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The Standardized Field Sobriety Tests (SFST) and measures of cognitive functioning

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ABSTRACT

Objective: The Standardized Field Sobriety Tests (SFST) are utilised widely to assess fitness to drive when law enforcement suspects a driver's ability to drive is impaired, whether by drugs or alcohol. The SFST ostensibly achieve this through assessment of the level of drivers' cognitive and psychomotor impairment, although no studies have explicitly assessed the relatedness of cognitive ability and performance on the SFST. The current study aimed to assess the relationship between the three components of the SFST with a well validated computerised cognitive battery.
Method: A sub-set of 61 placebo condition participants comprised the sample, with 33 females and 28 males (mean age 25.45 years). Correlations between the individual SFST subscales 'Horizontal Gaze Nystagmus' (HGN), the 'One Leg Stand' (OLS) and the 'Walk and Turn' test (WAT) and Cognitive Drug Research (CDR) sub-scales of 'Quality of Working Memory', 'Power of Attention' and 'Continuity of Attention' were analysed using point-biserial correlation.
Results: Sixty participants were included for analyses. A weak–moderate positive (five subscales) and a moderate–strong negative (two subscales) association was noted between seven of the nine individual CDR subscales and the SFST subscale of the WAT test (all $p<0.05$). Individually, a moderate positive association was noted between the sub-scale 'Nystagmus lack of smooth pursuit' and 'digit vigilance reaction time' and 'choice reaction time; reaction time' (both $p<0.05$) and 'Nystagmus head move and/or jerk' and 'simple reaction time' ($p<0.001$). When assessed as a partially composite factor, a comparable association was also noted between the composite score of the SFST subscale 'Nystagmus head move and/or jerk' and both (a) simple and (b) digit vigilance reaction time (both $p<0.05$). No association was noted between any of the individual cognitive variables and the SFST subscale 'OLS', or between composite cognitive scores 'Quality of Working Memory', 'Power of Attention' and 'Continuity of Attention' and total SFST scores.
Discussion: Variation in some aspects of cognitive performance was found to be moderately and positively correlated with some individual aspects of the SFST; particularly among tasks which assess reaction time. Impairment of these cognitive processes can also contribute to the completion of complex tasks such as driving or the SFST. Complex behavioural tasks such as driving are often severely impaired due to intoxication, and thus in a practical sense, the SFST can still be considered a useful screening tool to identify drug or alcohol impaired drivers.

1. Introduction

The Standardized Field Sobriety Tests (SFST) are commonly used by law enforcement personnel to give indication of an individuals' level of impairment by their ability to perform a series of tasks aimed to assess levels of divided attention, cognitive functioning

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and psychomotor performance (Burns and Moskowitz, 1977). The SFST were originally developed to give an indication of the degree of impairment among alcohol-affected individuals; however, subsequent validation studies have suggested the usefulness of the tool for identifying impairment as a result of consumption of drugs other than alcohol (Downey et al., 2012a, 2012b; Papafotiou et al., 2005; Porath-Waller and Beirness, 2014; Silber et al., 2005). Although it is widely accepted that the task components are indicative of levels of impairment as expressed by deficits in cognitive abilities, studies which explicitly assess the degree of shared association between these facets of cognitive ability and the behavioural requirements of the task are limited.

The SFST were originally developed to assess an individuals' level of impairment as a result of alcohol use to a sensitivity of 0.10% blood alcohol concentration (BAC) (Burns and Moskowitz, 1977), however, subsequent psychometric evaluation of the tests has similarly revealed sound efficacy in detecting impairment among individual's with a BAC of as low as 0.04% (Stuster et al., 1998) and 0.08% (Stuster, 2006), with a test accuracy of up to 91% (Stuster et al., 1998). The tests comprise three main behavioural components; the Horizontal Gaze Nystagmus (HGN), the Walk and Turn (WAT) and the One Leg Stand (OLS), which are used to assess different aspects of divided attention, cognitive functioning, and psychomotor performance. Alcohol is known to impair an individuals' ability to accurately and completely perform these tests. Alcohol produces deficits in non-voluntary eye-tracking ability, saccadic movements and smooth pursuit of a visual stimuli (Moser et al., 1998), as well as poorer performance in simple tasks which require sustained or divided attention (Dry et al., 2012) and/or balance and large muscle coordination (Modig et al., 2012). These deficits contribute to overall poorer performance on the SFST. Assessments of impairments attributable to illicit drug use have also demonstrated usefulness for Δ9-tetrahydrocannabinol (THC) concentrations of 1.8% and 3% and concurrent low and high alcohol use (Downey et al., 2012a), as well as among individuals affected by DL-3,4-methylenedioxymethamphetamine (MDMA) but not D-methamphetamine (Downey et al., 2012b; Silber et al., 2005).

