ROAD SAFETY RESEARCH REPORT

CR 189
2000

Development of Measures of Fatigue: Using an Alcohol Comparison to Validate the Effects of Fatigue on Performance

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Development of Measures of Fatigue: Using an Alcohol Comparison to Validate the Effects of Fatigue on Performance

DEMONSTRATION PROJECT FOR FATIGUE MANAGEMENT PROGRAMS IN THE ROAD TRANSPORT INDUSTRY

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AUSTRALIAN TRANSPORT SAFETY BUREAU
DOCUMENT RETRIEVAL INFORMATION

Report No.	Date	Pages	ISBN	ISSN
CR 189	July 2000	72	0 642 25579 2	0810-770X

Title and Subtitle

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Sponsored by / Available from

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Abstract

This study was the first of a series looking at the development of model work-rest schedules that have demonstrated effectiveness in managing driver fatigue. The aim was to develop a range of performance tests with demonstrated sensitivity for fatigue and for which the fatigue effects could be interpreted on the basis of a community-accepted standard for safety. Performance effects were studied in the same subjects over a period of 28 hours of sleep deprivation and following measured doses of alcohol up to approximately 0.1%Blood Alcohol Concentration (BAC). Subjects were 39 employees from the transport industry and the army. After 17 to 19 hours without sleep, corresponding to approximately 10.30pm and just after midnight, performance on some tests was equivalent or worse than that at 0.05%BAC. Response speeds were up to 50 percent slower for some tests and accuracy measures were significantly poorer at this level of alcohol. After longer periods without sleep, performance reached levels equivalent to the maximum alcohol dose given to subjects (0.1%BAC). The results also demonstrated that not all types of performance tests were affected by sleep deprivation. Also, differences between the performance of drivers and controls suggested that drivers took a more conservative approach to performance. This study demonstrated which of a set of performance tests can be used in evaluations of fatigue and fatigue countermeasures. The findings also reinforce evidence that the fatigue of sleep deprivation is important and likely to compromise speed and accuracy needed for safety on the road and in other industrial settings.

Keywords

FATIGUE MEASURES, ALCOHOL, PERFORMANCE

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ACKNOWLEDGMENTS

This study could not have been conducted without the generous support of Finemores Transport and the Transport Corps of the Australian Army, Randwick Barracks. In addition, we would like to extend particular thanks to the 39 people who participated in the study and who managed to maintain high spirits under often trying circumstances.

We would also like to thank the staff at the National Drug & Alcohol Research Centre for the use of their facilities over an extended period, and Dr Richard Mattick in particular for his expert assistance on matters relating to alcohol dosing.

Dr Jim Lemon at Bitwrit Software was responsible for computerising the PIPS test battery used in the study, and we are grateful for his expertise and ongoing advice and support.

We are also grateful for the assistance of Suzanne Briscoe, Jerry Frenkel, Slava Ingman, Penny Irvine, Andrew Lang, and Celia Ng.

EXECUTIVE SUMMARY

The aim of this study was to develop a range of measures that could be used in evaluating the effectiveness of different work-rest schedules for managing fatigue. To be useful for this purpose, tests need to have demonstrated sensitivity to fatigue and be able to be applied in working environments. In addition, to be useful, tests are needed that provide results that can be interpreted in terms of the person's relative capacity compared to a recognised standard for safety.

A range of eight tests were selected from the research literature based on evidence that they are affected by fatigue. The tests included Simple Reaction Time, Unstable Tracking, a Dual Task, the Mackworth Clock Vigilance Test, Symbol Digit Coding, Visual Search, Sequential Spatial Memory and Logical Reasoning. To investigate the effects of fatigue on these tests, subjects were kept awake for 28 hours and tested at regular intervals. As a comparison, the same subjects were also administered varying doses of alcohol up to 0.1% blood alcohol concentration (BAC) and tested after each dose using the same tests as for the sleep deprivation condition. An alcohol comparison was used as there are legal and community-accepted standards for alcohol use when driving which are based on the effects of alcohol on performance. Performance on these tests following levels of alcohol that are known to be too high for safe performance were compared with test performance after increasing amounts of sleep deprivation. It should then be possible to match the effects of sleep deprivation on performance with the effects of alcohol as they can be directly compared on the same tests.

The study involved 20 long-haul truck drivers (Drivers) and 19 people who were not employed as long haul drivers (Controls). Long haul drivers were compared to people who are not long haul drivers as there is evidence from previous research that long distance drivers may have, or may develop, a higher ability to overcome performance effects of fatigue.

Drivers and controls first completed a three hour practice session in the afternoon of the first day. On the second day they participated in either the alcohol or sleep deprivation condition. For the alcohol condition, subjects were tested every hour from 8am to 12pm . The first test was a baseline test and the next four tests occurred around 30 minutes after subjects were administered doses of alcohol aimed to produce increments of 0.025% BAC in time for each performance test session. The aim was to do performance tests at no alcohol, 0.025% BAC, 0.05% BAC, 0.075% BAC and 0.1% BAC. For the sleep deprivation condition, testing occurred every hour from 8am for the next four hours, then every other hour for the next 23 hours with the last test at 9am the following morning.

The results showed the following:

1. Performance effects of sleep deprivation were seen for most tests, in particular, those tests involving passive attention, such as the Mackworth Clock Vigilance Test, or a relatively difficult discrimination, such as the Simple Reaction Time Test.

2. Performance effects were seen due to alcohol for all tests with the strongest effects for Simple Reaction Time and the Mackworth Clock Vigilance Task. Unstable Tracking, the Dual Task, Symbol Digit Coding, and Sequential Spatial Memory also showed reliable effects.

3. The effects of sleep deprivation and alcohol were not the same for all tests. Sleep deprivation had no effect on performance on any measure of either the Visual Search test or the Logical Reasoning test whereas alcohol reduced performance accuracy markedly on both tests but did not affect the speed measures.

4. Some tests showed evidence of a circadian rhythm effect on performance. In particular, Simple Reaction Time, the Dual Task, the Mackworth Clock Vigilance Task, and the Symbol Digit Coding Task showed performance trends consistent with the expected drop in performance in the early hours of the morning and in the early afternoon. With the exception of the number of correct responses on the Mackworth Clock Vigilance Task, these circadian effects were only ever apparent on measures of response speed, and not response accuracy. The remaining tests showed no evidence of being affected by circadian influences.

5. Drivers showed different patterns of performance compared to controls. Drivers were slower but more accurate than controls in performance of the Symbol Digit test, suggesting that drivers took a more conservative approach to performance of this test.

6. Using the legal limits for alcohol as a standard, performance deficits equivalent to 0.05% BAC were seen after 17 to 19 hours of sleep deprivation on most tests corresponding to between around 10.30pm and just after midnight in this study. Levels equivalent to 0.1% BAC were predicted to occur after 18 to 20 hours awake which in this study occurred between 11.30pm and 1.30am.

7. For many people, 17 to 19 hours without sleep is the upper limit of their waking period. Where safety-sensitive activities are being carried out at this time, or where wakefulness continues beyond this period, people are likely to be at increased risk.

In conclusion, this study has demonstrated which tests are most sensitive to sleep deprivation and fatigue. The study has also provided a basis for making judgements about the extent of performance impairment on these tests that is likely to compromise performance capacity and, as a consequence, to compromise safety. Further research is needed to determine how these changes in performance capacity are related to crash risk. Nevertheless, based on the previous research on increased crash risk with increasing alcohol consumption over 0.05%BAC, the findings of this study suggest that performance impairments at the level of produced by 0.05%BAC or 0.1%BAC but due to sleep deprivation instead of alcohol may well have a similar effect on crash risk. As a result, this study has therefore established a set of tests that can be used in evaluations of alternative compliance schedules for managing fatigue .

INTRODUCTION

Fatigue is increasingly being recognised as an important cause of accidents. A consensus report by a number of sleep researchers concluded that sleep loss and circadian influences are determinants of performance-related incidents and accidents and are likely to compromise public safety (Mitler, Carskadon, Czeisler, Dement, Dinges & Graeber, 1988). Furthermore, analysis of the cost of sleep-related accidents in the USA estimated that fatigue was a factor in between 41.6% and 54% of motor vehicle accidents, for example, and cost between $29.2 and $37.9 billion in the United States alone (Leger, 1994).

A recent meta-analysis of the research on the effects of sleep deprivation on performance (Pilcher & Huffcutt, 1996) concluded that sleep deprivation, particularly partial sleep deprivation, has a substantial effect on mood and cognitive and motor functioning. Performance measures have often been used in fatigue research to estimate the effects of such situations as prolonged periods of work and irregular hours of work on performance (Folkard & Monk, 1985) and many studies have demonstrated that performance deteriorates under conditions of sleep deprivation. Yet these results have not led to widespread action to reduce the effect of fatigue on performance.

One of the major reasons for this inaction is the difficulties in interpreting the implications of effects of fatigue or sleep deprivation. Many tests have shown effects of fatigue but the extent to which these effects might be reflected in impairment of activities like driving is usually not known. The question of 'how tired do you have to be before your driving performance might be appreciably affected?' has not been addressed. Demonstrating statistically significant effects of a particular agent on performance only tells us that the agent changes performance. It is not sufficient however to help understand the importance of that change. Is the change sufficient to jeopardise safe performance for example? In the area of fatigue research, this problem has often been bypassed. Many of the studies have demonstrated performance effects but have not been able to translate the findings in terms of the likely effects in real-life or applied settings such as operating a vehicle or other machinery.

A recent study by Dawson and Reid (1997) attempted to address this issue. They examined the effects of an extended period of wakefulness on a hand-eye coordination test compared to the effects on the same test of doses of alcohol up to and beyond the legal limit for driving in all Australian states (0.05% BAC). The results showed that around 18 hours of wakefulness produced performance impairments in this test which were equivalent to the effects found at 0.05% BAC. Since the community has already established a legal limit for alcohol for activities like driving, alcohol is a good marker on which to standardise test measures.

The idea of using graded doses of alcohol as a marker for studying the adverse consequences of potentially harmful exposures is not new. Kennedy, Dunlap, Turnage and Fowlkes (1993) developed the concept of dose equivalency so that they could develop a quantitative definition of performance capacity. Alcohol was used as an index against which performance effects due to some other agent could be assessed.

Alcohol is a useful comparison because its harmful effects on performance are well-documented. Performance impairments due to alcohol have been demonstrated for such functions as visual and auditory simple and choice reaction time (Franks, Hensley, Hensley, Starmer & Teo, 1976; Lemon, Chesher, Fox, Greeley, & Nabke, 1993; Rundell & Williams, 1979), vigilance (Erwin, Wiener, Linnoila, & Truscott, 1978), tracking (Moskowitz & Burns, 1981) and divided attention (Landauer & Howat, 1982). Even better for the purposes of comparison, alcohol has legally recognised blood alcohol concentration (BAC) limits. In Australia, for example, the statutory BAC was set at 0.05% in all states based on epidemiological evidence (Howat, Sleet, & Smith, 1991). Using alcohol as a reference substance it should be possible to calibrate and set limits for other potentially harmful agents such as sleep deprivation.

There is an increasing need to develop more performance measures of fatigue which can be interpreted in terms of real world effects. In the area of driver fatigue, for example, the approach to managing fatigue is moving away from regulating driving hours to approaches based on greater flexibility in work and rest schedules. With this change, however, has come the need to have sensitive and valid tools for assessing fatigue in real-world settings.

The current study is part of a larger project which will evaluate a range of work-rest schedules being used in the long distance road transport industry with the overall aim of developing a set of models of work-rest schedules that are effective for managing fatigue. This part of the project will attempt to extend the work of Dawson and Reid (1997), by examining the comparative effects of fatigue and alcohol on a broader range of performance tests.

The aim of this part of the project was to identify a number of measures that have demonstrated sensitivity to fatigue and to establish a basis for interpreting the results of these measures by using the same performance tests to compare the effects of fatigue with the effects of known amounts of alcohol. Using the legal limits for alcohol as a guide for judging the importance of the effects of fatigue on performance, it will be possible to evaluate the effectiveness of fatigue management programmes for the long distance road transport industry.

METHOD

Design

The study employed a mixed design. Two separate groups of subjects participated: long-haul professional truck drivers, and a group of people employed in other occupations in the road transport industry who served as a control group. These groups were compared to investigate the possibility that drivers might be better able to forestall the effects of fatigue on performance, either as a function of practice or of some self-selection factor.

All participants were tested under two experimental conditions, an alcohol condition and a sleep deprivation condition. The order of these conditions was counterbalanced across subjects. During the sleep deprivation condition, subjects were asked to remain awake continuously for approximately 28 hours. During the alcohol condition, subjects were administered doses of alcohol calculated to raise blood alcohol in 0.025% steps. Performance was measured on an ascending BAC curve because there is evidence that the effects of alcohol on performance are most clearly demonstrated when BAC is increasing rather than when it is declining (Buysse, 1991). It was also felt that measurement across increasing BAC levels would reduce any confounding effects of "hangover" symptoms (e.g., fatigue) on performance. It should be noted, however, that some reductions in BAC were expected during the ascending BAC phase as a result of the necessary delays between alcohol doses to accommodate performance testing.

Performance was measured repeatedly across the alcohol and sleep deprivation conditions. During the alcohol condition, the first testing session served as a baseline, and subsequent sessions were alternated with the alcohol doses. Approximately 20 minutes was interpolated between alcohol dose consumption and the following test session to allow for absorption. BAC was monitored before and after each testing session.

During the sleep deprivation condition, the initial test sessions were scheduled in the same way as the alcohol sessions to ensure comparability between the conditions. Subsequent test sessions were scheduled at 2-hourly intervals, to ensure sufficient frequency to detect changes with increasing time awake.

The test measures were the speed and accuracy of subject's responses on tasks of Simple Reaction Time (RT), manual tracking, divided attention (simultaneous RT and manual tracking), sustained attention (Mackworth Clock Vigilance task), visual search, sequential spatial memory, symbol

decoding, and logical reasoning. These tasks were selected to tap many of the fundamental information processing skills demanded by the driving task, and have also been reported to be sensitive to fatigue in other research. Direct subjective ratings of fatigue were also collected at the time of each test session. Subjects made their ratings at the start and end of every test session so that the effect of testing per se on fatigue could be assessed. Background and demographic information about the participants' health and lifestyle, and recent sleep and work history were also obtained.

To minimise the effects of practice on test scores in the experimental sessions and to familiarise subjects with the experimental procedure and the computerised testing equipment, all participants initially completed a half day practice session on the performance tests. This was conducted on the day prior to the commencement of the first experimental condition.

Subjects

Twenty long-haul truck drivers (all male) were recruited from a large road freight company that had volunteered to participate in the Fatigue Management Pilot Programme. These people were designated the Driver group. Thirteen men employed in other capacities by the same company also participated and were designated the Control group. A further 6 people (4 men and 2 women) employed by the Transport Corps of the Australian Army also served as Control subjects. It should be noted that 3 subjects in the Control group were working as drivers at the time of the study, however, these people were engaged in daytime, local work, and did not work irregular hours nor travel long distances on a regular basis. Most of the Control group were currently employed in managerial, training and clerical positions (61.2%), with mechanics (11.1%) and soldiers (27.8%) forming the rest of the group. A sizable proportion of the control group had worked as professional drivers in the past (47.1%) before moving on to more administrative positions. On average, these people had ceased driving professionally approximately 5 years previously, and had spent approximately 14 years as drivers. The Driver group averaged approximately 13 years professional driving experience (Table 1).

Consistent with their more varied occupations, the Control group also tended to have more varied educational backgrounds with a larger percentage completing Years 11 and 12 at high school or going on to college or university (Table 1). Consistent with the job demands of the two groups, Control subjects tended to be frequent computer users (47.4%), whereas Drivers had little or no computing experience.

