An evaluation of the sensitivity of the Standardised Field Sobriety Tests (SFSTs) to detect impairment due to…

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The relationship between performance on the standardised field sobriety tests, driving performance and the level of Δ9-tetrahydrocannabinol (THC) in blood

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Abstract

The consumption of Δ9-tetrahydrocannabinol (THC) as cannabis has been shown to result in impaired and culpable driving. Testing drivers for the presence of THC in blood is problematic as THC and its metabolites may remain in the blood for several days following its consumption, even though the drug may no longer have an influence on driving performance. In the present study, the aim was to assess whether performance on the standardised field sobriety tests (SFSTs) provides a sensitive measure of impaired driving behaviour following the consumption of THC. In a repeated measures design, 40 participants consumed cigarettes that contained either 0% THC (placebo), 1.74% THC (low dose) or 2.93% THC (high dose). For each condition, after smoking a cigarette, participants performed the SFSTs on three occasions (5, 55 and 105 min after the smoking procedure had been completed) as well as a simulated driving test on two occasions (30 and 80 min after the smoking procedure had been completed). The results revealed that driving performance was not significantly impaired 30 min after the consumption of THC but was significantly impaired 80 min after the consumption of THC in both the low and high dose conditions. The percentage of participants whose driving performance was correctly classified as either impaired or not impaired based on the SFSTs ranged between 65.8 and 76.3%, across the two THC conditions. The results suggest that performance on the SFSTs provides a moderate predictor of driving impairment following the consumption of THC and as such, the SFSTs may provide an appropriate screening tool for authorities that wish to assess the driving capabilities of individuals suspected of being under the influence of a drug other than alcohol.

Keywords: Marijuana; Δ9-tetrahydrocannabinol; SFSTs; Driving impairment

1. Introduction

Research has indicated that drugs other than alcohol have been detected in as many as 26.7% of drivers killed on Australian roads and that cannabis Δ9-tetrahydrocannabinol (THC) is the drug that has been most commonly detected [1,2]. Furthermore, research into the culpability of drivers who have been killed in traffic crashes on Australian roads indicates that the odds ratio (relative odds of culpability) of drivers in whom THC was detected was 6.6. The odds ratio is calculated by determining the proportion of drivers responsible for crashes to those not responsible for crashes. By way of contrast, the odds ratio of drivers who presented with a blood alcohol concentration (BAC) of between 10 and 15 was 3.7 and the odds ratio of drivers in whom neither drugs nor alcohol were detected was 1.0 [2].

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The consumption of THC has been shown to lead to impaired car control [3], increase the number of obstacles hit on a driving course [4,5], increase the standard deviation of the lateral position of a vehicle [5,6], impair tracking ability [6] and increase the number of sideways movements of a vehicle as well as the percentage of time spent out of a lane [6,7].

Unlike testing for BAC however, the ability to determine whether drivers have consumed THC is limited by a number of factors, not the least of which is the fact that THC and its metabolites may remain in the blood for several days following its consumption, even though the drug may no longer have a deleterious effect on driving performance [1]. Therefore, rather than conducting a test to simply detect the presence of a drug in a driver's blood, law enforcement officers require a tool that will allow them to determine whether an individual's driving behaviour is impaired following the consumption of a drug. The standardised field sobriety tests (SFSTs) are currently being used in Victoria, Australia for this purpose [8], despite the fact that no studies have been conducted in order to determine whether performance on the SFSTs provides an accurate indicator of driving behaviour following the consumption of a drug other than alcohol.

The SFSTs have been demonstrated to be sensitive tests of impairment related to a BAC of up to 0.08% [9,10] and it has been argued that the SFSTs provide an accurate indicator of driving impairment caused by the consumption of alcohol [9,11–13]. The consumption of THC has also been found to impair performance on the SFSTs [14]. Furthermore, the drug evaluation and classification program (DECP) (a 12 step testing program that includes the administration of the SFSTs) has previously been found to reliably indicate whether individuals have consumed drugs other than alcohol [15,16]. However, these studies have only revealed that the SFSTs provide an indicator of whether a drug has been consumed, they have not indicated whether performance on the SFSTs provides a predictor of impaired driving behaviour following the consumption of a drug other than alcohol. Therefore, the aim of the present study was to assess whether performance on the SFSTs provides an indicator of impaired driving behaviour following the consumption of THC.

