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On-road Evaluations of a Regulated Hours Regime and an Alternative Compliance Regime

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On-road Evaluations of a Regulated Hours Regime and an Alternative Compliance Regime

DEMONSTRATION PROJECT FOR FATIGUE MANAGEMENT PROGRAMS IN THE ROAD TRANSPORT INDUSTRY

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Abstract

This is the third report in a series looking at the development of better models of work-rest schedules that have demonstrated effectiveness for managing fatigue in order to support the development of alternative compliance approaches to the regulation of working hours. This report describes evaluations of two work-rest schedules; one of a work-rest regime conducted under the current working hours regulations and the other of the first pilot Fatigue Management Programme allowed under the Queensland Department of Transport alternative compliance programme. This alternative work-rest schedule differed from the regulated regime in that it allowed longer periods of active work without rest (6 hours instead of 5 hours) and allowed the mandatory six hours of continuous rest to be taken in two parts instead of one. The results of the regulated hours evaluation showed small increases in fatigue and performance deterioration over the selected period of work, but comparison with alcohol-equivalent standards suggested that these increases were warning signs rather than major consequences for safety. The results of the alternative work-rest schedule indicated that the balance between work and rest was not entirely compatible with effective fatigue management. Some suggestions were made about how the work-rest schedule might be improved to overcome its problems.

Keywords

FATIGUE MEASURES, ALCOHOL, PERFORMANCE

NOTES:

(1) This report is disseminated in the interests of information exchange.
(2) The views expressed are those of the author(s) and do not necessarily represent those of the Commonwealth.

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The studies reported here could not have been conducted without the support of the drivers and management staff at the participating companies. We would like to extend our sincere thanks to them for their help and good humour.

Thanks are also due to Dr Jim Lemon at Bitwrit Software for his technical advice and assistance.

EXECUTIVE SUMMARY

This is the third report in a series describing research aimed at developing better models of work-rest schedules that have demonstrated effectiveness for managing fatigue. The ultimate purpose of these studies is to support the development of alternative compliance approaches to the regulation of working hours. Rather than attempting to estimate the effectiveness of alternative work-rest schedules by applying theoretical knowledge of the area of fatigue, these studies have actually measured fatigue on-road under a range of different work-rest schedules.

This report describes an evaluation of the first pilot Fatigue Management Programme allowed under the Queensland Department of Transport alternative compliance programme. This alternative work-rest schedule differed from the regulated regime in that it allowed longer periods of active work without rest (6 hours instead of 5 hours) and allowed the mandatory six hours of continuous rest to be taken in two parts instead of one.

The results of the evaluation cast some doubts on the effectiveness of the alternative work-rest schedule and suggest that the balance between work and rest in the schedule needs to be re-examined. Although reported fatigue levels were not particularly high at any time in the study period, reaction speed became significantly slower on both laptop and palmtop versions of the Simple Reaction Time test across the study period. Furthermore, the results showed that reaction speed at the end of the study period had slowed to be poorer than the performance level found in drivers at 0.05% BAC. For the Mackworth Clock Vigilance test, performance also showed deterioration over the study period and showed some evidence of being poorer than

the alcohol standardised performance at 0.05%BAC on occasions across the study period. For both tests, performance had deteriorated sufficiently to constitute a safety risk based on the community-accepted standard for on-road performance.

The results of the evaluation provide some hints about what aspects of the work-rest schedule needs to be changed. Drivers who did most work in this schedule rated themselves the most tired. This was also found in the first regulated regime evaluation (Williamson, Feyer, Finlay-Brown, & Friswell, in press, CR190) and consequently provides further evidence that long working hours are a serious risk factor for the experience of fatigue in driving

Most significantly, the length and quality of sleep and the number of breaks seem to be the major problems in this roster. The results show that the drivers who derived least benefit from their last rest were most likely to suffer effects on their capacity to perform. Many of the measures showed little or no improvement even after a sleep break, especially towards the end of the study period, suggesting a problem with either the positioning and/or the length of the breaks. This pattern was also seen in the simulated FMP evaluation described in the second report of the series (Williamson et al., in press, CR190) where by the second day of an extended work period (16 hours) breaks became increasingly useless in producing recovery of performance. Clearly, there needs to be a balance between the amount of work and the amount of rest needed to allow for proper recovery.