Psychometric evaluation of the SFST has yielded mixed results. Typically, the individual components of the tasks are assessed as a function of scorer inter-reliability or specificity (see Cole and Nowaczyk, 1994), or by assessing the sensitivity of the measure to detect variable levels of intoxication as a function of alcohol or other drugs (see Hlastala et al., 2005). To the best of our knowledge, only one study is available which assesses the correlational relationships between cognitive tasks and outcomes of the behavioural tasks on the SFST, albeit as a function of alcohol impairment and BAC (Kennedy et al., 1994). Here, the SFST were administered in conjunction with computerised tasks aimed to assess various aspects of cognitive ability. These preliminary data indicated that both the SFST and performance on a series of cognitive tasks contributed significantly to the overall predicted level of participant BAC, and correlational assessments of these two factors provided moderate explanation of the test variance (correlation coefficients ranged from .30 to .60). Indeed, these findings present the first indication of the test's ability to evaluate level of cognitive impairment associated with alcohol impairment. Despite these preliminary findings, several areas of investigation remain. Primarily, although the cognitive tasks included were comprehensive, it is not clear whether these accurately reflect the cognitive domains implicated in alcohol intoxication and thus exhibited in the SFST (i.e. the use of 'grammatical reasoning' task). Moreover, the effect of cognitive performance on composite SFST is unclear, as only selected individual sub-scales were assessed. Thus, the degree of shared association between cognitive performance levels on overall levels of impairment as assessed by the SFST is currently equivocal.

Road trauma which occurs as a result of driver impairment is a growing area of concern, and contributes to significant morbidity and mortality (Drummer et al., 2004; Peden, 2004; Ameratunga et al., 2006). The use of sobriety tests in the identification of affected individuals is widely utilised, and evaluation of impairment is currently based on the proxy cognitive, attention and psychomotor performance deficits often displayed as a result of alcohol or drug intoxication. Despite the wide availability and use of these tests, limited research has been conducted explicitly examining the degree of shared association between these facets of cognitive ability and the behavioural requirements of the tasks. Therefore, the current study aimed to provide the first assessment of the relatedness of the behavioural aspects of the SFST and associated cognitive domains.

2. Method

2.1. Participants

The sample comprised a sub-set of 61 adults (54.1% female) aged between 21 and 34 years (mean age 25.45, SD 3.25 years) who took part in a larger study which aimed to evaluate the association between illicit drug use and measures of cognitive (Stough et al., 2012a), psychological (Parrott et al., 2011) and driving performance (Downey et al., 2012b; Stough et al., 2012b). Detailed descriptions of the sampling procedure for the larger study are available elsewhere (see Stough et al., 2012a). Briefly, as part of the larger study, participants were exposed to orally administered MDMA, D-methamphetamine or placebo as part of a three-session double blind, placebo controlled, counterbalanced trial (see Downey et al., 2012b; Stough et al., 2012a, 2012b). Participants were included in the larger trial if they reported previous exposure to amphetamine-type stimulants and did not present with significant medical history (i.e. mental health problems, prior cardiac disorders, other medical illness), as assessed by medical examination, and all participants held a current full Australian drivers' license. Participants were requested to abstain from ingesting alcohol for at least 24-h and from other drugs for at least 7-days prior to each testing session. Tests were conducted at either 10:00 am or 12:00 midday and these times were maintained throughout all of the testing sessions. For the current study, only participant data from the placebo trial period was used.

Data for the Standardized Field Sobriety Test (SFST) was collected as part of the same study protocol and included the same study participants as described above. Participants were familiarised with the SFST protocol prior to the testing day to eliminate possible learning effects.

2.2. Measures

2.2.1. The Standardized Field Sobriety Test (SFST)

All three components of the SFST were administered to the participants, based on the procedure outlined by Burns and Moskowitz (1977) and described in detail below. The individual sub-scale component scores and composite SFST scores were used for analyses.

