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Examining the effect of *dl*-3,4-methylenedioxymethamphetamine (MDMA) and methamphetamine on the standardized field sobriety tests

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ABSTRACT

dl-3,4-methylenedioxymethamphetamine (MDMA) and methamphetamine are commonly used illicit drugs that are thought to impair driving ability. The Standardized Field Sobriety Tests (SFSTs) are utilized widely to detect impairment associated with drugs other than alcohol in drivers, although limited evidence concerning MDMA and methamphetamine consumption on SFST performance exists. The aim of this study was to evaluate whether the SFSTs were a sensitive measure for identifying the presence of the specific isomer *d*-methamphetamine and MDMA. In a double-blind, within-subject, counter-balanced and placebo-controlled study, 58 healthy and abstinent recreational drugs users were administered three treatments: 100 mg of MDMA, 0.42 mg/kg *d*-methamphetamine, and placebo. For each condition the SFSTs were administered at 4 and 25 h post treatment. *d*-methamphetamine was not found to significantly impair SFST performance unlike MDMA, which significantly impaired SFST performance in comparison to placebo with 22% of the sample failing the test at the 4 h testing time-point. No differences were observed at the 25 h testing time-point for any of the conditions. It was concluded that the SFSTs are not efficient in identifying the presence of low level *d*-methamphetamine, and are significantly better at detecting the presence of MDMA at the levels assessed.

Sobriety tests are designed to measure aspects of divided attention, cognitive functioning, and psychomotor performance to assess impairment related to alcohol or drug consumption that adversely affect driving performance. The Standardized Field Sobriety Tests (SFSTs) require participants to complete the Horizontal Gaze Nystagmus (HGN), the Walk and Turn (WAT) and the One Leg Stand (OLS) tests to the satisfaction of police who believe a driver to be intoxicated [1]. While the SFSTs were originally designed to assess alcohol intoxication [1], many countries utilize these types of performance based tests to detect impairment associated with drugs other than alcohol in drivers [2]. Failure of these tests can result in drivers having to provide evidentiary samples to determine drug use, associated fines for driving under the influence of drugs (DUID), and license suspension or cancellation. With drug-related road accidents and deaths increasing worldwide, greater empirical evidence concerning the efficiency of tests of intoxication, such as SFSTs, is necessary to identify the nature of impairments on standardized tests attributable to commonly used illicit drugs.

The SFSTs were developed to assess alcohol-impairment of drivers at 0.10% [1] Blood Alcohol Concentration (BAC), and have been found to be reliable and accurate predictor of BACs above and below 0.08% BAC [3]. They are currently utilized in all 50 states of the USA, and their use has been extended to programs that assess the effects of drugs other than alcohol. The most common program to be used in this way is known as the Drug Evaluation Classification Program (DEC Program: a 12 step program for driver assessment), and other similar programs are used in other countries for the assessment of drug effects include the Field Impairment Tests (FIT; UK) and Performance Impairment Tests (PIT; Australia). These various programs have been highly successful in identifying drivers as impaired in the field with the PIT being successful in 89% of cases [4] and the DEC being 94% effective in identifying impairment in drivers caused by drugs other than alcohol [5]. Even though the use of these tests has recorded success in the detection of intoxicated drivers in the field, controlled studies of specific drug effects on SFST performance needs to be conducted to assess the efficiency of detection of the SFSTs when driving impairment is not already evident.

The SFSTs are used to identify driving impairment associated with consumption of a drug other than alcohol, however, only

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limited empirical evidence exists for the efficiency of the SFSTs to identify impairment associated with drug consumption. The SFSTs have shown moderate predictive efficacy for predicting simulated driving impairment in low dose (65.8% correct) tetrahydrocannabinol (THC) and high dose (76.3% correct) THC conditions [6]. Whereas, SFST performance when under the influence of 0.42 mg/kg of *d*,*l*-dexamphetamine, *d*,*l*-methamphetamine, or *d*-methamphetamine has been found to be mostly unaffected in three double-blind, placebo controlled studies [2]. No controlled studies of the effect of *dl*-3,4-methylenedioxymethamphetamine (MDMA) have been conducted upon SFST performance. Amphetamine usage by professional drivers and young adults attending late or all night parties has been recognized as playing a contributory role in the increase of driving injuries and deaths of drivers testing positive to stimulants [7]. Given that these amphetamine preparations have reported transient cognitive and mood enhancing properties, and their consumption appears to compromise driving ability, whether through increased risk taking behavior [8] or alternatively cognitive disturbance of functions necessary to drive in a safe and legal manner, examination of their effect on SFST performance is necessary to elucidate what SFSTs are compromised upon MDMA or methamphetamine consumption. The purpose of this paper is to explore the effect of two commonly used amphetamine type stimulants, MDMA and *d*-methamphetamine, on SFST performance.

