39.8	14.3	9.4	12.5	3.4	3.6
32	0	54.1	3.1	0	0	.	0
33	.	.	.	.	.	.	
34	0	21.7	2.7	0	0	0	0
35	0	126	19.5	8	9	5.6	5.6
36	.	.	.	.	.	.	
37	0	78.3	28.3	16.9	5.9	5.1	3.2
38	0	.		0	0		2.4
39	0	9.7	.	.	.		0
40	0	16.6	2.8	2.1	2.6	2.1	0
MEAN (SD)	0 (0)	70.59 (58.44)	13.85 (11.59)	6.79 (6.44)	5.13 (4.95)	3.72 (3.79)	2.42 (2.82)