Table 1: Demographic and lifestyle comparisons

	DRIVERS	CONTROLS	TOTAL	TEST RESULT
Age (%)				
< 30 years	15.0	57.9	35.9	X
30-49 years	85.0	31.6	59.0	
≥ 50 years	0	10.5	5.1	
Marital status (%)				
Single	15.0	31.6	23.1	Fishers exact test
Married/defacto	85.0	68.4	76.9	p=0.27; no difference
Formal education (%)				
Year 10 or less	79.0	47.4	60.5	X
Years 11 or 12	5.3	26.3	15.8	
Technical college	15.8	10.5	13.2	
University or college	5.3	15.8	10.5	
Computer experience				
None	65.0	10.5	38.5	X
A little	35.0	42.1	38.5	
Frequent user	0.0	47.4	23.1	
Driving experience (yrs)				
Mean	13.3	14.0	13.5	X
SD	9.4	10.3	9.5	
Smokers				
%	30.0	36.8	33.3	
Mean number per day	23.8	19.5	21.46	t(11)=1.0,p=0.34;
SD	7.7	7.5	7.6	no difference
Ex-smokers				
%	30.0	21.1	25.6	
Mean years since quit	6.07	10.35	7.7	t(4.03)=0.9,
SD	4.4	8.8	6.4	p=0.42; no difference
Caffeine drinkers				
%	100.0	84.2	92.3	
Mean drinks per day	4.3	4.3	4.29	t(34)=0.03,
SD	1.6	2.5	2.0	p=0.98; no difference
Alcohol frequency				
Rarely	5.0	15.8	10.3	X
Weekly	45.0	36.8	41.0	
2-3 times weekly	50.0	36.8	43.6	
Daily	0.0	10.5	5.1	
Drinks per occasion				
≤ 3 drinks	65.0	42.1	53.8	$\chi^2(1)=2.06$,
≥ 4 drinks	35.0	57.9	46.2	p=0.15; no difference

Note: X denotes that tests were not conducted or are not reported because test assumptions were violated.

The Driver group was also more homogeneous with regard to age than the Control group and as a result had a slightly higher modal age. The majority of drivers (85%) were 30-49 years whereas Controls tended to be under 30 (57.9%).

On most other lifestyle and health variables, there was little difference between the groups (Tables 1 and 2). Most (76.9%) subjects were living in a stable relationship (marriage or defacto). One third (33.3%) of all subjects smoked, at an approximate rate of 21 cigarettes per day. A further quarter of the subjects (25.6%) were ex-smokers, having quit approximately 8 years before. The majority of subjects (92.3%) drank caffeinated beverages, on average 4 times a day. All subjects drank alcohol, this being a precondition of participation. Their typical consumption pattern was weekly (41.0%) or 2-3 times per week (43.6%), with approximately equal numbers of people consuming 3 drinks or less (53.8%) and 4 or more drinks (46.2%) on each occasion.

Table 2: Comparison of health and sleep problems

	DRIVERS	CONTROLS	TOTAL	TEST RESULT
Health problems (%)				
Diabetes	0.0	0.0	0	X
Asthma/hayfever	20.0	15.8	17.9	X
Disorders	0.0	0.0	0	X
Digestive disorders	15.0	0.0	7.7	X
Liver/kidney problems	0.0	5.3	2.6	X
Heart/circulatory problems	5.0	5.3	5.1	X
Headaches	0.0	5.3	2.6	X
Sleep problems (%)				
At least sometimes when asleep:				
Snore loudly	65.0	52.6	59.0	$\chi^2(1)=0.62$, p=0.43; no difference
Stop breathing	10.0	5.6	7.9	X
Excessive movement	75.0	84.2	79.5	X
Difficulty getting to sleep	15.0	10.5	12.8	X
Difficulty staying asleep	10.0	15.8	12.8	X
At least sometimes in the day:				
difficulty staying awake	15.0	15.8	15.4	X
Epworth daytime sleepiness (/24)				
Mean	6.75	6.63	6.69	t(37)=0.10, p=0.92; no difference
SD	4.25	3.24	3.74	

Note: X denotes that tests were not conducted or are not reported because test assumptions were violated.

Health and sleep related variables are summarised in Table 2. There were few reports of ongoing health problems, although 17.9% of subjects suffered respiratory ailments like asthma and hayfever, and 3 people, all drivers, reported stomach or digestive problems.

Self-reported daytime sleepiness and sleep disturbance patterns were similar for Drivers and Controls. The majority of subjects reported no ongoing difficulties getting to sleep (87.2%), staying asleep (87.2%), or staying awake (84.6% rarely or never experienced this problem). Similarly, Epworth daytime sleepiness scores (Johns, 1991; 1992) averaged 6.7 (/24; SD=3.7) which is similar to levels reported for medical students (mean 7.6; Johns, 1992) and hospital day workers (mean 5.9; Johns, 1991) but substantially lower than levels found among people with obstructive sleep apnea (mean 14.3; Johns, 1992). Nor was there any other indication that any subjects might have been suffering from sleep apnea. (In accordance with Haraldsson, Carenfelt & Tingvall (1992), apnea risk was defined as the co- occurrence, at least sometimes, of loud snoring, excessive movement and cessation of breathing while asleep, difficulty maintaining sleep and difficulty staying awake.)

Materials and measures

i. Alcohol manipulation

To calculate appropriate alcohol doses, each subject was weighed, fully clothed, on Propert 150kg analogue scales. All weights were adjusted downwards by a standard 2kg to account for clothing. Skinfold calipers were used to record tricep skinfold at the standard site described by Garrow (1993). Two such recordings were taken and averaged.

Weight, tricep skinfold, age and sex were used to determine an estimate of body density and then body fat percentage according to the formulae published by Durnin and Womersley (1974). This percent body fat was then compared to the average ranges published in Cooper (1977). If a subject's body fat percentage fell outside the average range, the subject's weight (for alcohol dose estimation) was adjusted by the percentage difference. Subjects whose percentage body fat was greater than the average range had their dose weight reduced, whereas subjects who were leaner than average had their dose weight increased.

On the basis of dose and time-course studies of BAC following oral doses of alcohol (e.g., Fraser, Rosalki, Gamble & Pounder, 1995), a standard dose regime comprising hourly 0.45g/kg doses was predicted to produce hourly 0.025% BAC increments. However, it was decided to use a conservative (0.35g/kg) dose for the initial drink, so that the appropriateness of the calculated drink volumes could be assessed. The final doses were also reduced to 0.35g/kg on a case by case basis if a subject's BAC appeared to be increasing more steeply than predicted or desirable. The actual drink volumes were calculated on the basis of the desired dose (g/kg), the subject's adjusted dose weight, the specific

gravity of alcohol (0.79) and the percentage of alcohol present in the subjects beverage of choice. Individual drink volumes ranged from 61ml to 190ml.

Subjects selected a commercially available alcoholic spirit for consumption during the experiment. One subject was unable to drink spirits and beer was supplied as an alternative at drink volumes of 669-860ml. The remaining subjects drank either vodka, rum, scotch, or bourbon. Subjects were provided with mixers as requested – typically cola or orange juice.

To reduce the likelihood of blood alcohol peaking very sharply after each dose, subjects were provided with snacks to eat (cheese, crackers, potato chips and/or fruit) approximately 20 minutes after consuming each drink.

BAC was measured using a Drager Alcotest 7110 breathalyser.

ii. Performance testing

Eight psychomotor and cognitive tests were selected from the Performance and Information Processing Systems (PIPS) Test Battery. The tests were computerised. Subjects responded via a devoted keypad (Genovation Micropad 622) or via a standard serial mouse. Two simple "masks" were constructed to fit over the keypads to prevent subjects from accidentally hitting irrelevant keys. The masks were easily and quickly changed by the subject, according to the instructions given at the start of each new task.

The individual performance tests tapped a range of cognitive and psychomotor skills and abilities and were chosen on the basis that they reflected some elementary process in the long-distance driving task and had been reported in the literature to be sensitive to sleep deprivation and/or alcohol effects. The following sections present a detailed outline of the tests employed.

Simple Reaction Time (RT): This was a simple visual-motor response speed test. Subjects were presented with a yellow circle moving in an irregular, counterclockwise path around the computer screen. The subject's task was to press a key on the keypad as quickly as possible whenever the circle changed colour from yellow to red. Responses were made with the non-preferred hand, to make them comparable with the later Dual Task. The time taken for subjects to respond to the colour change and the number of missed colour changes were both measured.

The test consisted of 40 colour change trials over a 2 minute period. The minimum interstimulus interval (ISI) was 2 seconds and ISI's varied pseudo-randomly given this and the task duration constraint. The maximum response time permitted was1 second.

Unstable Tracking: This task tested hand-eye co-ordination. Subjects were again presented with a moving yellow circle on the computer screen. In this test, however, the task entailed using the computer mouse to pilot a small green dot around the screen in an attempt to keep it inside the circle. The task was adaptive because the regularity of the circle's movement decreased as the subjects became more accurate at tracking it and increased if their tracking accuracy declined. The irregularity, or "wander", of the circle's movement thus acts as a measure of the tracking skill of the subject or task difficulty level attained.

The tracking test was 3 minutes in duration, and irregularity was adjusted every 5 seconds.

Dual Task: The Dual Task combined the Unstable Tracking and Simple Reaction Time tests and tapped people's ability to attend to two tasks simultaneously. Subjects tracked the moving circle using the mouse in their preferred hand and responded to colour changes in the circle using the keypad and their non-preferred hand. The task lasted 3 minutes. Forty colour changes occurred during this time, with a minimum interstimulus interval of 5 seconds. Reaction time responses were only recorded within 4 seconds of colour change onset. In addition, irregularity of the circle's movement was adjusted every 5 seconds in light of the subject's accuracy at tracking. The speed of reaction time to colour changes, the number of missed colour changes and the irregularity of the circle movement were all measured.

Mackworth Clock Vigilance Test: This task measured the ability to sustain attention in the face of monotonous stimulation. A circle, composed of 24 equally spaced dots in the manner of a clockface, was presented on the computer screen. Each dot in turn flashed briefly, so that the flashes formed a continuous circuit around the circle. Flashes occurred at constant (millisecond) intervals. Occasionally, a dot would be omitted from the flashing sequence. The subjects' task was to respond as quickly at possible via a button press on the keypad whenever a dot was omitted. The task continued for 15 minutes during which 15 flashes were omitted. The position of the non-flashing dots varied randomly, but occurred at approximately 1 minute intervals. Reaction time to missed flashes, the number of correct responses and the number of false alarm responses were recorded.

This task was modelled on that originally reported by N.H. Mackworth (1950; cited in J.F. Mackworth, 1970).

Symbol Digit Coding: In this task, a decoding key was presented at the top of the computer screen. Ten nonsense symbols were randomly paired with the digits between 0 and 9. At the bottom of the screen a random sequence of individual symbols from the decoding key were presented one at a time. The subjects responded to each symbol by pressing the associated number on the keypad as quickly as possibly. Once subjects had responded, the next symbol was presented. The task duration was 90 seconds. The number of symbols completed in this time was recorded together with the percentage of correct responses and the average response speed.

This task was modelled on the Symbol Digit Modalities Test, itself a variant of the Digit Symbol task of the Wechsler Adult Intelligence Scale (Lezak, 1983).

Visual Search Task: This task consisted of twelve trials. On each trial, the subjects were shown a small set of target letters together with a larger 60-letter set. The subjects task was to decide, as quickly as possible, whether or not all of the targets were contained in the larger set, and to press one of two buttons on the keypad to record their answer. The target and larger sets remained on the compute screen until the subjects made their response. Six of the trials had target sets of 2 letters while the other six trials had 6 letter target sets. In half of the trials of each target set size, the entire target set was not contained in the larger set whereas in the other half of trials the entire target set was present in the larger set. On each trial, the composition of the target and large sets were random, with the constraints that no letter appeared repeatedly in one target set, and that the large set meet the requirements of containing, or not, the entire target set. The order of trials with two or six targets, and those with and without the target set were also random. The length of the task varied depending on the speed of the subjects but was estimated to take no longer than 5 minutes.

Subjects' responses were scored in terms of the speed of correct responses and the number of correct responses.

The visual search task was modelled on the Search and Memory (SAM) or Memory and Search (MAST) task used by Folkard, Knauth, Monk and Rutenfranz (1976).

Sequential Spatial Memory: In this test, a 3 x 3 square grid was presented on the computer screen. Squares in the grid flashed one at a time in a sequence. Each flash lasted 250ms. Once the sequence was complete, the subject attempted to reproduce it from memory by moving the mouse cursor to each of the relevant squares in turn and clicking them. If the sequence was

reproduced correctly, it was then repeated with an additional square added to the end. The sequence continued to grow in this way until the subject was unable to reproduce it correctly, at which time the trial terminated and a new sequence began. Three such trials were presented to subjects at each test session. The test was estimated to take no more than 3 minutes.

The sequences of squares were random with the constraint that no square could flash twice without another square intervening. The length of the longest correct sequence on each trial, the position in each sequence at which the error occurred, and the time taken to reproduce the longest correct sequence were all measured. Only the direct measure of memory capacity, the length of longest correct sequence, was analysed.

Logical Reasoning: This test was based on Baddeley's (1968) grammatical reasoning task, and required subjects to make decisions, as quickly as possible, about whether or not a statement applied to a pair of letters (e.g., the statement 'B follows A' does not apply to the letter pair 'BA'). Thirty two statements were presented individually on the computer screen and a pair of letters appeared beneath each statement. Half of the statements contained the verb 'precedes' and half the verb 'follows'. Four forms of each verb were used equally often in the statements: follows/precedes, does not follow/precede, is followed/preceded by, is not followed/preceded by. The order of the letter pair and the order of the letters in the statement were each reversed for half of the statements. Half of the statements were false. Each statement remained on the screen for up to 10 seconds or until the subject made a response. The maximum task duration was therefore approximately 4 minutes.

Subjects responded by holding down a 'home' button on the keypad until they were ready to indicate their true/false decision about each statement. They then released the 'home' button and pressed one of two additional buttons designated 'true' or 'false'. In this way, the time taken for subjects to make their decision could be separated from the time taken to make the response. The number of correct responses, correct reaction times, and missed responses were recorded.

Subjective Fatigue Rating Scales: Three visual analogue scales (VAS) were presented to subjects on the computer screen at the beginning and end of each testing session. The three scales focused on different aspects of the fatigue experience and were anchored at the ends by the terms 'fresh – tired', 'clear-headed – muzzy-headed', and 'very alert – very drowsy'. Subjects used the mouse to position a cursor at some point between the anchors to reflect their current level of fatigue. The computer recorded cursor position at one of 20 positions along the dimension. These values were subsequently converted to percentages.

Most test sessions consisted of all eight tasks and took approximately 35 to 40 minutes to complete. However the second, third and fourth sessions in the alcohol condition contained only 5 tests, to accommodate the alcohol dosing procedure and alcohol absorption times. These sessions took 25 minutes and omitted the tasks with least face validity for driving, that is, the Logical Reasoning, Visual Search and Sequential Spatial Memory tasks. The second, third and fourth test sessions in the sleep deprivation condition were similarly reduced.

Test order was controlled in the following way. The eight (or five) tests in a session were allocated to eight (or five) different orders via a latin square procedure. A schedule of test sessions for the entire experiment was then devised for each pair of Driver and Control subjects in the following way. Random sequences of the eight- or five- test orders were constructed, with the constraint that each of the eight-test orders occurred at least twice per subject and none occurred more than three times, and each of the five-test orders occurred at least once per subjects and non occurred more than twice. In addition, a test order was not repeated unless at least two different orders intervened.

iii. Questionnaires

Information about the general health and lifestyle of the subjects was obtained in a questionnaire completed at the beginning of the study (Appendix 1). Participants were asked to report some basic demographic details such as age, level of education, current occupation, and martial status; as well as health-related lifestyle factors such as smoking and alcohol drinking habits. The questionnaire also obtained details about the subjects' sleep patterns and recent sleep history, and included the Epworth Sleepiness Scale (Johns, 1991; 1992). Information on subjects' work/rest schedule in the week prior to the study was also obtained. They were asked to report on day and night hours worked in the last week, details of their last shift, and the length and quality of their last rest period.

At the start of each experimental condition, subjects also completed questions on their sleep during the previous night, and their food and drug intake since waking.

iv. Other

Food, drinks and entertainments (e.g., videos, magazines, games) were also supplied to subjects during the course of the experiment, as requested.

Procedure

All testing was completed in laboratory facilities at the National Drug & Alcohol Research Centre, located at Randwick, in Sydney. The facilities included a dedicated testing room and anteroom, a lounge bar, kitchen, bathroom, and outdoor relaxation area. Groups of two to six subjects were tested over four day periods. At 14:00 on the day prior to commencement of their experimental conditions, subjects attended a half day practice session designed to familiarise them with the study and the performance tests. Upon their arrival at the Centre, participants were informed about the details of the study before formally consenting to participate (Appendix 2). They were then asked to complete the demographic questionnaire. Weight and tricep skinfold were subsequently measured and a brief introductory test session was then presented where each test was explained and any questions answered. Once subjects felt comfortable with the tests, they proceeded to complete three test sessions of regular (35-40 min.) duration. At the end of the practice session, participants were reminded of the schedule for the following day and were asked to try to refrain from consuming caffeinated drinks on the morning of the sleep deprivation condition, and to have a light breakfast on the morning of the alcohol condition. Subjects were also encouraged to get adequate sleep the night before each condition and to refrain from excessive alcohol consumption on these evenings. They were then free to leave.