A further aim of the present study was to determine whether the inclusion of a new sign in the SFST scoring procedure may improve the sensitivity of the SFSTS as a measure of driving impairment. The additional sign, head movements or jerks (HMJ) during performance of the horizontal gaze nystagmus (HGN) test, is not traditionally included in the SFST scoring procedure but is considered to be a possible symptom of drug use [8]. Inclusion of HMJ has previously been shown to increase the number of subjects classified as impaired on the SFSTs following the consumption of THC [14].

As the consumption of THC has been shown to impair driving performance and has also been shown to impair performance on the SFSTs, it was hypothesised that scores obtained from the administration of the SFSTs would correctly predict whether the driving behaviour of participants was impaired. It was further hypothesised that scores obtained from the administration of the SFSTs would provide a better predictor of driving impairment when the sign HMJ was included in the scoring procedure.

2. Materials and methods

2.1. Participants

Forty healthy participants (14 female and 26 male), aged between 21 and 35 years ($M = 25.5$, S.D. = 3.1) who had previously smoked cannabis participated in the study. Participants were recruited through advertisements. Prior to the commencement of testing, participants were required to undergo a medical examination that was performed by a general medical practitioner. Participants were required to complete a drug-use questionnaire and were requested to refrain from the use of all drugs other than alcohol, including medications, in the 7 days preceding the experimental session. Exclusion criteria were: history of cardiac disorders; history of substance abuse; history of mental health problems; history of allergic reactions to drugs and current medical illness.

2.2. Marijuana cigarettes

THC was administered to participants using marijuana cigarettes that were provided by the National Institute on Drug Abuse (NIDA) in the USA. Three different THC dosages were used: 0% THC (placebo); a low dose of 1.74% THC (0.813 g); and a high dose of 2.93% THC (1.776 g).

2.3. The standardised field sobriety test

All three tests that comprise the SFST battery were administered, as per the administration procedures used by the Victoria Police [8]. These procedures were based on those of Burns and Moskowitz [9] and are outlined below.

2.3.1. Horizontal and vertical gaze nystagmus (HGN and VGN)

In this test, participants were required to focus on an object, located 12–15 in. in front of their face, as it moved horizontally and then vertically. The investigator separately observed the left and right eye for the following four signs: lack of smooth pursuit (LSP); distinct nystagmus at maximum deviation (N_{max}); nystagmus onset before 45° (N45); and nystagmus at the vertical position (VGN). If a total of four or more signs were observed, the participant was judged to be impaired to a degree equivalent to a blood alcohol concentration of above 0.10%. An additional sign, head

movements or jerks, was also scored. It was recorded as being observed if, on more than one occasion, the participant was unable to keep their head still while following the moving stimulus with their eyes.

2.3.2. Walk and turn (WAT)

In this test, the participant was required to take nine heel-to-toe steps along a straight line and then turn around and take another nine heel-to-toe steps back along the line. The investigator observed for eight signs of impairment, these being: could not keep balance while listening to the instructions of the test (NB); started the test before the instructions were completed (STS); stopped walking during the test (SW); did not touch heel-to-toe while walking (MHT); stepped off the line (SOL); used arms to maintain balance (AB); turned improperly (not as demonstrated during instructions) (IT); and took the incorrect number of steps (more or less than nine up and/or nine back) (INS). If the participant failed to complete the test, all eight signs were recorded as being observed. If two or more signs were observed, the participant was judged to be impaired to a degree equivalent to a BAC equal to or above 0.10%.

2.3.3. One leg stand (OLS)

In this test, the participant stood on one leg, with the other stretched out in front of them, while counting out aloud for 30 s starting from 1000. The investigator observed the following behaviours of the participant during performance: swayed while balancing on one leg (S); used arms to maintain balance (AB); hopped during test to maintain balance (H); put raised foot down (FD). If the participant put their foot down more than three times and/or failed to complete the test, all four signs were recorded as being observed. If two or more signs were observed, the participant was judged to be impaired to a degree equivalent to a BAC equal to or above 0.10%.

2.4. The driving simulator

Driving performance was measured using a driving simulator (the Cybercar simulator manufactured by DNS Business Group Pty. Ltd.). This simulator has been used for the education and training of both novice and experienced drivers. The simulator is a capsule of 1930 mm in height, 1050 mm in width, 2200 mm in length. Contained within is a computer-based driving program that is displayed on a 38 cm monitor, as well as a full car interior that includes a steering wheel, indicators, horn, 5-speed gear stick, speedometer, rear view mirrors, side mirrors, adjustable seat and seat-belt.