Not only is the length of break important, but the results also suggest that the quality of sleep obtained in the break is important. Drivers in this study were on-road for around twice as long as in the previous evaluations. It is likely that on-road rest is of inferior quality to rest obtained at home. This may be one of the reasons for the performance effects seen in this study. If this is the case, one of the suggested targets for improving this FMP schedule would be to reduce the amount of time away from home.

This report also describes a second evaluation of the current working hours regulations for managing fatigue. A similar evaluation was described in the second report (Williamson et al., in press, CR190) in which drivers were studied from the beginning of a period of days of work after at least a 24 hour break, for the period until their next 24 hour break. The current study was a replication of the first in a different company in which the working hours regulations are implemented slightly differently. Unlike the first evaluation, where drivers tended to work from a main company depot so that trips started and ended in the same place, in this second company, drivers were based considerable distances away from the company depot. This meant that the study was more difficult to organise and that many drivers in the study had been driving for a substantial period when they began the study so making it difficult to estimate fatigue and performance levels from maximally rested drivers.

Nevertheless, the results of the second working hours evaluation showed the same as the first one. The results showed no evidence of significant increases in fatigue or deterioration in performance capacity over a selected period of work. Fatigue ratings showed only minor, non-significant changes from the beginning of the study period across the first work period for the remainder of the study period. Similarly, Simple Reaction Time and Mackworth Clock Vigilance test measures also showed only slight changes across the study milestones. These results need to be interpreted with some caution, however. For many drivers in the study, it was not possible to measure their performance when they were maximally rested. This means that the lack of change over the study period may have been because drivers were tired on both occasions. Using the alcohol performance standards, however, it was possible to conclude that performance was within the estimated performance standard for most drivers so suggesting that the roster is allowing adequate rest to balance work.

Like the previous evaluation, however, this study showed that long periods of work, inadequate breaks and poor quality sleep will produce adverse effects on performance. Drivers who did the longest working hours and especially night work showed the slowed reaction time in the Simple Reaction Time test. Similarly, where drivers had fewer breaks or poorer quality sleep in their breaks, their ability to maintain consistent and accurate performance on the Mackworth Clock Vigilance test was adversely affected.

These studies have reinforced again the usefulness of taking this evaluation and model-building approach to the problem of fatigue management in the long distance road transport industry. The techniques developed for the approach have demonstrated their usefulness for detecting fatigue effects in this study as well as the previous ones. The results have reinforced the conclusions of the earlier evaluation of the current working hours regime by showing that there appear to be no major effects of fatigue. They show, however, that where drivers work to the upper limits of the current regime, the risk of fatigue effects are significantly increased. The results also demonstrate the problems of an alternative compliance approach to fatigue management and point out the general areas for improvement in the work-rest schedule.

INTRODUCTION

Recent attempts to reduce the problem of driver fatigue for the long distance road transport industry have focussed on allowing operators and drivers more flexibility in work-rest scheduling rather than on regulated hours approaches. The rationale for this change has been based on the view that not all drivers respond to fatigue in the same way, not all operational needs are served by the current working hours regulations, and current regulations restrict drivers' ability to use their rest time at the most beneficial or needed times. Consequently, it has been argued (eg., Williamson, Feyer, Coumarelos, & Jenkins, 1992; Moore & Moore, 1996) that the rigidity of regulated hours should be replaced by greater flexibility in work-rest scheduling.

The Fatigue Management Programme set up by the Queensland Department of Transport has been an attempt to introduce more flexible work-rest scheduling within a regulated structure. Under this programme, operators of long distance road transport companies can introduce greater flexibility in trip scheduling if they can demonstrate that there are alternative approaches to managing work and rest on specific trips which will manage fatigue as well or better than would occur under the work-rest regulations.

Unfortunately, this alternative approach has inherent difficulties because of our lack of knowledge of the best ways of arranging work and rest in order to manage driver fatigue. Research has demonstrated that fatigue is a major and persistent problem for the long distance road transport industry due to the very long distances that need to be covered to move freight around Australia. In a national survey of long haul drivers (Williamson et al., 1992), most (85%) reported experiencing fatigue at least occasionally and, more importantly, that fatigue affected the quality of their driving by making them slower to respond (49%) and by disrupting gear changing (40%), speed maintenance (39%) and steering (37%). While we know that fatigue is a problem for the industry, we have less information about what are the best approaches to managing the problem.