1. Method

1.1. Participants

The sample comprised 58 participants; 31 females and 27 males aged between 21 and 34 years (mean age 25.49, SD 3.28), weighing between 46.5 kg and 118 kg (mean weight 73.41 kg, SD 16.32 kg). All participants had previously consumed amphetamine type stimulants and underwent a medical examination prior to participation to ensure that they had no history of cardiac disorders; current or past diagnosis of substance abuse; mental health problems (e.g., depression, schizophrenia); allergies to drugs; and no other medical illness. All participants had a valid full drivers license (no probationary or learner drivers) to ensure that they had at least three years of driving experience. The study was approved by the Institutional Human Research Ethics Committee, and all participants provided informed consent. Participants received $500 (AUD) for their participation in the study.

1.2. Treatments

The three sessions were double-blind, counter-balanced and placebo-controlled. The project consisted of three experimental sessions that involved the consumption of 100 mg of MDMA, 0.42 mg/kg *d*-methamphetamine, or placebo. Participants began testing days at either 10 A.M. or 12 midday, and maintained the same testing schedule for each session, all of which were separated by a 2-week washout period. In short, 100 mg of MDMA was selected as a moderate dose that has been previously administered [9]. Weight-related *d*-methamphetamine doses were made from a combination of capsules, with 0.42 g/kg being utilized to replicate previous research at Swinburne University of Technology [10] where the study was undertaken, resulting in a mean corrected weight-dose of 30 mg [11]. The lactose placebo capsules were virtually indistinguishable from the treatment capsules, and each participant took the same number of capsules in each condition. The MDMA and *d*-methamphetamine were purchased from Lipomed, Arlesheim, Switzerland.

1.3. Materials

The SFSTs comprise three tests: the Horizontal and Vertical Gaze Nystagmus (HGN and VGN), the Walk and Turn (WAT) and the One Leg Stand (OLS). For the HGN and VGN, participants are required to focus on a pen located 30–36 cm in front of their nose as the experimenter moves the pen horizontally and vertically. With the signs for both eyes of, lack of smooth pursuit; distinct Nystagmus at maximum deviation; Nystagmus onset before 45°; Vertical Gaze Nystagmus being recorded. Participants were classified as impaired on the test if they exhibited four or more (out of eight) of these signs. An additional sign, head movements and/or jerks (HMJ), was also recorded, as previous research has observed HMJ in participants affected by THC [6] and has not been used with participants affected by MDMA. HMJ was recorded if the participant was unable to keep their head stationary two or more times while following the moving stimulus. The WAT test requires participants to take nine heel-to-toe steps along a straight line, turn in a prescribed manner, and take nine heel-to-toe steps back along the line. The participant is classified as impaired if they show two or more of the following signs; not keeping balance while listening to the instructions of the test; starting the test before the instructions were completed; stopping walking during the test; not touching heel-to-toe while walking; stepping off line; using arms to maintain balance; turning incorrectly; or taking an incorrect number of steps. The OLS task requires the subject to stand on one leg, with the other leg extended to the front held approximately 15 cm above the ground. The participant is required to maintain this stance while counting out loud for 30 s by thousands. If two or more of the following signs or clues are observed, the participant is deemed to be impaired; swaying while balancing on one leg; using arms to maintain balance; hopping during test to maintain balance; putting raised foot down. *Overall performance on the SFSTs*: Overall performance on the SFSTs was calculated by summing the performance on the three tests (HGN, WAT, and OLS). In accordance with Victoria Police implementation training procedures, if the participant was identified as impaired on two or more of the tests, the participant was subsequently classified as impaired on the SFSTs.

All three tests that comprise the SFST battery were administered, as per the administration procedures used by the Victoria Police [12]. Participants were also familiarized with the SFST battery in a training session conducted by a trained researcher prior to the testing days to eliminate any possible learning effects on the tests that may affect the relative failure rate upon the individual tests.

1.4. Blood and saliva samples

Three blood samples were taken from each participant by a registered nurse during each experimental session; one at baseline, the second, 180 min post-treatment consumption, and the third, 25 h post-treatment. 10 ml samples of blood were obtained using a syringe by venipuncture from the antecubital vein. Blood samples were immediately stored in a −20 °C freezer and subsequently transported to a −70 °C freezer after 5–7 days. Blood samples were screened for the seven major drug classes (opiates, amphetamines, benzodiazepines, cannabinoid, barbiturates, cocaine and methadone) using ELISA/EMIT screens. Subsequently, blood samples were analyzed for specific amphetamine levels using the Gas Chromatography–Mass Spectroscopy method.