Participants were first required to complete a basic steering test and then a basic speed control test in order to familiarise themselves with the simulator. The basic steering test involved an assessment of the driver's ability to keep the wheels of the vehicle within the dividing lines of the road. Participants were required to familiarise themselves with the sensitivity of the steering wheel movements. In this test, speed was kept constant by the computer and participants were not required to use the accelerator or brake pedal. In the basic speed control test, the driver's ability to maintain a constant, safe speed in traffic (60 km/h speed limit) was assessed. Participants were required to familiarise themselves with the sensitivity of the accelerator and brake pedals. The computer generated a driving test score for the percentage of time that the steering wheel and/or brake and accelerator pedals were appropriately used during the familiarisation tests. A minimum score of 60% on the basic steering test and the basic speed control test was considered to indicate satisfactory use of the steering wheel, break pedal and accelerator pedal. Administration of these basic tests was repeated as necessary until the subject scored above 60% on each test, however scores on these tests were not used to assess the effect of THC on driving performance.

Following the administration of the familiarisation tests, two comprehensive tests were administered. The freeway traffic test was designed to assess driving ability in freeway traffic while the city traffic test was designed to assess driving ability in city traffic. A total of 126 variables can be scored to assess performance on these tests, of which, 33 relate to a driving error. For the purposes of the present study, the 33 variables related to driving error were assessed. On every occasion that an error was made on one of these variables, the simulator recorded a score of one point for that variable. At the end of the testing procedure, the total score for every variable was then multiplied by the ''loading factor'' of that variable, a factor that reflected the severity of the error. For instance, a serious error such as a collision, received a loading factor of 10, whereas a less serious error such as failing to signal when changing lanes received a loading factor of 2 [17].

The participants' driving performance was classified as either 'impaired' or 'not impaired' based on the scores obtained on all 33 variables. This scoring procedure was adopted from the Cybercar technical manual and is the recommended by the manufacturer for driver training and novice drivers. According to the technical manual, the total driving score is comprised of the total driving errors that are committed. Based on scores derived from performance by novice, drug free drivers that were part of a driver training program, a total driving score between 0 and 75 is considered to be a 'pass' on the driving test while a score of 75 and above is considered to be a 'fail' on the driving test. Hence, for the purposes of the present study, a score between 0 and 75 constituted a classification of 'not impaired' while a score of 76 and above constituted a classification of 'impaired'.

2.5. Procedure

The study was approved by the Human Research Ethics Committee of Swinburne University of Technology. Participants provided written, informed consent and were free to discontinue their participation at any time.

A randomised, counter-balanced, double blind, within-subject, repeated measures design was employed across three experimental sessions. In each session, an intra-venous cannula was inserted into the participant's forearm and a 10 ml blood sample was taken. The participant then consumed either a placebo low dose or high dose cannabis cigarette using a controlled smoking procedure, similar to that used by Cone and Huestis [18]. Participants were instructed to inhale marijuana smoke for 2 s, hold the smoke in their lungs for 10 s (or for as long as they could if they could not hold for 10 s) and exhale and rest for 35 s. This procedure was repeated a maximum of eight times and was ceased if the cannabis cigarette had been fully consumed. Another 10 ml blood sample was then taken and a further five blood samples were taken approximately every 25 min during the 2.5-h session.

The experimental session comprised the administration of: the SFSTs administered 5 min after the smoking procedure had been completed (SFST Time 1); the driving task administered 30 min after the smoking procedure had been completed (Driving Time 1); the SFSTs administered 55 min after the smoking procedure had been completed (SFST Time 2); the driving task administered 80 min after the smoking procedure had been completed (Driving Time 2) and the SFSTs administered 105 min after the smoking procedure had been completed (SFST Time 3).

At the completion of testing, participants were provided with taxi transportation. A minimum interval of 7 days was employed between each of the three testing sessions.