2.2.2. Horizontal and Gaze Nystagmus (HGN)

HGN refers to the involuntary jerking or sudden movement of the eye that naturally occurs when the eyes gaze to the side. In unaffected individuals, HGN occurs when the eye gaze is at high periphery angles; however this occurs at lesser angles when an individual is impaired by alcohol or drugs (Bosker et al., 2012). This test requires participants to focus on and follow the trajectory of a slow moving horizontal object which is presented directly in front of their face (usually a pen). During the task, the test investigator (in this case a trained research officer) observes both the left and right eye for three distinct signs; a lack of smooth pursuit (LSP), a distinct nystagmus at maximum eye deviation (Nmax), and the onset of nystagmus prior to 45° deviation (N45). The sign was recorded as 'present' or 'absent' for each factor, and a participant was noted to have failed the test if all factors were noted as 'present'. An additional sign, evidence of head movements and/or jerks (HMJ) was scored (present/absent) if participants were noted to involuntary move or jerk their head while following the horizontal stimulus. The HMJ, although not routinely included as part of the SFST, was included as part of the original study design and thus employed here.

2.2.3. Walk and Turn (WAT)

In this test, participants are instructed to walk nine steps, heel-to-toe, along a straight line turn as directed and then return to take another nine heel-to-toe steps back along the same line. The investigator then observes for the following eight signs (or clues) of error: not keeping balance when listing to test instructions, starting the test before the instructions were completed, stopped walking at some point during the test, did not touch heel-to-toe when walking, deviations from the straight line, using arms to maintain balance during the test, and turned improperly (not as directed). Test failure is noted if a participant performs two or more of the errors, or if the participant fails to complete the test, as per Victorian Police guidelines. Two or more errors on the WAT test are commonly used to represent impairment comparable to a blood alcohol content of 0.10% (Papafotiou et al., 2005).

2.2.4. One Leg Stand Test (OLS)

For this test participants are instructed to stand on one leg, with the other leg raised approximately 15 cm from the ground whilst they count aloud from 1000 (1001, 1002, etc.) for duration of 30 s. During the task, the investigator observes for the following four signs: swaying whilst balancing on one leg, using arms to maintain balance, hopping on one leg to maintain balance, and putting the raised foot down for balance. Test failure (impairment) is noted if two or more of these errors were observed, or if the participant puts their foot down more than four times during the test. Two or more errors on this task are often used to represent a level of impairment comparable to a BAC of 0.10% (Papafotiou et al., 2005).

2.2.5. Overall performance on the SFST

Overall performance on the SFST was calculated by summing the performance on the three tests (HGN, WAT, and OLS), which were derived from summing the total of signs 'present' each of the three tests. If a participant was identified as failing two or more of the three tests, they were subsequently classified as impaired on the overall SFST.

2.3. Cognitive assessments

Participants completed a computerised battery of cognitive tests from the Cognitive Drug Research (CDR) assessment system (Wesnes et al., 2000). Previous assessments of the CDR have demonstrated good sensitivity in detecting changes in cognitive function associated with the effects of psychopharmacological substances (Wesnes et al., 1988) and illicit drug use (Silber et al., 2006), as well as more subtle cognitive changes associated with organic neurodegeneration (as in Alzheimer's disease) (Simpson et al., 1991). Completion of the test batteries took approximately 20 min with the main cognitive outcomes being 'Quality of Working Memory' (composite score of sensitivity index scores for numeric and spatial working memory tests), 'Power of Attention' (composite simple reaction time, choice reaction time and digit vigilance reaction time) and 'Continuity of Attention' (composite digit vigilance accuracy, choice reaction time accuracy, digit vigilance false alarms) (Downey et al., 2012b). The individual sub-scales of these outcomes are described in detail below.

2.3.1. Simple reaction time

Participants are required to press the button labelled YES as quickly as possible in response to the presentation of visual stimuli (the word YES) on a computer screen. Thirty presentations of the stimulus were used in each test and were presented at intervals ranging from 1 to 4 s. Reaction time in milliseconds (ms) was used.

2.3.2. Digit vigilance

During this task, participants are required to press the YES button as quickly as possibly when a presented stimulus matches that which is presented in the top right of the computer screen. Series of stimuli are presented in quick succession (rate of 2.5 digits per second) and participants must indicate at each match. For this test, the test accuracy (percentage of correct responses) and average reaction time (ms) were used.

2.3.3. Choice reaction time

In this test participants are required to press the YES or NO button as quickly as possible in response to the corresponding visual stimuli presented on the computer screen. Thirty presentations of the stimulus were used in each test and were presented at intervals ranging from 1 to 4 s. For this test, the accuracy of responses and average reaction time (ms) were used.