This report is part of a project which aims to evaluate the effectiveness of alternative approaches to work-rest scheduling for managing fatigue and to compare their effectiveness with that of the current regulated hours approach. The first part of the last report from the project looked at the effectiveness of the regulated regime for controlling driver fatigue. The results indicated that provided drivers were not tired at the beginning of the work week, a trip of up to 14 hours could be performed without producing significant increases in reported levels of fatigue or showing adverse effects on performance (Williamson, Feyer, Finlay-Brown and Friswell, in press, CR190). The results also showed that drivers could manage fatigue over a working week, but they became less able to manage fatigue by having breaks and adequate sleep across the working week.

The second part of the last report from the project investigated the effects of an alternative approach to fatigue management on fatigue and performance. This evaluation was conducted as a simulation because it involved much longer working periods than are currently allowed under the regulated regime. The study was carried out using professional long haul drivers, but was conducted off-road due to concerns about safety. This study demonstrated that longer hours than allowed by regulation produced significantly higher levels of reported fatigue and had adverse effects on drivers performance, particularly on the second long work period. It seems too that the rest periods allowed in the schedule were not long enough to prevent a build-up of fatigue over consecutive long days of work.

The two evaluation studies described in this report are a similar approach to the evaluations described in the last report, only focussing on work-rest schedules with different characteristics. The first study was an evaluation of a work-rest schedule that was being trialed as part of the Fatigue Management Alternative Compliance Programme (FMP). The FMP focuses on specifying work-rest limits for trip routes rather than overall working hours. In this way, the FMP attempts to accommodate the operational needs of long distance road transport at the same time as managing fatigue effectively for drivers. The main differences between the FMP and regulated approaches are in the number of hours allowed over an individual trip and in the way rest is handled to compensate for the longer periods of work.

The second study described in this report evaluated a work-rest schedule currently in use under the regulated regime. This schedule was different from the previous evaluation of regulated hours in that the drivers began and ended their trips from a number of regional centres in which they lived rather than from the same central location. This meant that drivers had often travelled for some distances before picking up their freight and that activities within the trip such as loading and unloading tended to occur at different times rather than at the start and end of the trip.

The influence of these different ways of scheduling was evaluated. The aim of both evaluations was to investigate changes in reported fatigue and performance at designated times such as the beginning and end of a continuous work period or the beginning and end of a series of work periods between long breaks of 24 hours or more. So that the results of these and the earlier studies could be compared, the same benchmarked measurement techniques were used in both studies.

STUDY 1: EVALUATION OF AN ALTERNATIVE-COMPLIANCE FATIGUE MANAGEMENT PROGRAMME

The first study evaluated one of the FMP work-rest schedules allowed under the pilot programme. The main distinguishing features of the alternative schedule are the length of consecutive hours allowed. The standard regulations stipulate that one 30 minute rest break must be taken in every 5.5 hours of work, and no more than 14 hours may be worked in any 24 hour period, with driving per se limited to 12 hours. In addition to other breaks, one continuous break of not less than 6 hours must be taken per 24 hour period and at least one continuous break of 24 hours or more must be taken per 7 day period. Drivers may work a maximum of 72 hours per 7 day period. In contrast to standard regulated hours, the FMP under study acknowledges the demands of a particular trip route by specifying work and rest limits for that trip route. The limits common to all trips are: Drivers may work for periods of up to 6 hours, with a minimum of 15 minutes rest break between work periods. In addition to these short rest breaks, a minimum of 6 hours break from work per 24 hour period is also specified, which can be taken as either a single continuous period or two periods of at least 2 hours. Under this system, the maximum amount of work that can be done in any 24 hour period is 17.5 hours, and a 6 hour break is mandatory at the end of longer trips. While these are the specified limits under the FMP, guidelines for normal operation recommend shorter work periods punctuated by longer breaks, and regular long night sleeps between trips. Maximum work hours are 144 per fortnight, and drivers must take two 24 hour break periods in the fortnight (see Figure 1).