2.6. Data analysis

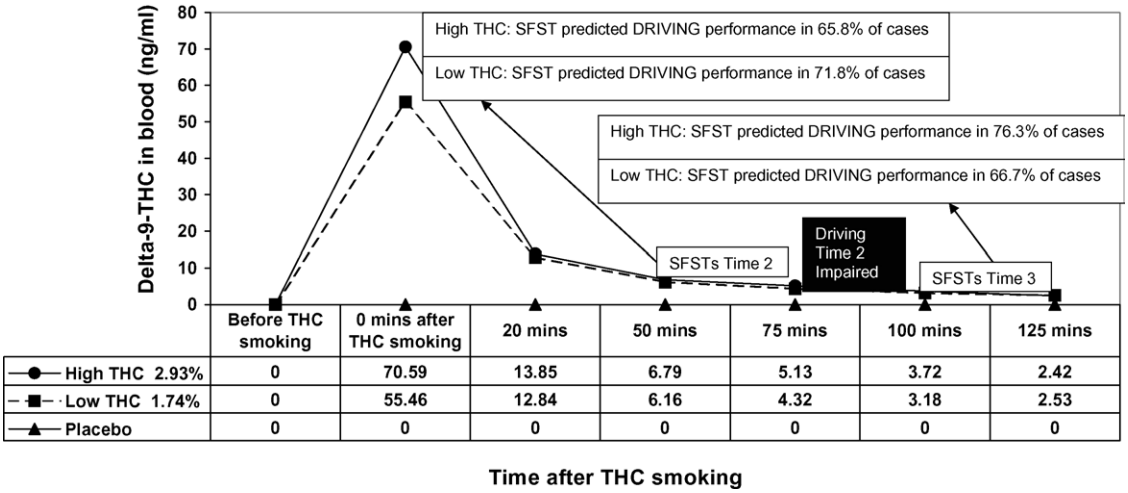
The seven blood samples taken from every participant were analysed for active THC. THC concentrations were measured by capillary column gas chromatography/mass spectrometry (GC/MS) [19]. The limit of detection was 2 ng/ml.

A repeated measures analysis of variance was used to determine whether driving performance differed between the treatment conditions. Discriminant analysis was then performed to determine whether overall performance on the SFSTs, as well as performance on the three component tests of the SFSTs (HGN, WAT and OLS), predicted driving performance. Discriminant structure co-efficients were obtained to determine which of the tests provided the best predictor of driving performance. Driving performance at Driving Time 1 was analysed with SFST Time 1 and SFST Time 2 whilst driving performance at Driving Time 2 was analysed with SFST Time 2 and SFST Time 3.

3. Results

The time-course of the level of THC in the blood following the consumption of low and high dose THC is displayed in Fig. 1. The SFST and driving performance at the different times of testing are also displayed. At 0 min after the completion of the smoking procedure, the level of THC in the blood was 55 ng/ml in the low THC condition and 71 ng/ml in the high THC condition. Blood THC levels then continually decreased and by 125 min after the completion of the smoking procedure, the level of THC in the blood was 2.5 ng/ml in the low THC condition and 2.4 ng/ml in the high THC condition.

Results revealed that at Driving Time 1 (30 min after the smoking procedure had been completed) driving was not significantly impaired in comparison to the placebo condition, although both the ''straddled the solid line'' ($p = 0.09$) and ''straddled barrier line'' ($p = 0.08$) driving variables did approach significance. The ''straddled the solid line'' variable indicates that two or more wheels of the vehicle moved



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

Fig. 1. The level of THC in blood and performance on the SFSTs and the driving task.

over a solid line that is marked out to divide traffic that is oncoming to the subject's vehicle. The ''straddling the barrier line'' variable indicates that two or more wheels of the vehicle moved over a broken line marked out to divide traffic moving in the same direction as the subject's vehicle. At Driving Time 2 (80 min after the smoking procedure had been completed) driving was significantly impaired, as indicated by both the ''straddled the solid line'' variable ($p < 0.05$) and the ''straddled barrier line'' variable ($p < 0.001$). The results indicated that when either low or high dose THC is consumed, impairment on both of these driving variables is observed.

As driving ability was significantly impaired only at Driving Time 2, a discriminant analysis was performed to determine whether performance on the SFSTs, at either SFST Time 2 or SFST Time 3, provided an accurate predictor of impaired driving behaviour at Driving Time 2.

3.1. Low THC condition

Based on performance on the SFSTs administered at SFST Time 2, 71.8% of participants were correctly classified as either impaired or not impaired on the driving task administered at Driving Time 2. Of the participants who were impaired on the driving task, 88.5% were correctly identified as impaired but only 38.5% of participants who were not impaired on the driving task were correctly identified as not impaired. The best single predictor of driving behaviour was overall performance on the SFSTs, followed by the WAT test. Including the sign HMJ did not improve the accuracy of the SFSTs to predict driving performance.