2.3.4. Spatial working memory

This test involved the presentation of a picture of a house with four of nine windows 'lit up', and participants were instructed to memorise the position of these windows. The picture was presented several times, and the participant was required to indicate by pressing a YES or NO button if the 'lit up' windows in the subsequent presentations were also present in the original picture. For this test, the sensitivity index (composite score of percentage of correctly identified stimuli and correctly rejected incorrect stimuli) and average reaction time (ms) were used.

2.3.5. Numeric working memory

In this test participants were instructed to memorise a series of five digits that were presented. The presentation of this stimulus was then followed by a series of 30 probe digits and participants were required to indicate if these featured in the original series of digits by pressing a YES or NO button. For this test, the sensitivity index and average reaction time (ms) were used.

3. Statistical analyses

Data for the SFST subscale and composite scores were coded as 0 = not present, 1 = present. Point-biserial correlation coefficient was used to assess the relationship between performance on each of the individual cognitive battery tests and scores on each of the individual SFST subscales (present/absent), the overall scores for the sub-scales, and then to ascertain the association between composite cognitive scores 'Quality of Working Memory', 'Power of Attention' and 'Continuity of Attention' and SFST scores (present/absent). All analyses were conducted using SPSS V18 for windows, and all tests were two-tailed with conventional $p < 0.05$ as significance threshold.

4. Results

Information for $n = 1$ participant was not included in analyses due to incomplete cognitive data, resulting in an eligible sample of $N = 60$ participants. All participants provided a BAC reading to confirm no alcohol had been consumed prior to beginning the study,

Table 1
Cognitive and SFST subscales: correlations and descriptive statistics ($N = 60$). Descriptive data are given as mean (SD) for cognitive factors and n (%) for SFST scales.

	1	2	3	4	5	6	7	8	9	10	11
1. Simple reaction time (ms)	–										
2. Digit vigilance; reaction time (ms)	–.48**	–									
3. Digit vigilance; accuracy	.26*	.12	–								
4. Choice reaction time; reaction time (ms)	–.56**	–.60**	.35**	–							
5. Choice reaction time; accuracy	–.27*	–.22	.05	–.30	–						
6. Spatial working memory; reaction time (ms)	–.11	–.29*	.15	–.52	.00	–					
7. Spatial working memory; sensitivity index	–.08	–.06	–.11	–.02	–.21	–.06	–				
8. Numeric working memory; reaction time (ms)	–.11	–.41**	.09	–.64**	–.21	–.70	–.06	–			
9. Numeric working memory; sensitivity index	–.11	–.12	.30	–.12	–.28	–.11	–.24	–.19	–		
10. Nystagmus; lack of smooth pursuit	.15	.29*	–.15	.31*	.02	.03	–.04	.07	.06	–	
11. Nystagmus; maximum deviation	–.05	–.09	.07	–.00	–.09	–.12	.17	–.05	.12	.03	–
12. Nystagmus at 45[a,d]	–	–	–	–	–	–	–	–	–	–	–
13. Nystagmus; head move and/or jerk	.30*	.12	–.11	.17	.07	–.9	.11	–.04	–.25	–.15	.09
14. Walk and Turn; no balance during instruction	–.10	–.01	–.01	.04	–.13	.04	.17	.03	.05	–.32*	.05
15. Walk and Turn; starts too soon	–.07	.03	–.10	–.10	–.45**	.24	–.16	.07	–.07	.02	.02
16. Walk and Turn; stops walking during test	.01	–.7	.10	–.06	.17	–.01	.12	.20	.09	.02	.02
17. Walk and Turn; misses heel-to-toe	.02	.12	–.10	–.01	.09	–.04	.12	.06	.09	.02	.02
18. Walk and Turn; uses arms for balance	.13	.10	.30*	–.08	.15	–.04	–.02	–.07	–.15	.10	.10
19. Walk and Turn; improper turn	–.05	.31*	–.02	.04	–.05	.26*	.02	.28*	–.11	.09	.09
20. Walk and Turn; steps off line	–.01	.00	–.00	–.00	–.07	–.06	.02	–.12	–.37**	.04	.04
21. Walk and Turn; incorrect number of steps	–.13	.16	.19	–.00	.22	.07	.06	.26*	–.09	.07	.07
22. One Leg Stand; swaying	.06	.07	.23	.09	.18	–.10	.01	–.05	–.07	.08	–.17
23. One Leg Stand; arms for balance	–.04	.21	–.08	.14	1.0	.01	.21	–.04	–.01	–.17	–.17
24. One Leg Stand; hopping	–.16	.04	.05	–.03	.04	–.03	.07	–.07	–.10	.07	–.22
25. One Leg Stand; puts foot down	–.17	.07	–.05	–.01	.17	.00	.12	.00	–.13	.06	–.25
M, *n* (%)	263.5	409.0	97.8	422.8	95.6	622.3	1.0	616.1	.92	2 (3.3)	2 (3.3)
SD	35.4	42.10	2.93	50.94	3.36	188.88	.05	192.44	.06		