The FMP approach has been to evaluate each alternative work-rest schedule proposed by companies. The evaluation involves a group of technical experts,

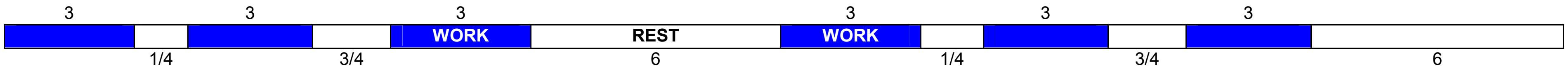
FIGURE 1: Example FMP guidelines for one trip route

Trip Schedule

Reasonable Expectation	work & rest	**32 hrs**	Reasonable Drive Time (500hp)	"work driving"	18-19 hrs
Not Quicker Than	work & rest	30 hrs	Sleep during trip	"Time Not Working"	at least 6 hrs *
			Sleep at end of trip	"Time Not Working"	at least 6 hrs *
			Safety Margin (optional leeway)	"Short Rest"	1-2 hrs
* Sleep before, during, and at the end of the trip is dependent on time of day, previous sleep and workloads and the individual driver's needs on the individual trip. The need for rest on route and at the end of the scheduled trip has mandatory minimum requirements for this schedule and will be determined by the individual driver's needs and also all the mandatory limits listed below.					

ACTIVITY	NORMAL	RISK LIMIT (not to be exceeded without authorisation from M/D)
Active work (combination of both driving and non-driving work)	aim to take a break each 3-4 hrs	**max 6 hrs at a time**
Short rest breaks (minmimum time to be classed as rest)	avoid back to back minimum breaks, aim for longer breaks	**1/4 hrs minimum**
Time not working in any 24 hr period (recommended as sleep time)	avoid back to back minimums, aim for at least 2-3 full night time sleeps a week (ie 8 hrs or more)	**6 hrs in any 24 hr period minimum**
Time not working (allowable break-up)	avoid back to back use of broken periods whenever possible	**not more than 2 parts (ie: 3+3, 2+4 etc)**
Time not working (during trip)	if you need more, take it	**6 hrs minimum**
Time not working (end of trip)	aim for more if possible	**6 hrs minimum**
Delivery never to come before your safety	**REST**	**STOP**

EXAMPLE



regulators, and enforcement representatives who recommend changes where necessary to minimise the amount of fatigue likely to be produced by a specific work-rest schedule.

The on-road evaluation undertaken in this project examines how successfully fatigue is managed by an alternative work-rest schedule and where, if at all, the schedule needs to be modified.

METHOD

Design

Professional long distance truck drivers were studied across a fortnightly work shift cycle. A small number of the drivers sampled were working under standard hours-of-service regulations but most were working according to their employer's Fatigue Management Plan (FMP).

Measurement of drivers' fatigue and performance began at the start of their first shift after a break of at least 24 hours and continued until the end of the their last shift in the fortnightly cycle, just prior to taking a break of 24 hours. This allowed the cumulative effect on fatigue and performance of successive shifts and rest breaks to be assessed.

Two cognitive psychomotor tasks (sustained attention and reaction speed) were used to measure performance. These were presented on palmtop computers. Drivers were asked to self-administer the tests at the start and end of every break from work which contained sleep during the study period. In addition, supervised testing occurred at the start and end of the fortnight. Drivers were also asked to keep a diary record of all breaks spanning an hour or more (including sleep breaks) and to rate their subjective fatigue at the start and end of these breaks.

As a check on the veracity of the palmtop test data, a longer version of the performance tests was also administered via laptop computers at the start and end of the study period. An advantage of using the laptop tasks in addition to the palmtop tasks was that they have previously been shown to index performance decrement across periods of sustained wakefulness (Williamson, Feyer, Friswell, & Finlay-Brown, in press, CR189; Williamson & Feyer, 2000; Williamson, Feyer, Mattick, Friswell, & Finlay-Brown, 2000). The laptop tests differed from the palmtop tests in a number of ways, by providing a larger screen for all tests, coloured stimuli in the RT task, and involved a longer test period in the sustained attention test.

General background information was also collected on the drivers' health and lifestyle, and on their work pattern and activities in the period leading up to the study.

Subjects

Twenty two professional long-distance truck drivers, employed by a southern Queensland company that specialised in refrigerated transport agreed to participate in the study. Sixteen of these drivers were working under the company's FMP. The remaining six were subject to standard working hours regulations. For various reasons, some of the subjects that were initially recruited withdrew during the study. One driver became ill, and two others felt that existing eyesight problems, affecting close-up detail, were compromising the validity of their test results. This left 14 FMP and 5 non-FMP participants.