1.5. Statistical analysis

The primary analysis was based on the proportions of subjects in each active-treatment group (*d*-methamphetamine and MDMA) who were classified as impaired on the SFSTs in comparison to the proportion of subjects in the placebo group who were impaired. A series of difference in proportions tests based on paired data were performed to establish whether the SFSTs accurately detect the presence of *d*-methamphetamine or MDMA [13]. A confidence interval is generated for the differences in the two proportions with Yates Chi Square being conducted on the corresponding *z* statistic calculated (95% confidence intervals) from the numerical difference between the proportions of each group.

2. Results

The levels of MDMA and *d*-methamphetamine in blood were assessed 3 h post consumption, with the respective concentrations at that time-point being, 203 μg/L (SD = 72 μg/L, range: 28–442 μg/L) dropping to 43 μg/L (SD26 μg/L, range: 10–134 μg/L) at the 24 h post dose time-point, and for *d*-methamphetamine, the average concentration was 92 μg (SD = 34 μg/L, range: 17–169 μg/L) dropping to 22 μg (SD = 12 μg/L, range: 10–69 μg/L) at the 24 h post dose time-point. At 4 h post treatment administration, *d*-methamphetamine did not impair overall performance on the SFSTs (*d*-methamphetamine, 2/58 impaired; placebo, 3/58 impaired), nor did it impair any of the individual tests that contribute to the total SFST ($p > 0.05$). MDMA, however, was observed to impair overall performance on the SFSTs in comparison to placebo (MDMA, 10/58; placebo 2/58; $\chi^2 = 4.55$, $p = 0.033$). The proportion of impaired classifications within the MDMA condition was also significantly greater than placebo for the individual assessments of HGN (MDMA, 9/58; placebo 0/58; $p = 0.005$), OLS (MDMA, 20/58; placebo 6/58; $p = 0.004$), HMJ (MDMA, 13/58; placebo 2/58; $p = 0.006$) and the overall impairment SFST score with HMJ included (MDMA, 13/58; placebo 2/58; $p = 0.006$). At the 25 h post-treatment time-point, *d*-methamphetamine and MDMA were found not to impair overall performance on the SFSTs (*d*-methamphetamine, 1/58 impaired; MDMA, 2/58; placebo, 1/58 impaired) in comparison to placebo. Table 1 depicts the accuracy of the SFSTs in detecting impairment due to MDMA and *d*-methamphetamine 4 h post consumption, and

Table 1
Participants classified as impaired or not on the SFSTs after MDMA, methamphetamine or placebo 4 h post treatment.

	Placebo		Methamphetamine		MDMA		CI difference in proportions	
	Impaired	Unimpaired	Impaired	Unimpaired	Impaired	Unimpaired	Placebo vs methamphetamine	Placebo vs MDMA
HGN	0	58	2	56	9	49	−0.1173:0.0325	−0.2693:−0.0606
WAT	9	49	7	51	15	43	−0.0950:0.1639	−0.2475:0.0452
OLS	6	52	7	51	20	38	−0.1368:0.1037	−0.3812:−0.0903
Overall SFSTs	2	56	3	55	10	48	−0.1103:0.0723	−0.2572:−0.0256
HMJ	2	56	4	54	13	45	−0.1331:0.0583	−0.3146:−0.0687
Overall SFST and HMJ	2	56	4	54	13	45	−0.1331:0.0583	−0.3146:−0.0687

Note: Confidence intervals (CI) are 95% (lower bound:upper bound); HGN, Horizontal Gaze Nystagmus; WAT, Walk and Turn; OLS, One Leg Stand; SFSTs, Standardized Field Sobriety Tests; HMJ, Head Movement/Jerks.

Table 2
Participants classified as impaired or not on the SFSTs after MDMA, methamphetamine or placebo 25 h post treatment.