Table 1 (*Continued*)

	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1. Simple reaction time (ms)														
2. Digit vigilance; reaction time (ms)														
3. Digit vigilance; accuracy														
4. Choice reaction time; reaction time (ms)														
5. Choice reaction time; accuracy														
6. Spatial working memory; reaction time (ms)														
7. Spatial working memory; sensitivity index														
8. Numeric working memory; reaction time (ms)														
9. Numeric working memory; sensitivity index														
10. Nystagmus; lack of smooth pursuit														
11. Nystagmus; maximum deviation														
12. Nystagmus at 45°[a]	–													
13. Nystagmus; head move and/or jerk	–	–												
14. Walk and Turn; no balance during instruction	–	.12	–											
15. Walk and Turn; starts too soon	–	.06	.03	–										
16. Walk and Turn; stops walking during test	–	.06	.03	.03	–									
17. Walk and Turn; misses heel-to-toe	–	.06	–.3	.03	.02	–								
18. Walk and Turn; uses arms for balance	–	.07	.03	.03	.02	.12	–							
19. Walk and Turn; improper turn	–	–.02	–.19	–.19	.07	.07	.07	–						
20. Walk and Turn; steps off line	–	–.49**	–.04	.04	–.26*	.06	–.26*	–.15	–					
21. Walk and Turn; incorrect number of steps	–	.04	.06	.06	.03	.03	–.03	–.07	–.27*	–				
22. One Leg Stand; swaying	–	–.02	–.11	–.11	.05	.05	–.36**	–.19	–.47**	–.16**	–			
23. One Leg Stand; arms for balance	–	–.14	–.24	–.24	.06	.06	.06	–.31*	–.12	–.10	–.26*	–		
24. One Leg Stand; hopping	–	.17	–.24	–.24	.06	.06	.06	–.09	–.00	–.10	–.12	–.28*	–	
25. One Leg Stand; puts foot down	–	.16	.10	.10	.05	.05	–.36**	–.06	–.08	.08	–.19	–.26*	–.54**	–
M, *n* (%) SD	0 (–)	11 (18.0)	4 (6.6)	1 (1.6)	1 (1.6)	1 (.8)	13 (21.3)	12 (19.7)	3 (4.9)	7 (11.5)	10 (16.4)	10 (16.4)	7 (11.5)	6 (9.8)

All significant correlations are bold.

[a] Cannot be computed because at least one of the variables is constant.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 2
Bivariate correlations between cognitive sub-scale variables and overall SFST sub-scale scores.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Simple reaction time (ms)	–												
2. Digit vigilance; reaction time (ms)	**–.48****	–											
3. Digit vigilance; accuracy	**.26***	.12	–										
4. Choice reaction time; reaction time (ms)	**–.56****	**–.60****	**.35****	–									
5. Choice reaction time; accuracy	**–.27***	–.22	.05	**–.30***	–								
6. Spatial working memory; reaction time (ms)	–.11	**–.29***	.15	**–.52****	.00	–							
7. Spatial working memory; sensitivity index	–.08	–.06	–.11	–.02	–.21	–.06	–						
8. Numeric working memory; reaction time (ms)	–.11	**–.41****	.09	**–.46****	–.21	**–.70****	–.06	–					
9. Numeric working memory; sensitivity index	–.11	–.12	.03	–.12	**–.28***	–.11	–.24	–.19	–				
10. Overall score Horizontal Gaze Nystagmus	–	–	–	–	–	–	–	–	–	–			
11. Overall score; head moves and/or jerks	**.29***	**.26***	–.00	.25	.25	–.03	–.03	.02	.02	–	–		
12. Overall score; Walk and Turn	–.13	.17	.13	–.12	–.12	.04	–.01	.17	.17	–	.06	–	
13. Overall score; One Leg Stand	–.18	.05	–.01	.05	.10	.06	.12	–.01	–.08	–	.04	–.15	–

All significant correlations are bold.
* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

and additionally provided a saliva sample to rule out consumption of amphetamines or cannabis. The means, standard deviations, and *n* (%) (SFST scales only) of each of the assessment sub-scales are presented in Table 1. The *n* (%) of individuals in this sample classified as impaired as measured by the individual SFST subscales was generally low, with the exception of 'Nystagmus head move and/or jerk' ($n = 11$, 18.0%) and the WAT tests 'uses arms for balance' and 'improper turn' ($n = 13$, 21.3% and 12, 19.7%, respectively).