The following morning, approximately two hours after they awoke (usually around 8:00am), subjects began either their sleep deprivation or alcohol condition. Upon arrival at the Centre, they completed brief questionnaire items concerning their sleep, eating and drug-taking behaviour since the previous day, and then began the testing regime.

In the alcohol condition, subjects first completed a baseline performance test and a baseline BAC test. Four doses of alcohol were then administered at hourly intervals. The alcohol doses were designed to achieve 0.025, 0.05, 0.075, and 0.1% BAC. Where possible, subjects chose their preferred alcoholic spirit and mixer. Approximately twenty minutes after each alcohol dose subjects were given something to eat (eg cheese & biscuits) to ensure that the alcohol was not absorbed too quickly. Approximately 30 minutes after each alcohol dose, each subject's BAC was measured, a test session was administered and a post-test BAC measurement was recorded.

Once all testing had been completed BAC readings were taken hourly. Subjects were requested to remain at the centre until their BAC was under 0.05% at which time they completed a waiver form (Appendix 3) and were free to leave. If subjects insisted on leaving before their BAC was below 0.05,

and provided that safe transport could be arranged, they were permitted to leave after signing an early release waiver (Appendix 4).

Under the sleep deprivation condition an identical testing schedule was followed for the first five test sessions, with tests every hour from baseline. From then on subjects completed a regular (35-40 min.) test every two hours, with the last test session commencing approximately 27 hours (usually 9:00am)after their waking time. A total of 15 performance test sessions were completed under the sleep deprivation condition, after which the subjects retired to sleep.

Meals were provided between test sessions five and six, eight and nine, and thirteen and fourteen, and drinks and snacks were freely available at other times. During the sleep deprivation condition however, caffeinated drinks were not made readily available.

During the intervals between testing sessions and during the BAC reduction period in the alcohol condition, subjects were free to engage in a range of activities including watching TV and videos, reading, chatting, playing games, and taking walks.

Analysis

Two basic forms of analysis were conducted. First, the changes in performance were analysed across test sessions using MANOVA trend analyses to identify changes with increasing time awake and increasing BAC. The analyses also examined the effect of group membership - Driver or Control. Three performance tests, Visual Search, Logical Reasoning and Sequential Spatial Memory, were only administered on the first and last testing sessions of the alcohol condition. Consequently, trend analyses were not conducted on these data. Rather, MANOVA was used to compare performance at the first and last test sessions.

The second form of analysis involved averaging the BAC levels recorded at the start and end of each of the five test sessions to produce a single value for each test session. These average BAC values and the associated performance test measures were plotted separately against test session for each subject. Due to individual differences in absorption of alcohol, the observed BAC values were not always at the anticipated level at each test session. This meant that the time at which the exact BAC levels of 0.025%, 0.05% 0.075% and 0.1% were achieved had to be interpolated from the graph for each subject. These times were then identified on the graph of performance test measures against test session and the corresponding test scores could then be interpolated for each subject. By this method it was possible to estimate the performance test score corresponding to each level of alcohol for each

subject. These levels were then averaged across subjects to reveal change in performance with each alcohol dose.

Performance at the criterion levels of 0.05% and 0.1% BAC was then compared with performance across sleep deprivation test sessions 8 to 13 (ie: 19:00hrs to 0500hrs) for each subject. This time window was chosen for the sleep deprivation condition before the data was collected because this period was most likely to produce fatigue effects as it covered the longest periods of sleep deprivation. This decision was reinforced when the sleep deprivation and performance relationship was plotted after data collection, as this period also showed the clearest linear trend across test sessions for all measures. For this analysis, time was treated as a continuously increasing quantity across midnight, for example, 0200 became 26.0h. Over this time window, the sessions were found for each subject between which performance under the sleep deprivation conditions first became worse than the performance levels found at 0.05% and then at 0.1% BAC. Using interpolation, the time since waking associated with performance equivalent to that at the two alcohol levels were then identified for each subject. The scores for time since waking were then averaged across subjects for each performance measure.

Not all subjects contributed to the time since waking scores for each measure as not all subjects showed a deterioration in performance over this time window for all performance tests. Only data from subjects who showed a change from better than the criterion BAC levels (0.05% and 0.1%BAC) to worse than the criterion levels over the 19:00 to 05:00 window were included in the averages for each test. The number of subjects contributing to each hours of wakefulness equivalent to BAC levels therefore reflects the percentage of subjects who showed significant performance deterioration over the selected time window.

RESULTS

i. Pre-experimental variables

- Recent work history

Table 3 shows that drivers and control subjects worked equivalent numbers of hours in the 7 days preceding the study, and on their last shift. However, there was some variation in the length of the break between the last shift and the commencement of the study at 14:00 on the practice day. For most subjects (26.3%, 23.7%, and 13.2%), this lag represented 1, 2, or 3 days off respectively, consistent with a weekend break. However, 4 subjects (10.5%; 3 drivers and 1 control) were on leave in the week preceding the study, whereas the 6 army subjects (15.8%) in the control group, had been at work on the morning of the practice day. Although, the control subjects might therefore be said to have had less break time as a group than the drivers, it should be noted that many of the driver and non-army control subjects travelled some 500 km by car to the Sydney testing centre on the morning of the practice day. In this sense, then, the overwhelming majority of subjects might be seen to have been at work during the morning of the practice day.

When the distribution of work hours in the preceding week was examined, drivers worked significantly more hours at night (between 6pm and 6am) than the control subjects.

Table 3: Comparison of Driver and Control groups on pre-experimental variables

Variable	**Group**						**Median test result**
	Driver			**Control**			
IN LAST 7 DAYS:	**Mean**	***SD***	**Median**	**Mean**	***SD***	**Median**	
Hours worked	45.2	*23.8*	57.5	46.4	*19.6*	51.0	$\chi^2(1)=0.65$, p=0.42
Length of last shift (hrs)	11.8	*5.3*	11.5	10.2	*7.5*	8.0	$\chi^2(1)=0.47$, p=0.49
Number of night hours (6pm-6am)	19.4	*19.7*	15.0	4.7	*6.6*	2.0	$\chi^2(1)=6.76$, p=0.009
Hours since last shift	100.7	*126.9*	68.0	56.9	*86.9*	46.5	$\chi^2(1)=1.34$, p=0.25
Day of Last Shift		**%**			**%**		Total %
Today		0.0			33.3		15.8
Yesterday		5.0			11.1		7.9
2 days ago		35.0			16.7		26.3
3 days ago		25.0			22.2		23.7
4 days ago		15.0			11.1		13.2
5 days ago		5.0			0.0		2.6
> 5 days ago		15.0			5.6		10.5

- Sleep and drug use prior to each experimental condition

Table 4 summarises subjects' behaviour prior to each experimental condition. Subjects slept approximately 7 hours prior to each test session and this did not differ significantly between the 2 groups, nor between the alcohol and the sleep deprivation conditions. Waking times were typically in the range 5:30 am to 6:30 am and did not differ between subject groups. However, waking times prior to the alcohol session were significantly later than those prior to the sleep deprivation session.

Subjects' ratings of the quality of their sleep were reasonably high (approximately 60-75% on average) and did not vary between the two groups. However, the quality of sleep obtained prior to the sleep deprivation condition was judged to be poorer than that obtained prior to the alcohol condition. This difference was of the order of 12%. Rated refreshedness at waking, however, did not differ significantly between groups or experimental conditions. Mean refreshedness was of a similar magnitude to rated sleep quality.

Subjects were asked to refrain if possible from consuming caffeine during the sleep deprivation condition, including the breakfast period between waking and the first test session. Many subjects remarked that this was a difficult request, and the data reflect that many subjects felt unable or unwilling to comply. The percentage of subjects who did consume caffeine at breakfast prior to the sleep deprivation condition was 59%, compared to 76.9% before the alcohol condition. The number of drinks consumed by those who did not abstain remained constant across the test conditions among control subjects, but increased slightly prior to the sleep deprivation session among drivers.

The majority of subjects drank alcohol on the day before each experimental condition (82.1% for both conditions). Anecdotal reports indicated that these drinks generally accompanied the evening meal or had been consumed as part of the alcohol condition of the experiment.

There was no difference between the two conditions nor the two groups on the intake of meals before either test condition. All but three of the subjects breakfasted prior to their experimental sessions. These three control subjects omitted breakfast prior to their sleep deprivation session and one of these people also failed to eat before the alcohol session. The remaining subjects breakfasted approximately 46 minutes before the commencement of the sleep deprivation condition and approximately 50 minutes before the alcohol condition.

Table 4: Sleep prior to the experimental conditions

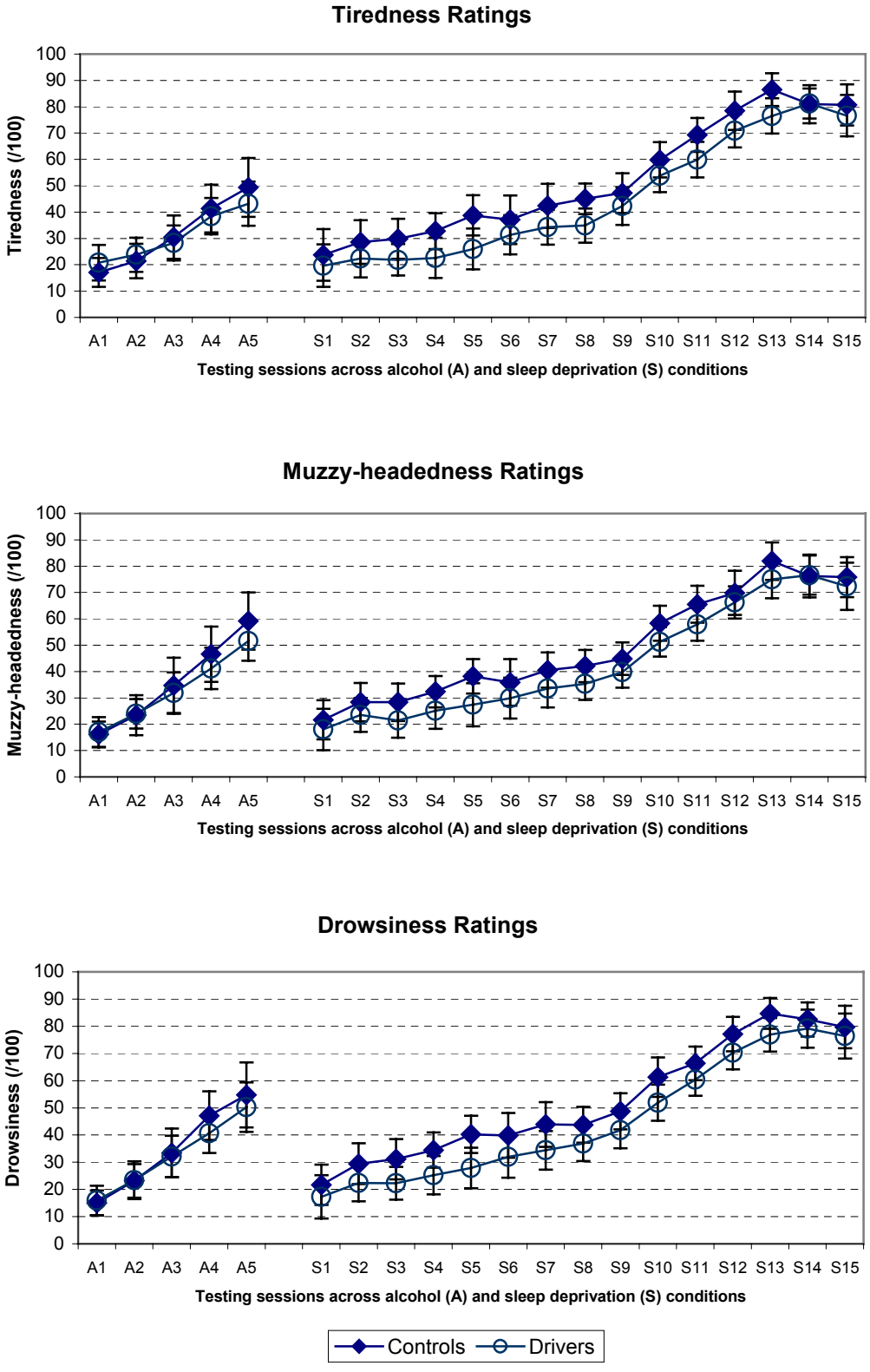
Variable	Driver Mean	Driver *SD*	Control Mean	Control SD	Group X Condition MANOVA results
Hours slept prior to:					
alcohol	7.00	*0.93*	8.11	*3.27*	Group F(1,37)=0.48, p=0.49
sleep deprivation	7.43	*1.17*	6.89	*0.64*	Condition F(1,37)=0.93, p=0.34
					Interaction F(1,37)=3.98, p=0.054
Waking time prior to:					
alcohol	6:20	*00:30*	6:07	*00:12*	Group F(1,36)=0.89, p=0.35
sleep deprivation	5:48	*00:12*	5:41	*00:09*	Condition F(1,36)=8.99, p=0.005
					Interaction F(1,36)=0.04, p=0.84
Sleep quality prior to:					
alcohol	68.15	*25.95*	75.11	*24.12*	Group F(1,37)=0.63, p=0.43
sleep deprivation	57.30	*23.55*	60.16	*26.83*	Condition F(1,37)=6.26, p=0.02
					Interaction F(1,37)=0.16, p=0.69
Waking refreshedness prior to:					
alcohol	66.35	*22.68*	79.37	*13.81*	Group F(1,37)=1.53, p=0.22
sleep deprivation	65.00	*19.97*	65.42	*25.63*	Condition F(1,37)=3.72, p=0.06
					Interaction F(1,37)=2.52, p=0.12

ii. Effectiveness of Fatigue Manipulation

Changes in the subjects' assessment of their own subjective fatigue were examined across testing sessions to determine the extent of fatigue experienced and the timing and pattern of change over the period of wakefulness in the sleep deprivation condition. The pre and post test ratings for each session were averaged to yield a single rating value for that session. A potential problem for this practice was revealed by analyses of the differences between the pre and post test ratings which demonstrated that the contribution of the test sessions themselves to fatigue was not constant across the sleep deprivation period. Rather, pre/post test differences on all three rating scales showed significant x^4 and x^5 trends (all p's < 0.003) which may indicate that the test sessions were more fatiguing at circadian low points. Having acknowledged this potential problem, it should also be noted that the largest increase in fatigue ratings over a test session occurred early in the sleep deprivation period at session 3 (approximately 10:30-11:00am) and is, therefore, unlikely to reflect circadian effects. At other times, testing tended to increase fatigue ratings by some 5-15 points (/100) on average. This level of variation was considered acceptable for averaging purposes.

Averaged ratings of tiredness, muzzy-headedness and drowsiness across the sleep deprivation and alcohol condition are presented in Figure 1. Initially, the fatigue ratings given at the first and last test sessions were compared using MANOVA analysis. In the sleep deprivation condition, these sessions were selected because they allowed for a comparison of fatigue at similar times of day, but after only 2-3 or after 27-28 hours of sustained wakefulness. The effects of group and condition were also assessed in these analyses.

Figure 1: Averaged pre and post test fatigue ratings with 95% confidence intervals



Subject group had no effect on fatigue ratings. For all three ratings the interaction between first or last test session and experimental condition was significant (Tiredness $F(1,35)=41.93$, $p<0.001$; Drowsiness $F(1,35)=23.83$, $p<0.001$; Muzzy-headedness $F(1,35)=13.27$, $p=0.001$) indicating that rated fatigue was equivalent at the start of the alcohol and sleep deprivation conditions, but that, not surprisingly, fatigue had increased much more by the end of the sleep deprivation condition than by the end of the alcohol condition. These results clearly indicate substantial increases in experienced fatigue as a consequence of sustained wakefulness, with mean ratings increasing by 58%, 59%, and 55% on the tiredness, drowsiness, and muzzy-headedness scales respectively (Table 5).

Table 5: Fatigue ratings (/100) at the first and last test sessions of the sleep deprivation and alcohol conditions

	Fatigue scale					
	Tiredness		Drowsiness		Muzzy-headedness	
Test session	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***
SLEEP DEPRIVATION						
First	21.62	*19.88*	19.66	*17.24*	20.07	*17.06*
Last (session 15)	79.32	*16.99*	78.92	*17.10*	74.73	*18.19*
ALCOHOL						
First	19.05	*13.80*	15.20	*11.05*	16.62	*11.77*
Last (session 5)	45.74	*22.02*	52.16	*23.63*	55.00	*20.94*

When the fatigue scale ratings obtained across all sessions in the sleep deprivation condition were subjected to MANOVA trend analysis by group, consistent results were obtained for the three different scales. Only trends at the level of X^4 or lower were examined because these were considered sufficient to capture the major circadian fluctuations in performance, and the alpha level used as the criterion of significance was adjusted to 0.0125 (0.05/4) to test these trends. Test results are presented in Table 6. On all three scales, significant increases in rated fatigue across sessions contained linear, quadratic, cubic and X^4 trends. These data suggest continuously increasing fatigue over the test sessions, which accelerates across the later sessions, and plateaus over the final two or three sessions. The X^4 trends appear to capture a minor peak in the ratings at around sessions 5 or 6 (12:30-15:00), suggestive of a post-lunch dip in alertness.