Based on performance on the SFSTs administered at SFST Time 3, 66.7% of cases were correctly classified as either impaired or not impaired on the driving task administered at Driving Time 2. Of the 26 participants, who were impaired on the driving task, 100% were correctly identified as impaired but of the 14 participants, who were not impaired on the driving task, none were correctly identified as not impaired. The best predictor of driving performance was the WAT test. The inclusion of the sign HMJ in the scoring procedure resulted in a more accurate prediction of driving performance than when HMJ was not included.

3.2. High THC condition

Based on performance on the SFSTs administered at SFST Time 2, 65.8% of participants were correctly classified as either impaired or not impaired on the driving task administered at Driving Time 2. Of the participants who were impaired on the driving task, 92% were correctly identified as impaired but only 15.4% of participants who were not impaired on the driving task were correctly identified as not impaired. The best single predictor of driving performance was the OLS test. The inclusion of the sign HMJ in the scoring procedure provided a more accurate predictor of driving performance than when HMJ was not included.

Based on performance on the SFSTs administered at SFST Time 3, 76.3% of participants were correctly classified as either impaired or not impaired on the driving task administered at Driving Time 2. Of the participants who were impaired on the driving task, 84% were correctly identified as impaired and 61.5% of those who were not impaired were correctly identified as not impaired. The best single predictor of driving performance was again the OLS test. The inclusion of the sign HMJ in the scoring procedure resulted in a more accurate prediction of driving performance than when HMJ was not included.

4. Discussion

The findings of the present study provide for the first time, a direct assessment of the relationship between THC consumption, performance on the SFSTs and driving behaviour. The consumption of THC was found to significantly impair driving performance 80 min after the smoking procedure had been completed. When driving performance was impaired, a greater number of SFST signs were observed than when driving performance was not impaired.

When driving was found to be impaired 80 min after completion of the smoking procedure, performance on the SFSTs correctly classified between 65.8% of individuals and 76.3% of individuals as either impaired or not impaired on the driving task. With regard to only those participants whose driving was impaired, between 84 and 100% of participants were correctly classified as impaired. These results suggest that if an individual's driving behaviour is impaired following the consumption of THC, then this will be reflected by impaired performance on the SFSTs. Therefore, the results of the present study suggest that the SFSTs provide an appropriate screening tool with which to determine whether an individual's driving performance is impaired following the consumption of THC.

It is necessary to consider however, that in some cases the high correct classification rate of the SFSTs was due to a high percentage of individuals being scored as impaired on the SFSTs. For instance, at SFST Time 3 after the consumption of low dose cannabis, SFST performance correctly classified all participants whose driving performance was impaired. However, a large number of participants whose driving performance was not impaired were also classified as impaired. This suggests that the SFSTs provide a more sensitive measure of THC consumption than driving ability itself. Although performance on the SFSTs may sometimes result in false positives, the high correct hit rate obtained when using these scores suggests that the SFSTs do provide an appropriate screening tool with which to assess an individual's driving behaviour following the consumption of THC.

The driving variables that were impaired following the consumption of THC were 'straddling barrier lines' and 'straddling solid lines'. These findings are consistent with

previous research that has revealed that THC impairs car control [3], increases the number of obstacles hit on a driving course [4,5], increases the standard deviation of the lateral position of a vehicle [5,6], impairs tracking ability [6] and increases the number of sideways movements of a vehicle, as well as the percentage of time spent out of a lane [5,7].

The impaired ability of drivers to maintain the lateral position of the vehicle appears to be due to the impaired attention and balance of participants, as indicated by performance on the SFSTs at SFST Time 2 and SFST Time 3. Signs that are indicative of impaired balance such as NB (no balance) in the WAT test and all signs of the OLS test were significantly related to level of THC. Indeed, after the consumption of the low dose of cannabis, the WAT test provided the best predictor of driving ability and after consumption of the high dose of cannabis, the OLS test provided the best predictor of driving ability. The new sign head movements or jerks, was also related to the level of THC when driving ability was impaired. These results suggest that the consumption of THC impairs both balance and attention, and that tests that assess these abilities may provide the best predictors of driving impairment following the consumption of cannabis.