Two (3.3%) participants were considered impaired as assessed by total SFST scores. To assess the association between scores on each of the cognitive battery sub-scales and scores on each of the SFST subscales (present/absent), point-biserial correlation coefficient analyses were applied (see Table 1). Results indicated a weak to moderate positive correlation between the SFST subscales WAT test 'uses arms for balance' and digit vigilance; accuracy ($r_{pbi} = .30$, $n = 60$), 'improper turn' and digit vigilance; reaction time ($r_{pbi} = .31$, $n = 60$), spatial working memory; reaction time ($r_{pbi} = .26$, $n = 60$) and numeric working memory; reaction time ($r_{pbi} = .28$, $n = 60$), and 'incorrect steps' and numeric working memory; reaction time ($r_{pbi} = .26$, $n = 60$) (all $p < 0.05$). A moderate to strong negative association was also noted between the WAT test subscales of 'starts the test too soon' and choice reaction time; accuracy ($r_{pbi} = -.45$, $n = 60$), and 'steps off the line' and working memory; sensitivity index ($r_{pbi} = -.37$, $n = 60$) (both $p < 0.001$).

A significant and moderate positive association was also noted between 'Nystagmus head move and/or jerk' and simple reaction time ($r_{pbi} = .30$, $n = 60$, $p = < 0.001$), and for 'Nystagmus lack of smooth pursuit' and digit vigilance; reaction time ($r_{pbi} = .29$, $n = 60$, $p = < 0.05$) and choice reaction time; reaction time ($r_{pbi} = .31$, $n = 60$, $p = < 0.05$). No significant correlations were noted between SFST subscale OLS and any of the cognitive variables. The association between individual cognitive battery sub-scale scores and overall scores on the SFST subscales are presented in Table 2. A moderate positive correlation was noted between the overall score for 'Nystagmus head moves and/or jerks' and simple reaction time ($r_{pbi} = .29$, $n = 60$) and digit vigilance reaction time ($r_{pbi} = .26$, $n = 60$) (both $p < 0.05$). No other significant associations were observed between the cognitive variables and the SFST overall sub-scale scores.

Point-biserial correlation coefficient analyses were also applied to ascertain the relationship between composite cognitive scores 'Quality of Working Memory', 'Power of Attention' and 'Continuity of Attention' and total SFST (present/absent) (Table 3). No association was noted between any measures of composite cognitive scores and level of impairment as measured by the SFST (all $p > 0.05$).

5. Discussion

The results from the current study indicate that a moderate relationship exists between poorer cognitive functioning and impairment on some aspects of the SFST. Assessment of the individual subscales revealed that reduced performance on cognitive tasks of reaction time, accuracy and sensitivity indices is largely positively associated with impairment as measured by some subsscales of the SFST, with the exception of two sub-tests; which displayed a moderate to strong negative association. No relationship was noted between the composite cognitive outcomes of 'Quality of Working Memory', 'Power of Attention' and 'Continuity of Attention' and total SFST scores.

Evaluations of the degree of shared association between performance on relevant cognitive tasks and the behavioural components of the SFST are limited. Of the available research, results have demonstrated a generally weak to moderate positive correlation between specific cognitive variables studied and the SFST (correlation coefficients cited between .30 and .60) (Kennedy et al., 1994). We similarly report a predominantly weak to moderate positive correlation between performance on individual cognitive tasks and the SFST; however, these relationships were found to be somewhat dependent on variable categorisation. Specifically, we report that when assessed as individual factors, these relationships, which were primarily positive, were typically observed between measures of reaction time on several of the cognitive tasks and the SFST sub-scale, the WAT test. These findings were somewhat expected, due to the conceptually close association between large muscle group motor control, degree of fine motor control and subsequent performance on reaction time tasks (Keele, 1968). Given the close relationship between an individual's level of impairment as a result of alcohol or other drugs and relative poorer performance on simple motor tasks, cognitive tests and driving simulator tasks (Stough et al., 2012a, 2012b; Gouzoulis-Mayfrank et al., 2000; Tzambazis and Stough, 2000), it is therefore feasible to speculate that poorer

Table 3
Bivariate correlations of composite cognitive scores and SFST score ($N = 60$).