The two subject groups did not generally differ in terms of rated fatigue over the testing sessions, however, the control subjects rated themselves as consistently more drowsy ($F(1,36)=4.27$, $p=0.046$) than the drivers.

Table 6: MANOVA trend analysis results for fatigue ratings over test sessions in the sleep deprivation condition

Trend	Fatigue rating scales Tiredness	Drowsiness	Muzzy-headedness
GROUP	Not significant	F(1,36)=4.27, p=0.046	Not significant
SESSION			
Multivariate	F(14,23)=31.09, p<0.001	F(14,23)=43.58, p<0.001	F(14,23)=27.13, p<0.001
Univariate			
Linear	F(1,36)=361.92, p<0.001	F(1,36)=370.42, p<0.001	F(1,36)=279.87, p<0.001
Quadratic	F(1,36)=12.30, p=0.001	F(1,36)=10.45, p=0.003	F(1,36)=11.08, p=0.002
Cubic	F(1,36)=16.73, p<0.001	F(1,36)=8.51, p=0.006	F(1,36)=10.84, p=0.002
X^4	F(1,36)=50.38, p<0.001	F(1,36)=43.96, p<0.001	F(1,36)=33.30, p<0.001
INTERACTION	Not significant	Not significant	Not significant

iii. Effectiveness of the BAC manipulation

In the alcohol condition, the BAC values recorded at the start and end of each performance test session were averaged to give an indicative BAC for that test session. These values are summarised in Table 7 for drivers, control subjects and the entire sample.

Table 7: Averaged BAC values at each test session as a function of subject group

Test Session *	Drivers		Controls		Total sample	
	Mean	***SD***	**Mean**	***SD***	**Mean**	***SD***
2	0.012	*0.008*	0.022	*0.009*	0.017	*0.010*
3	0.046	*0.013*	0.054	*0.010*	0.050	*0.012*
4	0.085	*0.014*	0.087	*0.016*	0.086	*0.015*
5	0.118	*0.016*	0.113	*0.017*	0.115	*0.017*

* Test session 1 was a baseline session where recorded BACs = 0.000

Clearly, BACs did not increase in regular 0.025% increments as intended. Rather, the initial BAC was slightly lower than 0.025%, whereas the BACs following the 3rd and 4th alcohol doses were slightly higher than 0.075% and 0.10% respectively. Nonetheless, there was a strong increasing linear trend in BAC over test sessions (Multivariate $F(3,34) = 429.18$, $p<0.001$; Univariate linear trend $F(1,36) = 1215.90$, $p<0.001$). Trend analysis also revealed the presence of a cubic function in the data ($F(1,36) = 7.67$, $p=0.009$), reflecting somewhat steeper increases in BAC following the middle alcohol doses. This pattern is in accord with the conservative initial alcohol dose given, and the experimental practice

of reducing the final doses if a subject's BAC was climbing too rapidly. Subject group had no significant effect on BAC.

iv. Relationship of performance to fatigue and BAC

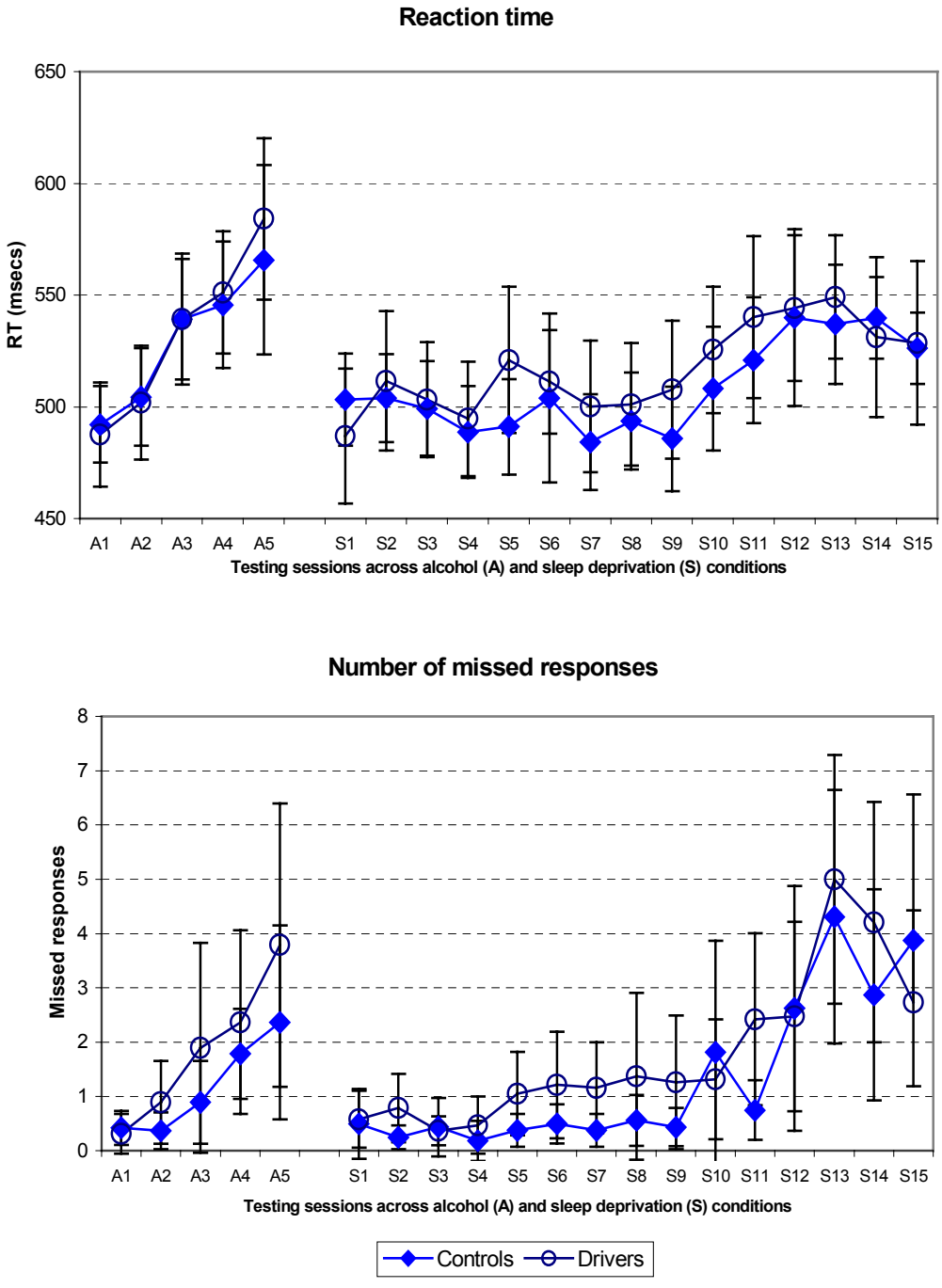
Performance scores on the various tests were examined as raw scores. Performance data were subjected first to MANOVA trend analyses to identify changes over test sessions with increasing time awake and increasing BAC. Because subjective fatigue varied systematically with test sessions it was assumed that test session was a valid index of fatigue. The analyses also examined the effect of subject group. Only those effects with significant overall multivariate Fs were examined further for univariate trends. In line with the approach taken for the fatigue ratings, only univariate effects reflecting linear, quadratic, cubic or X^4 trends were tested on the sleep deprivation data and a family-wise alpha of 0.0125 (0.05/4) was again used as the criterion of significance. For the alcohol condition, and in view of the cubic trend apparent in the BAC data over test sessions, univariate linear, quadratic and cubic trends were tested using an alpha of 0.017 (0.05/3) as the criterion for significance. For those tests which were only administered at the start and end of the alcohol condition, a simple Manova analysis of these scores was conducted, using an alpha of 0.05 to determine significance.

- Simple Reaction Time

Two measures were derived from this task: reaction time (RT) and the number of missed responses.

In the sleep deprivation condition, mean RT showed a significant overall multivariate effect of test session ($F(14,20)=6.37$, $p<0.001$), which univariate tests revealed was due to a linear slowing of responses over the course of the sleep deprivation sessions ($F(1,33)=47.60$, $p<0.001$), together with significant quadratic ($F(1,33)=12.03$,$p=0.001$), cubic ($F(1,33)=8.00$,$p=0.008$), and X^4 ($F(1,33)=21.75$, $p<0.001$) trends. There was no effect of subject group per se, and the overall multivariate test for the interaction of group and test session were not significant. Figure 2 shows that responses slowed over sessions, with this
slowing becoming increasingly rapid after session 9 (approximately 21:00 or after 15 hours awake). The final 3-4 sessions witnessed a plateau in RT, consistent with the cubic trend, and a daytime RT peak at sessions 5-6 (12:30 – 15:00) accounts for the observed X^4 trend.

Figure 2: Simple Reaction Time measures with 95% confidence intervals



In the alcohol condition, analysis revealed a significant multivariate effect of test session on mean RT ($F(4,33)=17.95$, $p<0.001$). Only the linear trend was significant ($F(1,36)=71.11$, $p<0.001$), confirming a regular slowing of RT with additional alcohol doses. Neither group nor the interaction between group and test session were significant effects.

The number of missed responses (Figure 2) showed a similar, but simpler, pattern of results to the mean RT. In the sleep deprivation condition, the multivariate effect of test session was significant ($F(14,20)=3.68$, $p<0.004$) but only the linear univariate trend and the quadratic univariate trend reached significance (respectively $F(1,33)=34.21$, $p<0.001$; $F(1,33)=17.70$, $p<0.001$). Similarly in the alcohol condition, the linear trend was significant ($F(1,36)=15.33$, $p<0.001$; multivariate $F(4,33)=4.49$, $p=0.005$). In both cases, accuracy decreased as test sessions proceeded. Subject group and the interaction between group and test session did not produce significant effects in either experimental condition.

- Unstable Tracking

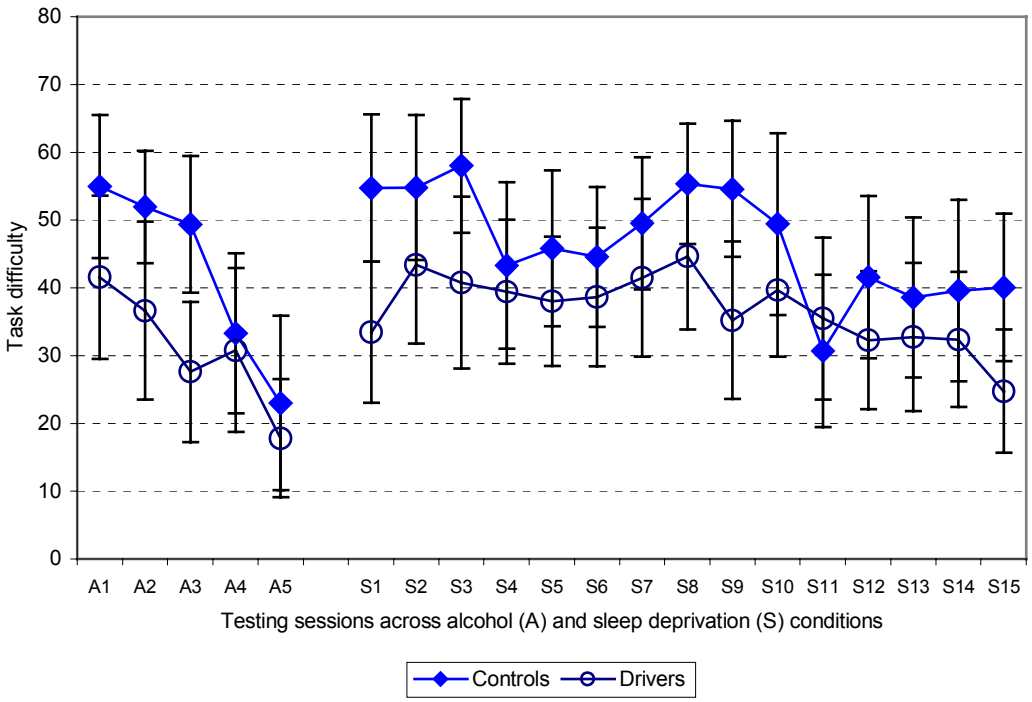
The average level of task difficulty ('wander') that subjects were able to maintain over 5 second epochs was the only measure extracted from this task, and in both the sleep deprivation and alcohol conditions, test session was the only significant factor (sleep deprivation multivariate $F(14,22)=3.72$, $p=0.003$; alcohol multivariate $F(4,33)=14.14$, $p<0.001$). In the sleep deprivation condition, level of task difficulty showed a linear decrease over sessions ($F(1,35)=22.92$, $p<0.001$), whereas in the alcohol condition both the linear ($F(1,36)=42.44$, $p<0.001$) and quadratic ($F(1,36)=8.31$, $p=0.007$) trends reached significance. This result indicates that the task difficulty level achieved by subjects decreased with additional alcohol doses and that this decline accelerated over later sessions (Figure 3).

- Dual Task

The data for this task are plotted in Figure 4.

The task difficulty level attained in the tracking component of the Dual Task during the sleep deprivation condition showed a significant multivariate effect of test session ($F(14,22)=4.38$, $p=0.001$), comprised of a linear decrease in difficulty with increasing sleep deprivation ($F(1,35)=40.68$, $p<0.001$) and a quadratic acceleration of this decline over the later test sessions ($F(1,35)=16.47$,$p<0.001$). The same trends were apparent across the alcohol sessions

Figure 3: Unstable Tracking performance with 95% confidence intervals

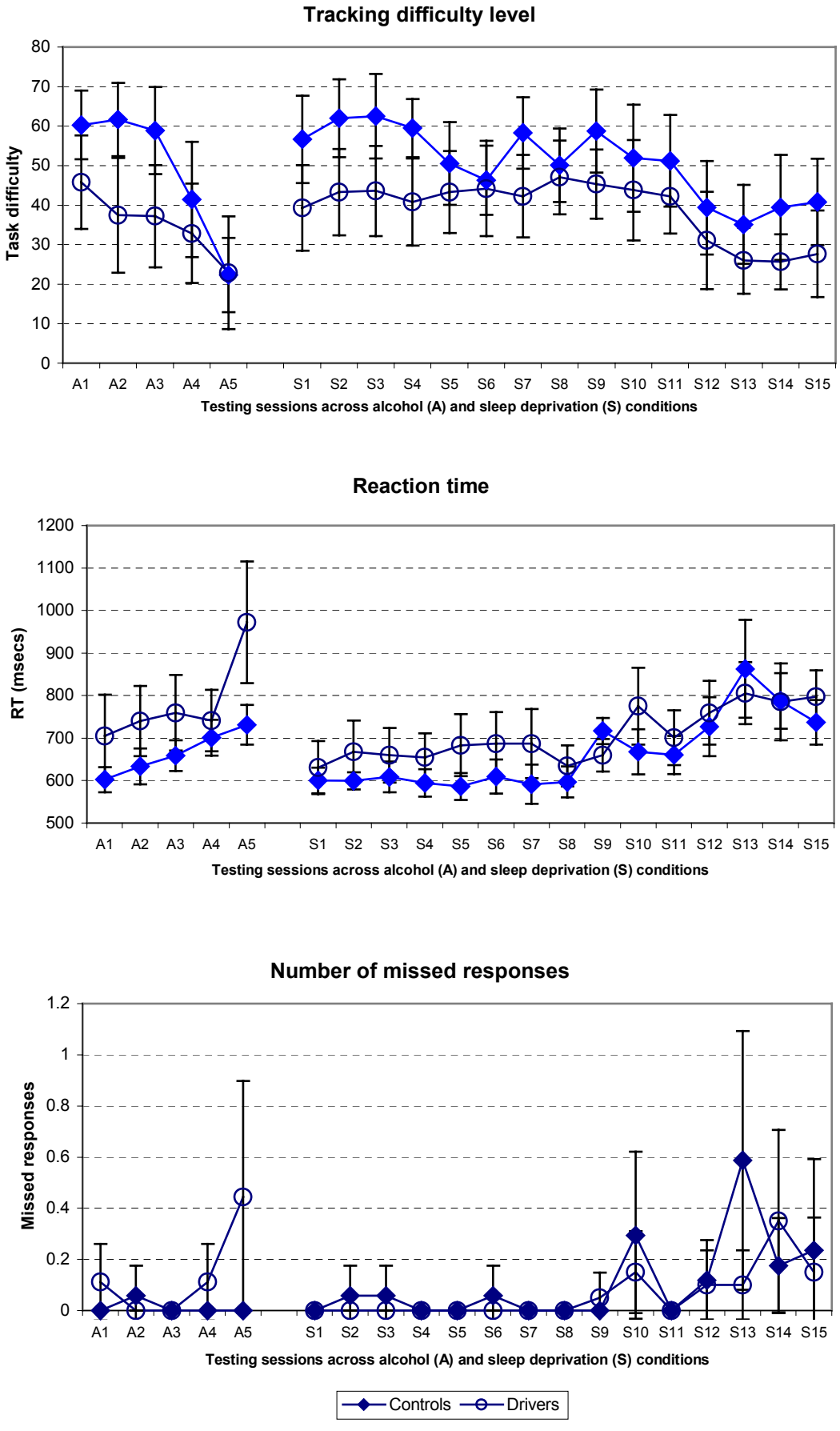


(multivariate $F(4,30)=8.23$, $p<0.001$; Linear trend $F(1,33)=30.99$, $p<0.001$; Quadratic trend $F(1,33)=6.92$, $p=0.013$).