The inclusion of the 'new' sign head movements or jerks in the scoring procedure provided a better predictor of driving impairment than when HMJ was not included, particularly when high dose THC was consumed. This finding supports previous suggestions that the inability to maintain a steady head position while visually tracking a moving stimulus provides an indicator of impairment associated with the consumption of THC [8,14]. It is therefore suggested that when assessing drivers in the field, the sign HMJ should be included in the SFST scoring procedure.

Blood tests taken before and after Driving Time 1, when driving performance was not significantly impaired, revealed that the level of THC in blood ranged between 6.16 and 13.85 ng/ml, across the two THC conditions. Blood tests taken before and after Driving Time 2, when driving performance was significantly impaired, revealed that the level of THC in blood ranged between 3.18 and 5.13 ng/ml, across the two THC conditions. Given a multiplication factor of 1.6 when converting values in whole blood to values in plasma [20], the findings of the present study are consistent with previous research in which it has been reported that driving ability is maximally impaired approximately 1 h after the beginning of smoking, during the elimination phase of THC, when THC plasma levels have fallen below 13 ng/ml [18,21]. Berghaus et al. [21] reported that tracking is impaired when the levels of THC in plasma are 6 ng/ml, attention is impaired when the levels of THC in plasma are 9 ng/ml and visual functioning is impaired when the levels of THC in plasma are 12 ng/ml. In the present study, participants were found to be impaired on the variables 'straddling the barrier line' and 'straddling the solid line', consistent with the suggestion that tracking, attention and balance are impaired following the consumption of THC.

The negative relationship that was observed between driving performance and the level of THC in blood may be because the level of THC in the central nervous system does not peak until some time after the level of THC in the blood has peaked. Similar to the case with benzodiazapines, whereby maximum impairment is observed 1 h after peak plasma levels are attained [22,23], maximum impairment associated with THC consumption may occur once peak drug plasma levels have plateaued. The negative relationship between driving performance and the level of THC in blood may also be due to the subjective experience of THC intoxication being magnified immediately after its consumption. Subjective effects of THC have been reported to be experienced after only one or two inhalations so individuals may initially compensate for the effects of the drug [21]. During the elimination phase of THC in blood, the subjective experience of the symptoms may have diminished and participants may no longer feel it necessary to compensate for the effects of the drug, resulting in more impaired driving performance.

It is necessary to consider that the purpose of the present study was to determine whether the SFSTs are of benefit when assessing whether drivers under the influence of drugs are fit to drive. As driving performance was not impaired at Driving Time 1, participants were deemed to be fit to drive. Driving performance was only significantly impaired at Driving Time 2 and as such, the data presented in the present study, pertained to how accurately the SFSTs administered before and after Driving Time 2 predicted driving performance. It should be considered that in real-world scenarios, the amount of false positives could be quite high if the SFSTs alone are used to determine whether an individual is driving under the influence of drugs. It is possible that a number of people may perform poorly on the SFSTs, despite not having consumed drugs. However, in real-life scenarios, SFSTs are not administered to a driver unless there is some suggestion that (a) driving is impaired or (b) the driver is under the influence of a drug other than alcohol. In such scenarios, the SFSTs are not the only measure used to determine whether an individual's driving performance is impaired by drugs. Authorities may use a number of other factors to make such assessments including: evidence of erratic driving, symptoms of drug use and medical examinations [8]. Using the SFSTs in combination with these other factors should minimise the number of false positives that are recorded. Furthermore, it is the authors' view that in real-life scenarios, a high incidence of false negatives is more detrimental to the safety of motorists than a high incidence of false positives. False negatives would mean that drivers under the influence of drugs would be passed fit to drive, despite the fact that they may not be fit to do so. The results of the present study suggest that using the SFSTs to assess drivers suspected of being under the influence of drugs other than alcohol would limit the number of false negatives that may otherwise occur.

In conclusion, the results of the present study indicate that the consumption of cannabis cigarettes containing either

1.74 or 2.93% THC significantly impairs performance on both the SFSTs and on driving behaviour. Furthermore, the results suggest that performance on the SFSTs provides a moderate predictor of driving impairment following the consumption of THC. Given that the level of THC in the blood does not provide an accurate and reliable indicator of whether driving performance is impaired, data obtained from the administration of the SFSTs may provide important information concerning drug intoxication and driver fitness. The SFSTs therefore appear to be an appropriate screening tool for authorities that wish to assess the driving capabilities of individuals suspected of being under the influence of a drug other than alcohol. Finally, the results suggest that the SFSTs provide a better predictor of driving impairment when the sign HMJ is included in the scoring procedure.

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