		1	2	3	4
1.	Quality of Working Memory	–			
2.	Power of Attention	–.13	–		
3.	Continuity of Attention	**–.33****	–.04	–	
4.	SFST score	.07	–.13	.17	–

All significant correlations are bold.
** Correlation is significant at the 0.01 level (2-tailed).

performance on these specific tasks are indeed reflective of an individual's level of impairment as measured by the SFST, and that such associations can be considered reflective of relative impairment. Indeed, reaction time has been shown to be a reliable indicator of an individuals' relative risk of being involved in road trauma, and often assessed as a function of age (both young and old) (Cantin et al., 2009) or other factors, such as physical injury (Cyr et al., 2009) or drug intoxication (Ramaekers et al., 2000). We also reported a moderate to strong negative relationship between the SFST subscales of the two WAT tests 'starts the test too soon' and 'steps off the line' with cognitive tasks 'choice reaction time; accuracy' and 'working memory; sensitivity index', respectively. It is possible that these correlations are reflective of higher-order cognitive processes, of which may be differentially represented to the capacities used for simple reaction time tasks. Such assumptions may also partially explain the lack of significant associations between any of the cognitive factors and the SFST subscale of the OLS test in the current study; as this may again be mediated by unassessed or unrepresented facets of cognitive functioning.

Although the results of the current study are somewhat reflective of the findings of the limited pool of previous research, it is difficult to consolidate our findings with those reported by Kennedy et al. (1994). The noted discrepancies are likely due to the examination of the included cognitive outcomes, as well as the differing study methodologies. Indeed, the variables examined by Kennedy et al. (1994) included different facets of cognitive functioning (such as mental arithmetic and grammatical reasoning) both in the absence of, and with alcohol intoxication, and thus it is possible that these factors are differentially represented in the expression of impairment as measured by the SFST (Kennedy et al., 1994). The cognitive battery used in the current study employs assessments which are arguably more sensitive at detecting aspects of cognitive functioning commonly implicated in substance-intoxicated individuals (such as reaction time), and which are theoretically related to the SFST components. Further research examining the reliability of selected facets of cognitive domains may assist in refining appropriate future assessments.

When assessed as partially composite factors, a moderate positive correlation was noted between the SFST subscale score for 'head moves and/or jerks' and two reaction time tasks of the cognitive sub-scale, with no other associations noted. A comparably strong positive relationship was also noted for the SFST sub-scale 'head moves and/or jerks' and simple reaction time, and 'lack of smooth pursuit' and both digit vigilance and choice reaction time when assessed as individual sub-scores. HGN is recognised to be present in individuals affected by alcohol (Citek et al., 2003) or drugs such as Zolpidem (Logan and Couper, 2001), and is considered a relatively effective measure of detecting impairment among these individuals when assessed by highly-trained personnel (Citek et al., 2003). It is possible that impairments in this function, even among non-intoxicated individuals, are reflective of deficits in finer motor control, and thus may provide some explanation for the current findings. That no other significant associations were noted for the HGN and cognitive performance may be due to inherent variations in the scoring process. Indeed, assessments of this variable have shown that a large degree of variation exists with regard to positive identification of affected individuals. These discrepancies may, in part, be due to scorer error, unexplained bias or variations in testing environments (Rubenzer and Stevenson, 2010). Thus, additional research is warranted which employs a validation-based assessment of this variable with regard to cognitive outcomes in order to clarify the degree of these associations.

No significant association was detected between the composite cognitive outcomes of 'Quality of Working Memory', 'Power of Attention' and 'Continuity of Attention' and total SFST scores. This is in contrast to other studies which have independently demonstrated a close association between the same composite measures of cognitive ability and intoxication (Stough et al., 2012a), as well as performance on both the sub-scales and total SFST and relative levels of intoxication (Porath-Waller and Beirness, 2014). It is possible that the SFST may only measure specific and limited behaviourally translatable facets of cognitive functioning, rather than give indication of overall cognitive performance. Similarly, it is possible that deficits in these domains are sensitive to intoxication, and are not as evident among samples of healthy controls, such as those individuals employed for the current study. Further research is required to consolidate these discrepancies and to further examine the relationship between the SFST scores and composite measures of cognitive functioning among different populations of healthy and intoxicated individuals.