In contrast to the Unstable Tracking task, where the two subject groups did not differ, control subjects doing the tracking component of the Dual Task attained significantly higher wander levels than the driver subjects under both experimental conditions (Sleep deprivation condition $F(1,35)=5.12$, $p=0.03$; Alcohol condition $F(1,33)=4.26$, $p=0.047$).

It should be noted that this group difference does not appear to be due to pre-existing differences in the mouse (response) skills of the two groups. When MANOVA trend analyses of both the Unstable Tracking and the Dual Task tracking data were conducted using computing experience rather than subject group as the between subjects factor there was no effect of computing experience on wander in the alcohol condition. This is at odds with the group effect reported above for the alcohol condition. Further, in the sleep deprivation condition, subjects with no prior computing experience (mostly driver subjects) and those who were frequent computer users (all control subjects) did not differ in the wander levels attained (overall $F(2,34)=3.37$, $p=0.046$; $t(20)=1.73$, $p=0.09$).

Figure 4: Dual Task measures with 95% confidence intervals



Mean RT on the Dual Task during the sleep deprivation condition showed no effects of group, but did show the typical effect of test session ($F(12,22)=8.76$, $p<0.001$). Univariate linear ($F(1,35)=64.68$, $p<0.001$), quadratic ($F(1,35)=27.88$, $p<0.001$), and X^4 ($F(1,35)=23.38$, $p<0.001$) trends were significant, but unlike the Simple Reaction Time task, the cubic effect was not. These patterns indicate a slowing of RT over sessions, but particularly after session 9 (21:00, or after 15 hours awake).

In the alcohol condition, mean RT slowed linearly across the test sessions (multivariate $F(4,30)=6.89$, $p<0.001$; linear trend $F(1,33)=25.89$, $p<0.001$) and the control group were somewhat faster to respond than the driver group ($F(1,33)=7.97$, $p=0.008$).

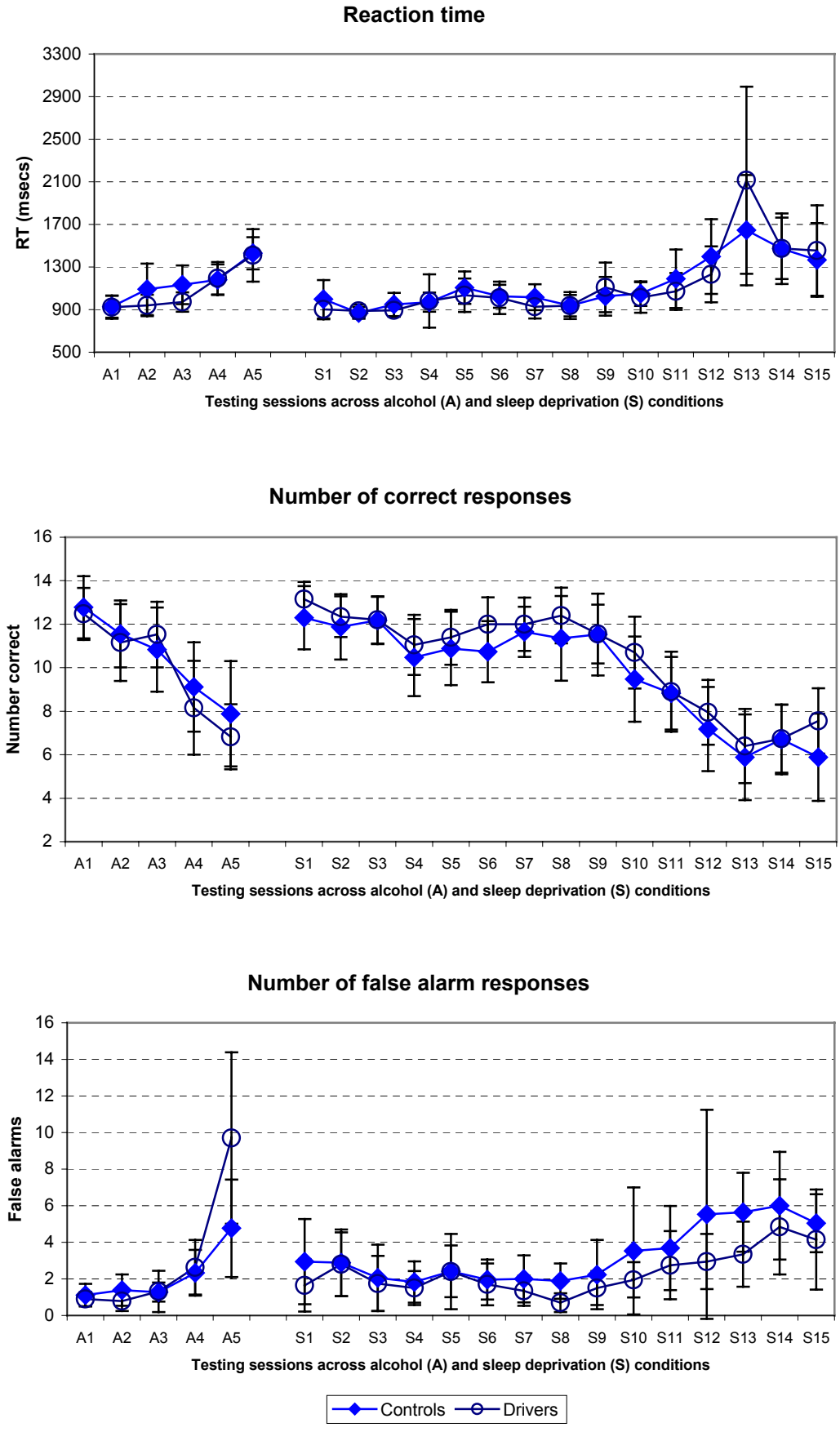
The number of missed responses in the alcohol condition was also lower among the control subjects than the driver subjects ($F(1,33)=5.63$, $p=0.024$), indicating that neither group was trading off speed for accuracy or vice versa. In the sleep deprivation condition, the groups performed equivalently, with both showing a univariate linear increase in missed responses across the test sessions ($F(1,35)=11.33$, $p=0.002$). There were no significant trends in the number of missed responses across test sessions in the alcohol condition.

- Mackworth Clock Vigilance Test

Mean RT to the infrequent stimuli on this task showed a linear slowing across sleep deprivation test sessions (multivariate $F(14,16)=5.23$, $p=0.001$; univariate linear $F(1,29)=50.85$, $p<0.001$). There was also evidence for accelerated slowing of RT in the later test sessions, with a significant quadratic trend ($F(1,29)=10.22$, $p=0.003$). The significant X^4 trend ($F(1,29)=7.17$, $p=0.012$) suggests that a period of response slowing also occurred earlier in the sleep deprivation sessions. The data (Figure 5) suggest a peak at approximately midday. In the alcohol condition, response speed decreased linearly across the test sessions (multivariate $F(4,29)=15.82$, $p<0.001$; linear univariate $F(1,32)=40.66$, $p<0.001$).

Response accuracy (the number of correct responses) showed the same pattern of trends as response speed. In the sleep deprivation condition, correct responses decreased linearly over test sessions (multivariate $F(14,22)=13.44$, $p<0.001$; univariate linear $F(1,35)=168.39$, $p<0.001$), and the decline accelerated in later sessions (univariate quadratic $F(1,35)=27.82$, $p<0.001$). A decline in accuracy spanning sessions 4 to 6 (approximately 11:30 to 15:00; Figure 5) was indicated by the significant univariate X^4 trend ($F(1,35)=31.50$, $p<0.001$). In the alcohol condition, the number of correct

Figure 5: Mackworth Clock Vigilance measures with 95% confidence intervals



responses decreased linearly (multivariate $F(4,32)=15.77$, $p<0.001$; univariate $F(1,35)=63.18$, $p<0.001$) with no other significant trends.

A second measure of response accuracy was also investigated (Figure 5). For the sleep deprivation condition, the number of false alarm responses (responses made at inappropriate times) confirmed the linear and quadratic trends observed in the RT and correct response data (multivariate $F(14,22)=2.25$, $p=0.043$; univariate linear $F(1,35)=16.30$, $p<0.001$; univariate quadratic $F(1,35)=20.94$, $P<0.001$). That is, false alarms became more frequent across test sessions, and occurred with accelerating frequency toward the end of the sleep deprivation period. However, the X^4 trend, suggestive of a daytime circadian slump, approached but did not reach significance on this measure ($F(1,35)=6.26$, $p=0.017$). In the alcohol condition, false alarms increased linearly over the test sessions (multivariate $F(4,32)=5.39$, 0.002; univariate linear $F(1,35)=21.57$, $p<0.001$) but also showed a significant quadratic trend ($F(1,35)=13.44$, $p=0.001$) indicating accelerated frequency in the later sessions.

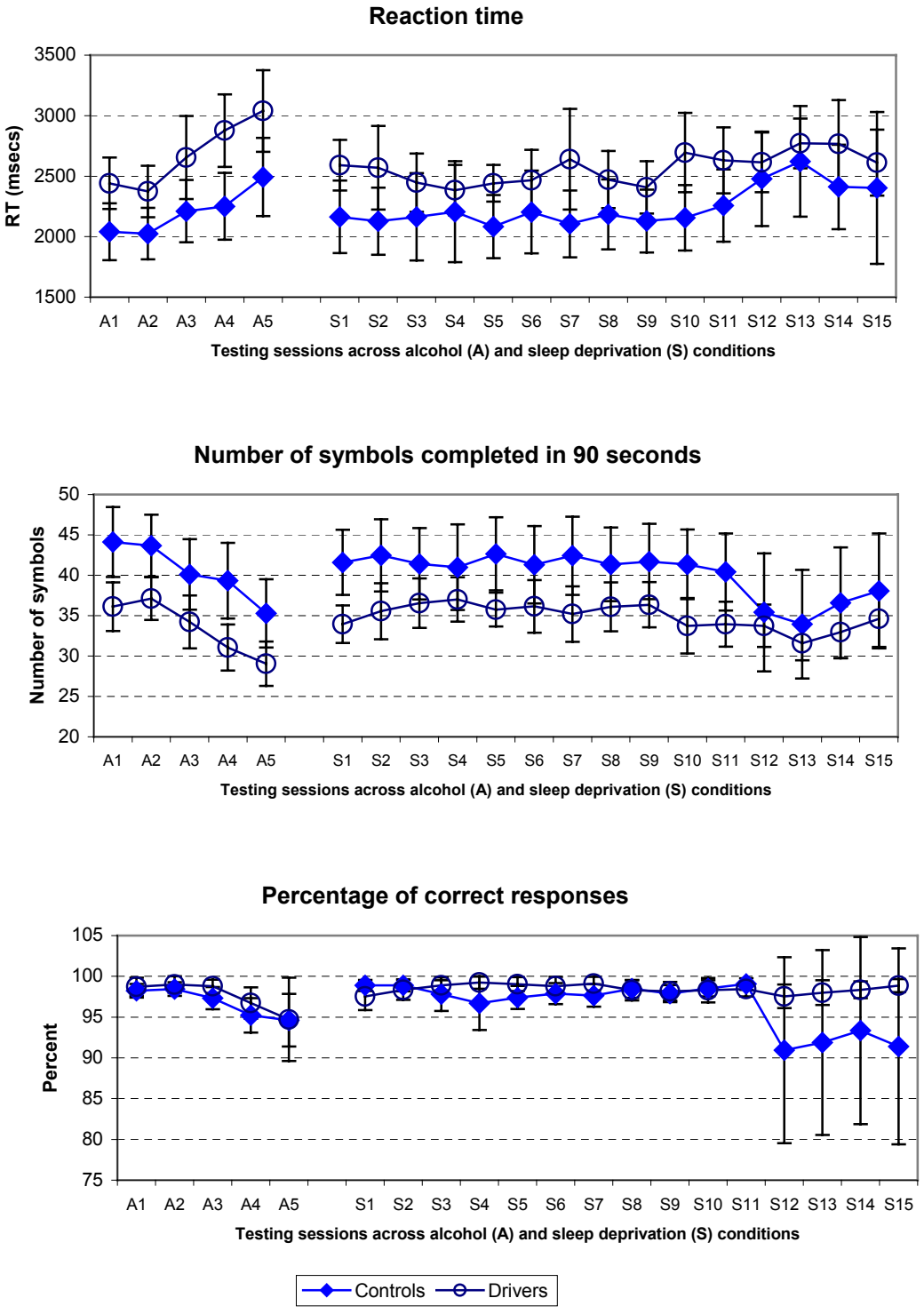
There was no difference between the two subject groups on any measure.

- Symbol Digit Coding

Mean response time per symbol on the coding task increased linearly across the testing sessions in the sleep deprivation condition (multivariate $F(14,21)=6.82$, $p<0.001$; univariate linear $F(1,34)=18.85$, $p<0.001$) and in the alcohol condition (multivariate $F(4,31)=10.62$, $p<0.001$; univariate linear $F(1,34)=33.60$, $p<0.001$). No other trends were significant. Control subjects responded more quickly than drivers in the alcohol condition ($F(1,34)=8.22$, $p=0.007$) but not in the sleep deprivation condition. See figure 6.

The alternate measure of response speed, the number of symbols presented in the 90 second task, revealed a more complex pattern of changes across the sleep deprivation condition (multivariate $F(14,22)=2.5$, $p=0.025$; figure 6), probably as a function of the lower response variability evident on this measure compared to the RT measure. As well as showing a significant linear decrease (univariate $F(1,35)=10.69$, $P=0.002$), this measure also showed a significant cubic trend (univariate $F(1,35)=9.33$, $p=0.004$) and a significant X^4 trend (univariate $F(1,35)=8.62$, $p=0.006$). The cubic and X^4 trends captured the downturn in symbol rate from test session 8 (approximately 19:00) onwards and the subsequent upturn at session 14 (approximately 7:00). Only the linear decrease in symbol numbers reached significance in the alcohol condition (multivariate $F(4,31)=22.31$, $p<0.001$;

Figure 6: Symbol Digit measures with 95% confidence intervals



univariate $F(1,34)=65.82$, $p<0.001$). In both conditions the control group completed more symbols than the driver group (sleep deprivation $F(1,35)=4.27$, $p=0.046$; alcohol condition $F(1,34)=8.76$, $p=0.006$).

In contrast to the response speed data, accuracy (the percentage of correctly decoded symbols) showed no significant change over sessions in the sleep deprivation condition (Figure 6). Accuracy in the alcohol condition, however, showed a linear decline, consistent with the response speed data for this condition (multivariate $F(4,31)=3.77$, $p=0.013$; univariate $F(1,34)=10.66$, $p=0.002$). Control and driver groups maintained similar levels of accuracy in both conditions.

- Visual Search Task

MANOVA trend analyses were only conducted on the sleep deprivation condition data for this task because only two testing sessions were given in the alcohol condition. The alcohol condition data were analysed with MANOVA comparisons of the first and last tests.

This task contrasted performance when subjects were searching for a two letter set or for a six letter set. The trend MANOVAs on the sleep condition data thus included 3 factors – group, size of search set, and test session.

There were no significant changes in correct response time across sleep deprivation test sessions. The only significant effects on this measure indicated that the control group's correct response times were faster than the driver group's ($F(1,34)=5.68$, $p=0.023$), and all subjects took longer to find the six letter sets than the two letter sets ($F(1,34)=220.11$, $p<0.001$; Figure 7). Similarly in the alcohol condition, response times were faster for the two letter sets than the six letter sets ($F(1,32)=202.93$, $p<0.001$) but no other effects were significant.