	Placebo		Methamphetamine		MDMA		CI difference in proportions	
	Impaired	Unimpaired	Impaired	Unimpaired	Impaired	Unimpaired	Placebo vs methamphetamine	Placebo vs MDMA
HGN	1	57	1	57	2	56	−0.0755:0.0755	−0.1013:0.0610
WAT	8	50	4	54	9	49	−0.0472:0.1879	−0.1493:0.1150
OLS	3	55	9	49	6	52	−0.2226:0.0111	−0.1615:0.0536
Overall SFSTs	0	58	1	57	2	56	−0.0914:0.0465	−0.1173:−0.0325
HMJ	2	56	3	55	2	56	−0.1103:0.0723	−0.0865:−0.0865
Overall SFST and HMJ	2	56	4	54	2	56	−0.1331:0.0583	−0.0865:−0.0865

Note: Confidence intervals (CI) are 95% (lower bound:upper bound); HGN, Horizontal Gaze Nystagmus; WAT, Walk and Turn; OLS, One Leg Stand; SFSTs, Standardized Field Sobriety Tests; HMJ, Head Movement/Jerks.

Table 2 depicts the results from the SFST 25 h post treatment consumption.

3. Discussion

The present study found that 0.42 mg/kg of *d*-methamphetamine did not impair performance on the SFSTs, however, a 100 mg dose of MDMA did significantly impair overall performance of the SFSTs in comparison to placebo with 22% of participants being adjudged impaired on two or more of the SFSTs 4 h post drug consumption. The presence of *d*-methamphetamine was detected in only 5% of cases, consistent with only previous study examining SFST performance under the effect of *d*-methamphetamine [2]. The levels of *d*-methamphetamine (30 mg) assessed may be considered a low dose in comparison to levels recently reported in the evaluation of Victoria's legislative framework for testing drivers for impairment caused by drugs other than alcohol [4]. This evaluation observed that blood samples taken from drivers convicted of driving while impaired by a drug (having failed the SFSTs) returned an average concentration of amphetamine of 185 ng/ml, suggesting impairment on the SFSTs may only be detectable after much larger or repeated doses of *d*-methamphetamine. The average level of MDMA detected in the same evaluation was 308 ng/ml, somewhat higher than the mean concentration observed in the current study (50% higher). Having said this, these relatively lower concentrations of MDMA and *d*-methamphetamine have been observed to significantly impair driving and signalling performance in a related driving simulator study [14].

d-methamphetamine was found not to be significantly impairing on any of the discrete tests of the SFSTs, and the addition of the HMJ test did not increase the correct identification of *d*-methamphetamine presence. This finding is consistent with the drug recognition expert manual, and other research studies that indicate that the HGN, OLS, WAT, and HMJ tests are not appropriate for detecting low level methamphetamine [2]. They are, however, highly reliable when used to substantiate the suspicion of drug impairment in drivers with 89% of cases being successfully identified as driving while impaired by a drug in the aforementioned Australian evaluation [4]. Given that at low doses methamphetamine has been found to improve some aspects of cognitive functioning, significant impairment in driving would only be expected during withdrawal phases or at higher doses where commonly reported effects of agitation, inability to focus attention restlessness, motor excitation, time distortion, depressed reflexes, poor balance and coordination, and the inability to follow directions [15] would contribute to impaired driving, and the resulting failure of the SFSTs.

Of greater note was the observed impairment on each discrete SFST in comparison to placebo within the MDMA condition, and the improved efficiency of the SFST total score when HMJs were considered. While only 22% of participants were adjudged impaired on the SFSTs at what is considered a 'low' dose of MDMA recreationally, the greater efficiency of the SFSTs in identifying MDMA intoxication may be a result of the mild visual disturbances, muscle tension and ataxic effects of low dose MDMA consumption [16]. The relative efficiency in detecting MDMA intoxication by the SFSTs is encouraging given the inconsistency between studies concerning the effect MDMA has on controlled simulated [17] and real-life driving [18,19], and the epidemiological data detailing the growing prevalence of MDMA in the blood of injured and deceased drivers [7]. While drugs of abuse are generally thought to compromise driving ability [20], understanding of the types of behaviors impaired drivers will display [21], and the types of performance measures that can detect illicit drug use in drivers suspected of DUID is of significant importance to law enforcement agencies worldwide.

In conclusion, under double-blind, within-subject, counterbalanced and placebo-controlled conditions, *d*-methamphetamine was not found to significantly impair SFST performance unlike MDMA, which significantly impaired SFST performance in comparison to placebo with 22% of the sample failing the test. The results presented herein indicate that the SFSTs are not efficient in identifying the presence of low level *d*-methamphetamine, and are somewhat better at detecting the presence of MDMA. Given that the SFSTs are most often used to substantiate driving impairment when BAC are within the legal limit but driving impairment is observed and no alternative measure of drug use is available [22], field administered tests are still necessary to

identify drivers who pose a risk on the road due to drug consumption.

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