Interpretation of the findings presented within this study must be considered in light of some limitations. The study sample comprised a sub-set of placebo-group allocated participants who took part in a previous drug trial quantifying previous exposure to amphetamine-type substances. Repeated exposure to stimulant-type mediations such as MDMA and D-methamphetamine has a cumulative and deleterious effect on cognitive acuity and ability as a result of damaged dopaminergic and serotonergic neurons (White, 2002; Kalechstein et al., 2007). Baseline performance on the cognitive tasks was not assessed within the experimental design, thus it is difficult to infer or detect whether the sample displayed lower or differential baseline cognitive abilities compared to non-drug exposed groups. Habitual or infrequent amphetamine-type drug use (whether reported weekly or monthly) is not uncommon among population-based samples of younger individuals (as used in the current study) (de Almeida and Silva, 2003; Wu et al., 2009), as well as among individuals involved in motor-vehicle accidents (Mathijssen and Houwing, 2005), and thus these results may have more practical implications when considering the validity of the SFST, compared to assessments of drug-naïve populations.

The use of a relatively young group of participants may further impact the ability to generalise these findings as it is unclear as to whether these associations would be differentially represented among older groups. Cognitive function is accepted to decline in the normal ageing process, with these declines starting in the 20s, and these declines have been described as large in magnitude and they occur for the majority of individuals (Salthouse, 2010). Performance on the CDR tests utilised in this study has been illustrated to be reduced with increasing age (Wesnes and Edgar, 2011). As the aim of this study was to assess the relationship between study variables rather than the effect of age, the use of young, healthy individuals may be advantageous by reducing the impact of age-related effects. Conversely, any age-related reductions in cognitive capacity associated with increasing age that may have concomitantly affected SFST performance, will not have been adequately assessed.

The generally low proportion of individuals meeting criteria for impairment as measured by total SFST scores ($n = 2$) may, in part, provide some explanation for the absence of association with cognitive variables when assessed in this manner. Moreover, it is unclear whether this association is directly translatable to intoxicated individuals, as participants were drawn from the control portion of the study, and were not drug-exposed at the time of testing. Therefore, additional studies are warranted if more conclusive arguments regarding the relatedness of the SFST scales and cognitive factors among drug and alcohol affected individuals are to be drawn. Despite this, evaluation of the individual components of these relationships suggests that these associations are largely evident among behaviourally translatable facets of the tests only. It is possible that the SFST may instead only measure distinct behaviourally exchangeable aspects of cognitive functioning, and not give accurate indication of overall measures of cognitive performance. It is acknowledged that some discrepancy may exist between cognitive deficits and overt behavioural impairments, and thus additional studies are warranted among affected individuals to further test these assumptions.

The utility of the SFST in classifying intoxicated drivers have insofar been based on the assumption that shared deficits in translational cognitive and behavioural domains resulting from substance use are detectable using these methods. We have demonstrated that although there is some degree of relatedness between cognitive performance and individual subscales of the SFST, these preliminary assumptions are far from definitive, and thus more comprehensive assessments are urgently required if the utility and reliability of this method is to be maintained. Specifically, additional studies which incorporate a wider demographic of individuals may provide further information pertaining to more subtle aspects of the tests as a function of age. Moreover, although several tests have demonstrated the utility of these assessments in detecting impairment due to both low (Stuster et al., 1998) and high range (Stuster, 2006) alcohol intoxication and illicit drugs such as THC (Papafotiou et al., 2005) and methamphetamine (Downey et al., 2012b), additional studies are warranted to assess the relative impact of newer-age substances (such as synthetic cannabis) and prescription medications to mirror trends of drug usage in the population.

6. Conclusions

In summary, these findings suggest that when assessed individually, selective cognitive measures were moderately and positively correlated with some individual aspects of the SFST; particularly among tasks which assess reaction time. As no association was noted for composite measures of cognitive functioning, this indicates that the SFST may only measure limited and individual behaviourally translatable facets of cognitive functioning, rather than overall measures of cognitive performance. This study provides the first explicit assessment of the degree of shared association between cognitive factors directly implicated in alcohol and drug intoxication and subsequent driving performance as assessed by the SFST. It further confirms that the SFST are a useful screening tool to identify impaired driving in a practical sense for law enforcement purposes.

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