Accuracy (number correct) did not vary between the groups and there was no effect of test session (Figure 7). Only the size of the letter set significantly affected accuracy, with search being more accurate for the smaller sets ($F(1,34)=38.99$, $p<0.001$). In the alcohol condition, subjects again responded more accurately to the smaller letter sets ($F(1,33)=53.66$, $p<0.001$), but also showed greater accuracy at the first test session than at the last test session ($F(1,33)=13.86$, $p=0.001$), indicating an alcohol-related drop in accuracy.

Figure 7: Visual Search measures with 95% confidence intervals

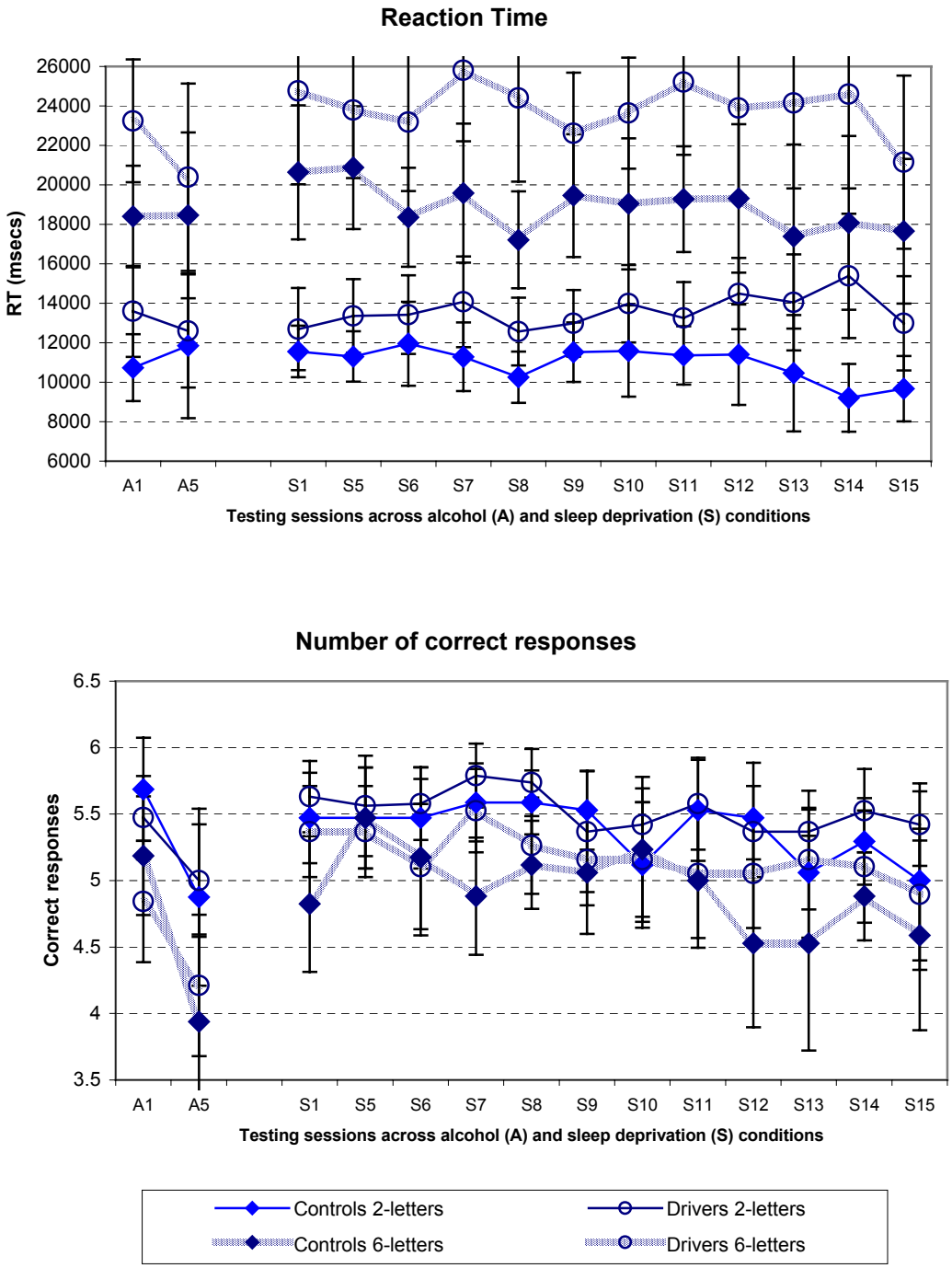
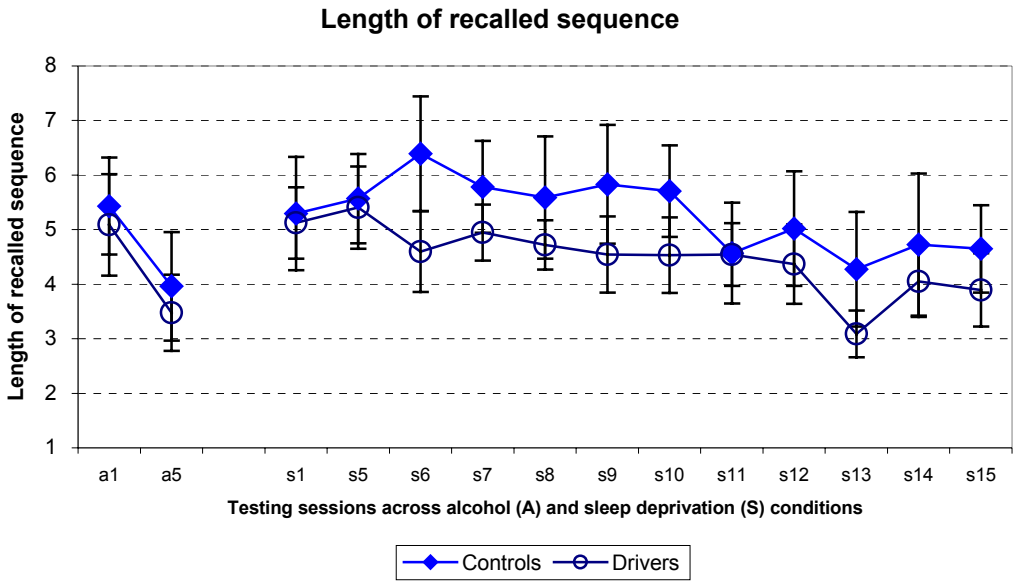


Figure 8: Sequential Spatial Memory with 95% confidence intervals



- Sequential Spatial Memory

MANOVA trend analyses were only conducted on the sleep deprivation condition data for this task because only two testing sessions were given in the alcohol condition. The alcohol condition data were analysed with MANOVA comparisons of the first and last tests.

The average number of recalled positions over the three trials in each session was calculated for use in analyses. The maximum number of positions recalled showed significant changes across sleep deprivation test sessions (multivariate $F(11,24)=4.01$, $p=0.002$). In particular, the amount recalled decreased linearly across test sessions ($F(1,34)=37.13$, $p<0.001$). In addition, the control group recalled longer sequences than the driver group (see Figure 8).

When this measure was analysed with computing experience as a factor rather than group, an identical pattern of results was found, suggesting that the group differences may have been a function of subjects' mouse skills (overall $F(2,33)=7.84$, $p=0.002$; no experience vs frequent use $t(19)=3.80$, $p<0.001$; a little vs frequent use $t(21)=3.27$, $p=0.003$).

In the alcohol condition, the number of positions recalled deteriorated between the first and last test sessions ($F(1,34)=18.76$, $p<0.001$). There was no effect of subject group.

- Logical Reasoning

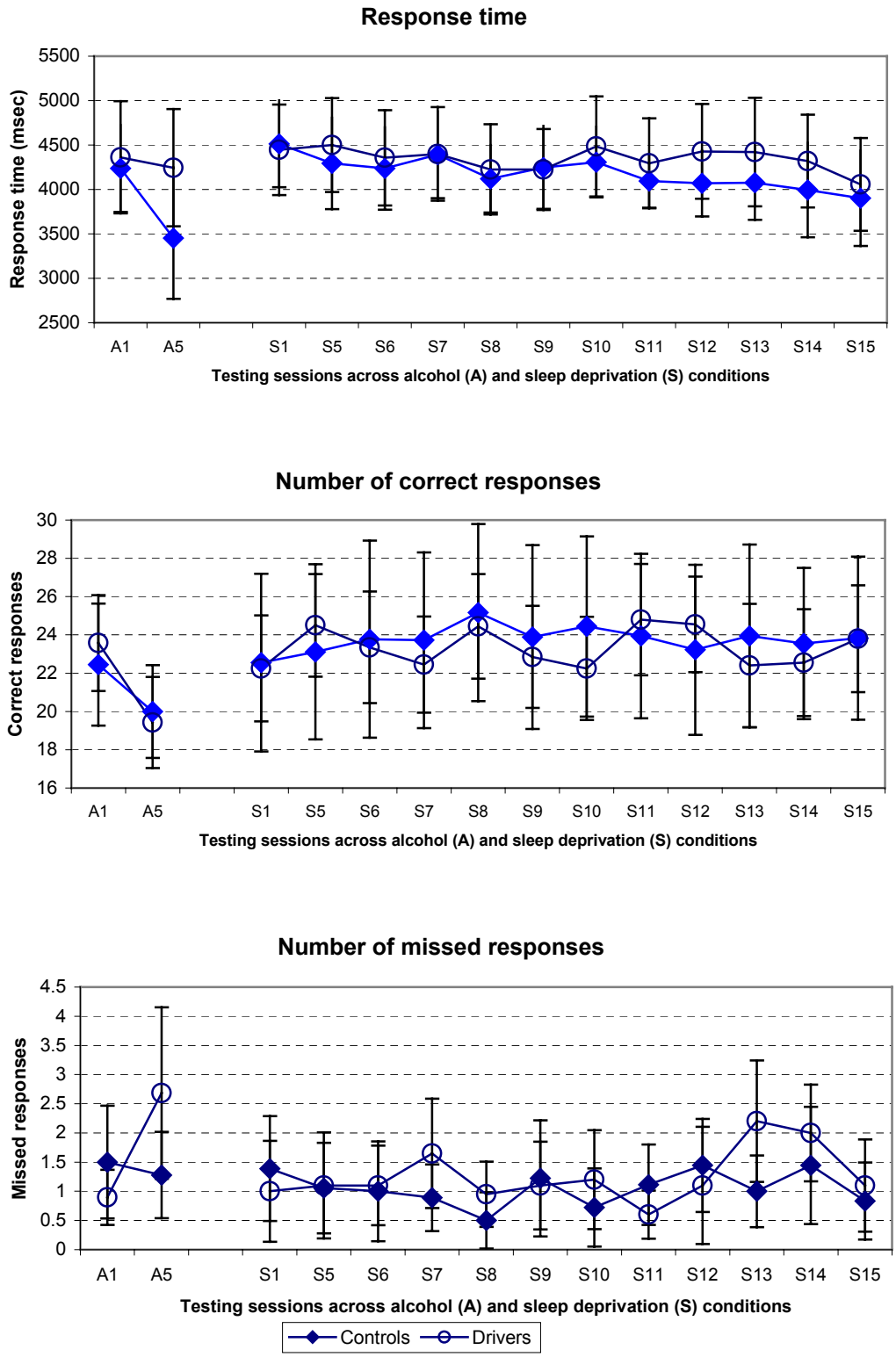
MANOVA trend analyses were only conducted on the sleep deprivation condition data for this task because only two testing sessions were given in the alcohol condition. The alcohol condition data were analysed with MANOVA comparisons of the first and last tests.

The number of correct logical decisions did not show the predicted linear trend in the sleep deprivation condition (Figure 9). The only significant effect in this condition was a quadratic trend over sessions (multivariate $F(11,26)=4.29$, $p=0.001$; univariate quadratic $F(1,36)=6.93$, $p=0.012$). There was no difference between the groups. In the alcohol condition, however, accuracy declined between the first and last test sessions ($F(1,35)=4.13$, $p=0.05$).

The number of missed responses was not affected by subject group or test sessions in the sleep deprivation condition. Similarly, correct response speed showed no effect of group, and while the multivariate effect of test session was significant ($F(11,26)=2.77$, $p=0.02$), none of the univariate trends approached significance (all p's >0.13), indicating no regular pattern of change with increasing time awake (Figure 9).

In the alcohol condition, there was evidence for a significant increase in missed responses between the first and last test sessions ($F(1,35)=4.69$, $p=0.04$), however a significant interaction between subject group and test session suggests that this drop in accuracy may only have occurred for the Driver group ($F(1,35)=4.28$, $p=0.05$). Surprisingly, correct response speed was significantly faster at the end of the alcohol test sessions than at the start ($F(1,35)=10.57$, $p=0.003$). No other effects were significant for this variable.

Figure 9: Logical Reasoning measures with 95% confidence intervals



v. Equating fatigue and BAC effects

In order to determine points of equivalent performance between particular BAC levels and periods of wakefulness, the 0.05% BAC and 0.1% BAC equivalence points were interpolated for each subject from the alcohol and performance graph for each test measure, then this value was read directly from each subject's sleep deprivation and performance graph. These alcohol equivalence points were then averaged separately across subjects for 0.05% and 0.1% BAC equivalence levels for each performance test measure.

Table 8 shows average performance across subjects at the beginning of the study before alcohol had been administered and the interpolated performance estimates for 0.05% BAC and 0.1% BAC. As expected, increasing levels of alcohol produced significant reductions in performance for most tests and measures. The results show that the extent of loss of function varies between tests although there were consistent effects within different types of measures. At 0.05% BAC for example, response speed decreased by around 8 to 15% for Simple Reaction time, Dual Task, Mackworth Vigilance and Symbol Digit tests corresponding to a slowing of around 45, 66, 136 and 182 msec respectively. Hand-eye coordination measures showed a similar overall decrement of around 10% at this level of BAC. Measures of overall test accuracy also showed significant decrements due to alcohol, especially the number of missed signals in the reaction time test which increased by 200% and the number of false alarm responses in the Mackworth test which were more than 50% higher at 0.05%BAC. The number of correct responses in the Mackworth test and length of the recalled series in the Spatial Memory task also both decreased by about 13% at 0.05%BAC. Subjective ratings of tiredness also showed a significant linear decrement of 77% by 0.05%BAC. Two tests, Grammatical Reasoning and Memory and Search tests showed very little decrease in performance at 0.05%BAC .

At 0.1%BAC performance was poorer for all measures for all tests and some measures showed more than twice the decrement as 0.05%BAC. The biggest changes were seen for the accuracy measures, the number of misses in the reaction time test which was nearly seven times poorer at 0.1%BAC than at baseline and the number of false alarms for the Mackworth Vigilance test which increased to three times the level at baseline. Hand-eye coordination in both tracking and Dual Tasks also showed a much larger decrement than other tests, with a 50% deterioration at this BAC level. Response speed for the Mackworth test also deteriorated more than might be expected to show 42% slowing compared to baseline.

Table 8: Average performance at baseline and interpolated performance estimates at BAC milestones for the alcohol condition.

		Baseline	%BAC	
TEST	**MEASURE**	**0.00**	**0.05**	**0.1**
Reaction time	***Speed (msec)***	489	534	566
	Accuracy (misses)	0.36	1.17	2.81
Dual Task	***Speed (msec)***	662	725	792
	Hand-eye coordination difficulty level	50.59	45.43	23.69
Tracking	***Hand-eye coordination difficulty level***	47.76	44.35	23.39
Mackworth	***Speed (msec)***	958	1094	1361
	Accuracy (No. targets detected)	12.64	10.91	7.76
	Accuracy(False alarms)	1.05	1.63	4.48
Symbol digit	***Speed (msec)***	2233	2415	2656
	Speed (No. targets inspected)	40.11	37.32	32.74
	Accuracy (% correct)	99.00	97.83	94.52
Grammatical reasoning[(1)]	***Speed (msec)***	4286	4135	3945
	Accuracy (No. correct)	23.19	21.89	20.05
Memory and search[(1)]	***Speed (msec) – 2 targets***	12222	12399	12500
	Speed (msec) – 6 targets	20853	20302	19555
	Accuracy (No. correct) – 2 targets	5.59	5.31	5.01
	Accuracy (No. correct) – 6 targets	5.05	4.66	4.21
Spatial memory[(1)]	***Length of recalled series***	5.34	4.65	3.73
Tiredness	***Rating***	17.84	31.63	44.83

(1) Performance estimates based on only the first and last test occasion.

In comparison, the other measures, response time for the Simple Reaction Time, Dual Task and Symbol Digit tests, the Spatial Memory test and subjective ratings of fatigue all showed around twice as much deterioration at 0.1%BAC compared to 0.05%BAC. Similarly, the higher cognitive tests, Grammatical Reasoning and Memory and Search also showed around twice the level of deterioration mainly in accuracy at this BAC, but the level of deterioration was quite small (around 10%), even at this higher level of alcohol. These results show that alcohol does not exert universal effects on all functions and the pattern of effects also differs between them.

Sleep deprivation also produced decrements in both performance and self-rated alertness. Table 9 shows the interpolated performance estimates at different times since waking. As discussed earlier, this analysis covered the period 19:00hrs to 05:00hrs and performance estimates were made for each subject corresponding to the beginning of testing on the sleep deprivation day (2.27 hours after waking), at the beginning of the analysis window (13.27 hours after waking and 14, 18 and 22 hrs after waking. The analysis showed that sleep deprivation showed effects on a similar range of tests as did alcohol. At the beginning of the analysed time window (19:00h) performance for most tests was very similar to performance during the first session of the sleep condition test day. Over the time window, however, performance decrements occurred with increasing sleep deprivation for both speed and accuracy measures of the Simple Reaction time, Dual Task, Tracking and Mackworth tests and for the length of the recalled series for the Spatial Memory test. For example, between around 7pm and 3am (corresponding to approximately 13h to 23h sleep deprivation), reaction speed decreased by 57% for the Mackworth Clock test, 9% for Simple Reaction time, 27% for Dual Task and 15% for Symbol Digit tests. Hand-eye coordination decreased by between 31% for the tracking component of the Dual Task and 26% for the Tracking task alone.

Accuracy also decreased markedly with sleep deprivation. The number of missed signals increased by more than 40% for the Mackworth test, by 187% for the Simple Reaction Time test and the number of false alarms increased by 200% for the Mackworth Clock test. The Symbol Digit test only showed decrements for the speed measures but not the accuracy measure. The Grammatical Reasoning and Memory and Search tasks showed only relatively small decreases of around 5 to 10% with increasing sleep loss for any measures.

Table 9: Interpolated performance estimates as a function of time of day (hours since waking where average waking time was 5:44) during the selected sleep condition time window. Performance during the first test session of the sleep condition is included for comparison with the start of the selected window.

TEST	MEASURE	First sleep test session 8:00 (2.27)	Start of analysed window 19:00h (13.27)	Time of day (Hours since waking) 19:44h (14.00)	23:44h (18.00)	27:44/ 3:44h (22.00)
Reaction time	***Speed (msec)***	494	495	497	521	540
	Accuracy (misses)	0.69	1.08	0.98	1.67	3.10
Dual Task	***Speed (msec)***	618	617	627	709	775
	Hand-eye coordination difficulty level	48.84	48.31	49.11	46.62	33.37
Tracking	***Hand-eye coordination difficulty level***	44.07	49.52	47.66	40.83	36.70
Mackworth	***Speed (msec)***	1020	964	1010	1225	1511
	Accuracy (No. targets detected)	12.77	12.00	11.89	9.86	7.04
	Accuracy(False alarms)	2.15	1.28	1.48	2.85	4.24
Symbol digit	***Speed (msec)***	2289	2245	2282	2430	2577
	Speed (No. targets inspected)	38.49	40.05	39.30	36.90	34.30
	Accuracy (% correct)	98.05	98.32	98.29	98.37	97.41
Grammatical reasoning	***Speed (msec)***	4413	4054	4128	4255	4182
	Accuracy (No. correct)	21.62	23.59	23.13	22.76	22.46
Memory and search	***Speed (msec) – 2 targets***	11988	11336	11620	12439	12581
	Speed (msec) – 6 targets	22423	20729	20787	21460	21101
	Accuracy (No. correct) – 2 targets	5.54	5.65	5.57	5.37	5.35
	Accuracy (No. correct) – 6 targets	5.08	5.16	5.14	5.12	4.80
Spatial memory	***Length of recalled series***	5.25	5.15	5.14	4.87	4.27
Tiredness	***Rating***	19.87	38.74	40.52	58.62	75.47

Table 10 shows the levels of sleep deprivation estimated to produce performance decrements equivalent to varying levels of alcohol for each performance measure. The results indicate that on average, 0.05%BAC equivalence occurred after being awake for around 16.91 to 18.55 hours, placing the time of the effect in this study to between 22:38 and 00:17. At 0.1% BAC, equivalence occurred between 17.74 and 19.65 hours of wakefulness which falls in the late evening to early hours of the morning, corresponding in this study to between 23:28 and 01:23.

Table 10: Equating the effects of sleep deprivation and alcohol consumption. Amount of sleep deprivation required to produce performance decrements equivalent to varying levels of alcohol (BAC).

	HOURS (DECIMAL) OF WAKEFULNESS EQUIVALENT TO BAC LEVELS					
	0.05% BAC			**0.1% BAC**		
TEST& MEASURE	**Mean**	**95% CI**	**% ***	**Mean**	**95% CI**	**% ***
Reaction time task						
Speed (ms)	18.04	17.12-18.96	76	18.71	17.56-19.86	64
Accuracy (misses)	17.31	16.51-18.11	42	17.74	16.51-18.97	45
Dual Task						
Speed (ms)	17.73	16.75-18.71	84	19.65	18.58-20.77	67
Hand-eye coordination (level of difficulty)	18.43	17.41-19.45	79	19.42	18.40-20.44	58
Tracking task						
Hand-eye coordination (level of difficulty)	18.25	17.37-19.13	74	19.01	18.91-19.97	61
Mackworth Clock Vigilance						
Speed (ms)	17.08	16.20-17.96	82	18.10	16.85-19.35	58
Accuracy (misses)	17.64	16.72-18.56	68	18.80	17.93-19.67	76
Symbol digit task						
Speed (ms)	18.55	17.43-19.67	50	18.91	17.92-19.90	48
Speed (No. symbols inspected)	18.52	17.46-19.58	57	18.64	17.65-19.63	79
Accuracy (% correct)	16.91	15.72-18.10	41	18.39	17.01-19.77	42
Spatial memory task						
Accuracy (length of recalled sequence)	18.05	17.09-19.01	86	17.88	16.92-18.84	64

* Numerator = number of subjects contributing data;
Denominator = number of subjects whose range of BAC levels incorporated 0.05% (n=37 or 38) or 0.1% (n=33).

Measures within and between tests were affected at very similar levels of sleep deprivation. The performance test that appeared to be affected first was the passive vigilance test, the Mackworth Clock test, where equivalence to 0.05%BAC occurred after just over 17 hours of wakefulness for all measures. The accuracy measure of the Symbol Digit test reached levels equivalent to 0.05% alcohol earlier than any other measure for any test, but equivalence occurred considerably later for the other Symbol Digit test measures.

The likelihood of missing targets in the Simple Reaction Time test was also affected by sleep deprivation slightly earlier compared to other tests at 0.05%BAC equivalence as it also occurred at just over 17 hours of wakefulness. The two tests that showed little change with increasing sleep loss, Grammatical Reasoning and Memory and Search tasks, were not included in this analysis as alcohol equivalences are likely to be misleading.

As can be seen from Table 10, the percentage of subjects showing poorer performance than 0.05%BAC and 0.1%BAC across the session 8 to session 13 window varied considerably between tests. More than three-quarters of subjects showed deterioration in performance to become poorer than the 0.05%BAC criterion for speed measures in the Simple Reaction Time, Dual Task and Mackworth Clock Vigilance tests and in the accuracy of the Spatial Memory Search test. In contrast, for the accuracy measures of the Simple Reaction Time and Symbol Digit tasks only around 40 percent of subjects showed performance decrements sufficient to be at or poorer than the 0.05%BAC. As might be expected, for most tests, a smaller percentage of subjects showed performance levels equivalent to 0.1% BAC. Nevertheless for most tests, more than half of the subjects showed deterioration in performance equivalent to 0.1%BAC. Fewer subjects reached 0.1% BAC for the accuracy measures of Simple Reaction Time and Symbol Digit tests just as for 0.05%BAC equivalence. For a few measures, more subjects reached 0.1%BAC equivalence than 0.05%BAC, notably, accuracy on the Mackworth Clock test, and the number of symbols inspected in the Symbol Digit test. This finding is most likely because these measures had a performance ceiling and a relatively large percentage of subjects remained at the ceiling, even at 0.05%BAC and only showed a performance decrement between the 0.05%BAC and 0.1%BAC levels.

DISCUSSION

Sleep deprivation had clear effects on mood and on test performance. As would be expected, subjective ratings of fatigue showed very clear direct effects of lack of sleep. Most tests also showed considerable deterioration in functioning with increasing sleep deprivation. The results suggest that particular types of tests were more affected by fatigue. Tests involving monotony and passive concentration such as the extremely passive Mackworth Clock Vigilance Test and tests involving a reasonably difficult visual discrimination such as the Simple Reaction Time and Dual Tasks were very obviously affected by sleep deprivation.

These results are consistent with a recent review of the literature on the performance effects of sleep deprivation which concluded that sleep deprivation had a significant effect on human functioning (Pilcher & Huffcutt, 1996). A considerable number of studies have shown sleep-loss related reductions in performance on tests like Simple Reaction Time and vigilance tasks (like the Mackworth Clock test) both in laboratory and field studies (e.g., Angus & Heselgrave, 1985; Dinges, Whitehouse, Orne & Orne, 1988; Gillberg, Kecklund, & Akerstedt, 1994; Heselgrave & Angus, 1985; Lisper, Dureman, Ericsson, & Karlsson, 1971; Kribbs & Dinges, 1994; Riemersma, Sanders, Wildervanck, & Gaillard, 1977).

On the other hand a number of the more complex tests, Logical Reasoning and Visual Search in particular, showed little or no effects on performance with sleep deprivation periods of up to 28 hours. These results suggest that tests that are cognitive, more complex and/or difficult are not as susceptible to the effects of sleep deprivation. This is at odds with the conclusions of some previous researchers (e.g., Bonnet, 1994; Pilcher & Huffcutt, 1996) where difficult cognitive tasks (like Logical Reasoning) were considered most susceptible to the effects of sleep loss. Reviews of the evidence for the effects of sleep loss on cognitive tasks however raise some questions about the basis of this belief. For example, Johnson (1982) concluded that performance effects depend on the type of cognitive task used. Nevertheless, a number of previous studies have shown sleep deprivation effects on both the Grammatical Reasoning and Visual Search tasks used in this study (Angus & Heselgrave, 1985; Babkoff, Mikulincer, Caspy, Kempinski, & Sing, 1988; Bonnet & Arand, 1994; Dinges, Whitehouse, Orne & Orne, 1988; Heselgrave & Angus, 1985; Webb & Levy, 1984).

It is not clear why the subjects in this study were able to maintain much the same levels of performance on these tests through the period of sleep deprivation. This finding is not due to the tests being too difficult since both groups of subjects kept their performance at the 75% accuracy level or higher throughout the period of sleep deprivation. It is possible that the period without sleep was too

short and that with a longer period, performance effects would have been seen. Pilcher and Huffcutt (1996), however, found that cognitive tests were most susceptible to short periods of sleep deprivation (≤45 hours) rather than longer periods without sleep. It is also possible that maintenance of good performance on these tests occurred because relative to the monotony of the simpler tests like Simple Reaction Time and the Mackworth Clock, the complex cognitive tests were interesting and therefore arousing. This may have produced better performance for longer periods for these more interesting tests.

In contrast to the sleep deprivation effects, alcohol was shown to impair performance on all tests. On two of the complex cognitive tests, Logical Reasoning and Visual Search, the expected effects of alcohol were mainly seen for accuracy but not for speed. Since sleep deprivation also failed to produce effects on speed of performance on these tests, these results suggest that these measures are not very sensitive to any external influences. Interestingly subjective levels of fatigue also increased significantly with increasing levels of alcohol, but not nearly to the levels seen for sleep deprivation.

All tests showed a linear decrease in performance capacity with increasing doses of alcohol. A very large number of studies have demonstrated alcohol effects on most functions, although the dose-response relationship varies (Transportation Research Board, 1987). For all tests in this study significant performance effects occurred with between 0.05% and 0.1% BAC which is consistent with the regulated standard adopted in many parts of the world (Howat et al., 1991).

Since the sleep deprivation condition spanned more than 24 hours, it is possible that changes in performance in this condition may have been entirely or in part due to circadian or time of day effects. The study was designed to simulate the effects of starting work in the morning and continuing into the night. This also meant, however, that the last hours of sleep deprivation coincided with the lowest point in the circadian rhythm, a time when the circadian effects on performance are likely to be the greatest (Monk, 1994). Examination of the nature of the relationship between time of day and performance showed that for all tests, the greatest effect was a linear change in performance as would be expected from increasing sleep deprivation, but that a circadian influence was likely for some tests, but not all, and not all measures from each test. Clear circadian rhythms were shown in all subjective fatigue ratings and all measures in the Mackworth Clock test. Circadian rhythms were also seen in speed but not accuracy measures for a number of tests, specifically the Simple Reaction Time test, the Dual Task, and the Symbol Digit test. For all these measures the circadian influence would have increased the degree of performance impairment in the early hours of the morning beyond the effects of sleep deprivation alone. The remaining tests, Tracking, Logical Reasoning, Visual Search and Spatial Memory and the accuracy measures on the Simple Reaction Time and Dual Task showed no

influence of circadian function consequently where impairment occurred it could be attributed to sleep deprivation alone.

Some functions are therefore more vulnerable to circadian influences suggesting that they are more likely to be impaired in the early hours of the morning no matter how sleep deprived they are. Previous research supports this finding (Colquhoun, Blake & Edwards, 1968; Folkard, Totterdell, Minors & Waterhouse, 1993). For example, Folkard et al. (1993) also found that some Simple Reaction Time measures showed the largest endogenous or circadian influence and an accuracy measure showed the least.

Performance of drivers and controls were similar on most tests, but not all. Drivers were significantly slower than controls at performing the Symbol Digit test in both alcohol and sleep deprivation conditions. On the other hand, accuracy levels for drivers were close to 100 percent for both conditions. Drivers were able to maintain consistently high performance on this test in the face of increasing sleep loss. In contrast, the overall faster control group showed greater variability in the percentage of correct responses as sleep loss increased. These results suggest that the overall slower performance of drivers on this test was a strategic approach to maximise accuracy by trading-off speed of performance. It seems that drivers were overall slower to respond on this test, but were able to maintain their accuracy even after long periods without sleep when controls were beginning to find it more difficult to maintain accuracy. An alternative explanation could be the differences between drivers and controls in their experience with computers. This possibility can be discounted however since analysis of the effects of experience in using computers showed no difference in performance for the Tracking task. As this is the most mouse-intensive test, it should have shown differences in computer experience between drivers and controls, if they existed. These results suggest that drivers used a more conservative strategy in approaching this test at least. They also demonstrate that choice of study population is important. In order to develop performance tests for fatigue for long distance drivers, for example, it is necessary to evaluate the tests on long distance drivers.

Comparing the effects of sleep deprivation with the effects of standardised doses of alcohol demonstrated that, depending on the test, sleep deprivation of between 17 hours and 19 hours produced performance effects equivalent to the effects of 0.05% BAC. The earliest effects were seen for the Mackworth Vigilance test overall and for the accuracy measure of the Symbol Digit task. Longer periods of sleep deprivation were equivalent to higher alcohol doses.

Equivalence with the 0.05% BAC standard was very similar within tests. Both parts of the Dual Task either when tested alone, or in combination, showed equivalence at between 17 to 19 hours of sleep loss. For all measures for the Mackworth Clock, equivalence occurred at around 17 hours of sleep

loss and for the Symbol Digit test after about 18 hours without sleep. In this study these periods of sleep loss corresponded to between 10pm and just after midnight (between 2200 hours and 0048 hours).

These results demonstrate that performance impairments which have been judged as the legal limit for safety in many states of Australia, start to occur at around 17 hours after waking on average. These results are very similar to those found by Dawson & Reid (1997). It is significant that these periods of wakefulness also correspond to the normal waking day for most people. In the community a 16 to 17 hour period of wakefulness would be regarded as normal, with bedtime typically occurring in the mid to late evening depending on the time of rising. It could be argued, therefore, that this common waking-sleeping pattern plays a major role in ensuring safety. If the usual period of wakefulness of around 16 to 17 hours is extended, performance is likely to be impaired sufficiently to represent a considerably greater risk of injury.

For the task of driving, these results imply that drivers who have been awake for more than 16 hours will be significantly slower at reacting and will be increasingly likely to miss information as the period of sleep loss increases even further. It should be noted, however, that these results only suggest the length of the safe period of wakefulness. They do not directly imply anything about the length of the working/driving period. It is also not possible to make any conclusions about how different types of work, heavy or light, physically or mentally demanding, might interact with sleep loss to reduce the safe period of wakefulness.

In addition, the results only allow limited conclusions about the combined effects of circadian rhythms and sleep loss. The study was designed to only look at the effects of sleep loss over a night without sleep following a day of wakefulness since this is the form that sleep loss often takes. This design meant, however, that the period of maximum sleep loss coincided with the time that circadian influences should have been greatest. As a result, performance deficits may have been higher for measures that were vulnerable to circadian influences so enhancing the apparent effects of sleep loss. To evaluate the effects of the interaction between sleep loss and circadian rhythms a further condition should be carried out in which the period of wakefulness begins from as late in the afternoon or evening as possible so that sleep loss is low during the period of greatest circadian vulnerability. One of the difficulties with this approach would be that day sleep is notoriously poorer than night sleep so ensuring that subjects are rested enough before the period of wakefulness begins may be a problem. Nevertheless, this additional study would tell us whether the safe period of wakefulness could be extended by manipulating sleep periods around the circadian cycle.

This study clearly demonstrated that sleep loss produces notable effects on fatigue and on performance. Performance effects include a range of tests of functions likely to be important for driving such as reaction speed and accuracy, vigilance and hand-eye coordination. These effects were not simply due to circadian influences since not all tests showed a relationship with time of day and because performance effects were more strongly related to sleep deprivation for all tests. The results have revealed which of the battery of tests will be most useful for detecting fatigue in evaluating work-rest schedules. Clearly the Simple Reaction Time test, Unstable Tracking, the Dual Task and the Mackworth Clock Vigilance test are the best candidates for use as evaluation tools and they could be used in many settings, including on the road and in industry to evaluate such issues as working hours.

Most importantly, this study has allowed us to interpret these performance effects in terms of an accepted standard for safety. Using the legal limit for alcohol use when driving as the standard, the results showed that after around 17 to 18 hours of sleep loss, subject's performance on many tests had dropped to that seen at the legal limits for safe driving. While many people remain awake for periods of 16 hours or greater for reasons due to their work, family or social life, these results suggest that it is around this length of wakefulness that fatigue reaches a level significant enough to compromise performance capacity. Any decrements in performance resulting from sleep deprivation may, as a result, compromise safe performance and in turn potentially increase crash risk.

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APPENDIX 1: EXPERIMENTAL QUESTIONNAIRE

Code Number:

PARTICIPANT

BACKGROUND INFORMATION

Sleep Deprivation & Alcohol Study

Sept 1997

FATIGUE MANAGEMENT SURVEY

As part of our research on the best ways to manage fatigue in the long distance road transport industry, we need to find out about the people participating in the study. In particular we need to collect some general information on your lifestyle, health and work history.

All information you give to us will be **CONFIDENTIAL** and **ANONYMOUS.** You will be assigned a code number so that your name will not appear on any of your results.

On the following pages there are some questions about these matters that we would appreciate you filling in as carefully as possible.

THANK YOU FOR YOUR HELP

Part 1 - Practice Session

Date: _____

What is your: Age: (Please tick)

< 20 years	( )
20 – 29 years	( )
30 - 39 years	( )
40 – 49 years	( )
50 –59 years	( )
60 or more years	( )

Sex: M F *(Circle)*

		Please Tick
Are you:	married or living in a defacto relationship?	( )
	widowed, separated or divorced?	( )
	single?	( )

Do you currently drive a truck for a living? Yes ( ) No ( )

If **YES**, how long have you been driving a truck for a living?_____ years

If **NO**, have you ever driven a truck for a living?

Yes ( ) **How long ago?** _____months _____years
For how long? _____months _____years

No ( )

What is your current occupation? _____

How much experience have you had using personal computers ? *Please tick*

None	( )
A little	( )
Frequent user	( )

How far did you continue with formal education? *(Please tick)*

To Primary school level	( )
To High school Year 7, 8, 9, or 10 level	( )
To High school Year 11 or 12 level	( )
To Tafe level	( )
To College or University level	( )

Do you suffer any of the following health problems?	*Please circle*	
Diabetes	Yes	No
Asthma/Hayfever	Yes	No
Sleep disorders eg sleep apnea	Yes	No
Stomach or digestive problems	Yes	No
Liver or kidney problems	Yes	No
Heart or circulation problems eg angina, high blood pressure	Yes	No
Headaches or migraines	Yes	No

Do you smoke cigarettes? Yes ( )

No ( )

Given up ( )

If **YES,** how many cigarettes do you smoke on average per day? _____ cigarettes

If **GIVEN UP**, how long ago did you give up? _____years

Do you drink caffeinated drinks? Yes ( )

No ( )

If **YES,** what sorts of caffeinated drinks do you *usually* consume?

_____

How many of these drinks do you have on average per day?

_____

Do you drink alcohol? Yes ( )

No ( )

If YES, how much of the alcohol you drink, do you drink at one time?

One drink ( )

2-3 drinks ( )

4-5 drinks ( )

more than 5 drinks ( )

1 drink =	***1 middy beer or 1 glass wine or 1 nip spirits***
1 can beer =	***1.5 drinks***

How often do you usually drink alcohol? *Please tick*.

Every day ( )
2-3 times a week ( )
Once a week ( )
1-2 times a month ( )
Rarely ( )

When you are sleeping, how often do you: *Please tick one option*

Snore loudly ?
always ( )
often ( )
sometimes ( )
rarely ( )
never ( )

Stop breathing ?
always ( )
often ( )
sometimes ( )
rarely ( )
never ( )

Move around a lot ?
always ( )
often ( )
sometimes ( )
rarely ( )
never ( )

Do you have difficulty getting to sleep ? Yes ( )

No ( )

Do you have difficulty staying asleep once you are asleep ?

Yes ( )

No ( )

Do you have difficulty preventing yourself from falling asleep during the day ?

always ( )
often ( )
sometimes ( )
rarely ( )
never ( )

Have you had your adenoids removed ? Yes ( )

No ( )

Please continue
over page

How likely are you to **DOZE OFF OR FALL ASLEEP,** in contrast to just feeling tired in the following situations?

These situations refer to your usual way of life in recent times. Even if you have not done some of these things recently try to work out how they would have affected you.

Use the following scale to choose the **MOST APPROPRIATE NUMBER** for indicating how likely it is you would have dozed off in each situation

0 Would **never** doze
1 **Slight** chance of dozing
2 **Moderate** chance of dozing
3 **High** chance of dozing

Situation	***Chance of Dozing***
Sitting and reading	_____
Watching TV	_____
Sitting inactive in a public place (eg. In a movie theatre or at a meeting)	_____
As a passenger in a car for an hour without a break	_____
Lying down to rest in the afternoon when circumstances permit	_____
Sitting and talking to someone	_____
Sitting quietly after a lunch without alcohol	_____
In a car, while stopped for a few minutes in traffic	_____

How many hours have you worked in the last 7 days ? _____ hours

How many of these were between 6 pm and 6 am ? _____ hours

When did your last shift end ? time _____ am/pm

day _____ date _____

How long was your last shift ? _____ hours

How many hours did you sleep last night ? _____ hours

How would you rate the quality of your sleep last night?
(Please draw a cross at the point which most closely describes the quality of your sleep)

Very poor quality — *Very good quality*

What time did you wake up this morning ? _____

How did you feel when you woke up this morning ?

(Please draw a cross at the point which most closely describes how refreshed you felt)

Not at all refreshed — *Very refreshed*

When did you last have an alcoholic drink?

_____

Are you taking any medication? Yes ( ) No ( )

If **YES**, what ? _____

What have you eaten today ?

_____

How long ago did you last eat ? _____

Have you had any drinks containing caffeine today ? eg. Coffee, tea, coke

Yes ( )

No ( )

If **YES**, what did you have and how much ? _____

Code Number:

Body fat and alcohol dose estimation

Body size measures

Tricep calliper skinfold measurement (mm): .....

Weight (Kg): .....

Calculate Body Density where BD = c – mlog(skinfold), and

Age	C	M
20-29	1.1131	0.0530
30-39	1.0834	0.0361
40-49	1.1041	0.0609
50+	1.1027	0.0662

BD = _____

Calculate % BF = 100 x (4.95/BD – 4.5)

%BF = _____

If %BF is **within** the Average Male range below, use actual Weight for dose calculations.

If %BF is **below** Average Male range **but** the person is unlikely to have developed functional tolerance, use actual Weight for dose calculations.

Else if %BF is **above or below** the Average Male range below,

i) calculate %DIF = %BF – average % = ____ - 17.5
%DIF = _____

ii) calculate Adjusted Weight = Weight – (%DIF/100 x Weight)
Adjusted Weight = _____

Male %BF norms

Average Male	range	16% - 19%	average %	17.5%

PTO FOR DOSE CALCULATION

1st dose

Identify g/kg (eg 0.3) = _____

Calculate g needed = g/kg x adjusted weight = _____

Identify % alcohol in drink = _____

Calculate g per ml = 0.79 x %alcohol in drink = _____

Calculate dose = g needed/g per ml = _____

2nd and subsequent doses

Identify g/kg (eg 0.45) = _____

Calculate g needed = 0.45 x adjusted weight = _____

Identify % alcohol in drink = _____

Calculate g per ml = 0.79 x %alcohol in drink = _____

Calculate dose = g needed/g per ml = _____

Code Number:

Part 2 - Alcohol Session

Date: _____

How many hours did you sleep last night? _____ hours

How would you rate the quality of your sleep last night?
(Please draw a cross at the point which most closely describes the quality of your sleep)

Very poor quality — *Very good quality*

What time did you wake up this morning? _____

How did you feel when you woke up this morning?

(Please draw a cross at the point which most closely describes how refreshed you felt)

Not at all refreshed — *Very refreshed*

When did you last have an alcoholic drink? _____

Are you taking any medication? Yes ( ) No ( )

If **YES**, what ? _____

What have you eaten today ?_____

How long ago did you last eat ? _____

Have you had any drinks containing caffeine today ? eg. Coffee, tea, coke

Yes ( )

No ( )

If **YES**, what did you have and how much ? _____

Code Number:

Part 3 – Sleep Deprivation Session

Date: _____

How many hours did you sleep last night ? _____ hours

How would you rate the quality of your sleep last night?
(Please draw a cross at the point which most closely describes the quality of your sleep)

Very poor quality — *Very good quality*

What time did you wake up this morning ? _____

How did you feel when you woke up this morning ?

(Please draw a cross at the point which most closely describes how refreshed you felt)

Not at all refreshed — *Very refreshed*

When did you last have an alcoholic drink?_____

Are you taking any medication? Yes ( ) No ( )

If **YES**, what ? _____

What have you eaten today ?_____

How long ago did you last eat ? _____

Have you had any drinks containing caffeine today ? eg. Coffee, tea, coke

Yes ( )

No ( )

If **YES**, what did you have and how much ? _____

APPENDIX 2: INFORMED CONSENT FORM

PARTICIPANT INFORMATION AND CONSENT FORM

DEVELOPING MEASURES OF DRIVER FATIGUE FOR THE LONG DISTANCE ROAD TRANSPORT INDUSTRY

**University of New South Wales, School of Psychology,
New Zealand Occupational and Environmental Health
Research Centre and National Drug and Alcohol Research Centre**

DEVELOPING MEASURES OF DRIVER FATIGUE FOR THE LONG DISTANCE ROAD TRANSPORT INDUSTRY

Driver fatigue is a major safety issue in the long distance road transport industry in Australia mainly because of the distances that have to be travelled. One of the options currently being explored in Australia to manage fatigue better is a move away from regulated working hours to more flexible fatigue management programs (FMP's). An FMP aims to ensure that companies manage all the risk factors that contribute to heavy vehicle driver fatigue. One critical aspect of developing more flexible fatigue management programs is to have good measures of driver fatigue. The aim of this study is to develop measures of driver fatigue that can be used to estimate fatigue on the road.

What is involved?
You will be asked to participate in performance testing in our laboratory at the National Drug and Alcohol Research Centre on three occasions. You will not be working on the night before each of these occasions and you will be asked not to take alcohol or other social drugs in the 24 hours before testing. The first test occasion will be to practise the performance tests. The performance tests consist of some simple tests which assess how fresh you are mentally. On the second occasion, we will keep you awake for a total of 30 hours starting with your usual waking time in the morning after a good nights sleep. Every two hours we will test you using the performance tests. The purpose of this test day is to look at the effect of a long period of no sleep on your test performance. On the third test occasion you will be asked to drink measured amounts of alcohol until you reach 0.1% blood alcohol levels. We will monitor your alcohol levels using a breathalyzer. As your blood alcohol level rises, we will test your performance using some of the same tests as before. After the alcohol session we will ask you to remain in the Centre until your breath alcohol levels are close to zero. Taxis will be used to get you to and from the Centre for each test day.

We will also be asking you information about your general health, recent work history and a bit about your eating, drinking and sleeping activities in the 24 hours before each test session. All information you provide will be completely confidential. After we have collected all information we need, we will not be keeping your name at all.

We cannot and do not guarantee or promise that you will receive any benefits from this study.

We will arrange with your employer to make you available for these test days at normal rates of pay. Your participation in this project is voluntary. You will be free to withdraw from the project at any time without penalty or prejudice. Please note that your decision to participate will have no bearing on your employment. Under no circumstances will your results be shown to your employer.

If you have any questions about the study please do not hesitate to contact Ann Williamson, Rena Friswell or Samantha Brown on 9385 3806.
If you wish to complain about any aspect of this conduct of this research project please contact Mrs Margaret Wright, Executive Officer, Ethics Secretariat, University of New South Wales on 9385 4234.

DEVELOPING MEASURES OF DRIVER FATIGUE FOR THE LONG DISTANCE ROAD TRANSPORT INDUSTRY

CONSENT FORM

You are invited to participate in the study of ways of measuring driver fatigue for the long distance road transport industry. if you wish to participate, please complete the consent form below.

I, _____ agree to participate in the study of ways of measuring driver fatigue for the long distance road transport industry.

I acknowledge that I have read the above statement, and that the statement has been explained to my satisfaction. I have been given the opportunity to ask any questions relating to any possible physical or mental harm I might suffer as a result of my participation, and have received satisfactory answers. I understand that I can withdraw from the experiment at any time without prejudice.

I understand the information that I provide will be strictly confidential, and that only the study's research team will have access to information that identifies me with my responses.

I also understand that I am free to withdraw my consent and stop my participation at any time.

.

_____ _____

(Signature) (Date)

_____ _____

(Signature of Witness) (Date)

APPENDIX 3: ALCOHOL RELEASE WAIVER FORM

DEVELOPING MEASURES OF DRIVER FATIGUE FOR THE LONG DISTANCE ROAD TRANSPORT INDUSTRY

COMPLETION OF STUDY
WAIVER

Following my consumption of alcohol as part of my participation in the above study at the National Drug and Alcohol Research Centre, I have been shown my breathalyser reading and note that it is below 0.05 Blood Alcohol Content or 0.02 Blood Alcohol Content if I am a provisional licence holder. I have therefore been advised that I may leave the Centre. I will either be accompanied home by a person mutually acceptable to me and the Research Coordinators, or a taxi will be called. I anticipate no adverse consequences on my behaviour arising from my participation in the study and I therefore release The University of New South Wales and the National Drug and Alcohol Research Centre, or any employee, member or representative thereof from all or any claim that I may have arising out of my participation in the study.

_____ _____
(Signature) (Date)

_____ _____
(Witness Signature) (Date)

APPENDIX 4: ALCOHOL EARLY RELEASE WAIVER FORM

DEVELOPING MEASURES OF DRIVER FATIGUE FOR THE LONG DISTANCE ROAD TRANSPORT INDUSTRY

EARLY RELEASE WAIVER

Following by consumption of alcohol as part of my participation in the above study at the National Drug and Alcohol Research Centre (NDARC), I have been shown my breathalyser reading and note that it is above 0.05 Blood Alcohol Content (or above 0.02 Blood Alcohol Content in the event that I am a provisional driving license holder).
I have been advised that I should not leave the National Drug and Alcohol Research Centre before my breathalyser reading has fallen below 0.05 or 0.02 in the event that I am a provisional license holder, but have chosen to do so of my own free will. I have
also been advised that I should, under no circumstances, drive a motor vehicle until I can be sure that my blood alcohol level is below the legal limit for driving. I understand that my decision to leave against advice will in no way preclude me from being provided a taxi or being driven home by a mutually acceptable person.

Despite the fact that I have left NDARC against advice, I anticipate no adverse consequences on my behaviour arising from my participation in the study at NDARC, and I therefore release the University of New South Wales and NDARC, or any employee, member or representative thereof, from any claim that I may have arising out of my participation in the study.

_____ _____

(Signature) (Date)

_____ _____

(Witness Signature) (Date)