Table 1 summarises the characteristics of the sample. The study participants were all men and had extensive driving experience. Overall the average professional driving experience was 20 years. Two participants had been driving for only four years, but the remainder had been driving for at least ten years. The majority of the subjects (79%) were aged between 30 and 59 years and most (95%) were living in an ongoing relationship. Most of the group (90%) had ceased formal education

TABLE 1: Demographic details of on-road FMP study subjects

Demographic Factor	% of all subjects (n=19)	% of FMP subjects (n=14)
AGE:		
• 20 – 29 years	16	0
• 30 – 39 years	26	28.6
• 40 - 49 years	32	35.7
• 50 - 59 years	21	28.6
• 60 + years	5	7.1
EDUCATION LEVEL:		
•Primary school	11	14
• High school years 7 - 10	79	78.6
• High school years 11 - 12	11	7.1
PC EXPERIENCE:		
• No previous experience	95	93
• A little experience	5	7
• Frequent PC user	0	0
SOCIAL DRUG HABITS:		
• Cigarettes - Non-smoker	32	29
- Ex-smoker	32	36
.- Current smoker	37	36
• Alcohol - Non-drinker	5	7
- Current drinker	95	93
RELATIONSHIP STATUS:		
• Married/Defacto	95	100
• Divorced/Widowed/Separated	0	0
• Single	5	0
DRIVING EXPERIENCE:		
• Years of driving experience		
- ≤ 5 years	11	7
- 6 - 10 years	16	14
- 11 - 20 years	32	29
- Over 20 years	42	50

before Year 11, and none had post-secondary qualifications. The entire group had had little or no prior experience with computers. The majority of subjects drank alcohol (95%) but less than half (37%) currently smoked. Comparison of the demographic characteristics of drivers who were involved in the Fatigue Management Programme with all study participants showed that there were very few differences. The only differences were that FMP drivers were marginally older.

Materials and measures

i. Performance testing

Two tests from the Performance and Information Processing Systems (PIPS) Test Battery were administered on palmtop computers (Hewlett Packard 200LX). Each driver was allocated a palmtop for the duration of their study period. Palmtops were packed in a standard lunchbox for ease of transport, together with a Genovation keypad (Serial Micropad 623) which plugged into the computer and served to increase the key size. The tests, a Simple Reaction Time task (RT) and a 5 minute version of the Mackworth Clock Vigilance task (Mackworth, 1970), together lasted 7 minutes. RT was always the first to be completed. Particulars of the tests are presented below.

Simple Reaction Time (RT): Subjects pressed a key on the keypad as quickly as possible whenever the outline of a circle, moving about the computer screen, changed from a solid to a dotted line. During the 2 minute task, 40 such changes occurred with a minimum interstimulus interval (ISI) of 2 secs. The maximum response time permitted was 1 sec. Response speed and the number of correct responses were measured.

Mackworth Clock Vigilance task: Twenty four points lying on a circle flashed consecutively in a continuous circuit for 5 minutes on the computer screen. Subjects pressed a button on the keypad as quickly as possible whenever one of the points failed to flash in its turn. Omitted flashes occurred 5 times with a minimum ISI of 45 secs. The maximum allowed response time following each omitted flash was 10 secs. Flashes themselves lasted 500milliseconds (ms). Reaction time, the number of missed responses and the number of false alarm responses were measured.

Visual Analogue Scale ratings of subjective fatigue were made in conjunction with the palmtop tests and were recorded manually in a “Work Diary”. Three scales were employed (Fresh - Tired, Clear-headed - Muzzy-headed, and Very Alert - Very Drowsy) to capture different aspects of the fatigue experience.

The tests presented on laptop computers were identical to the palmtop tests except that in the RT task, the moving circle changed colour, rather than changing line style and, in the Mackworth Clock Vigilance Task, three times the number of flashes and omitted flashes (15) occurred and the task was, consequently, three times as long (15 minutes). Together these two tasks took 17 minutes to complete. As with the palmtop tests, the RT task was always completed first. Tests were administered on Compaq laptop computers. Subjects responded on peripheral Genovation keypads (Micropad 622). A custom-built “mask” was fitted over the keypad to conceal the non-essential keys.

At the beginning of the laptop tests, the three Visual Analogue Scales of subjective fatigue were presented on the computer screen, and subjects made their ratings with the aid of standard serial mice.

ii. Documentation

All subjects completed an informed consent form (Appendix 1) and a brief questionnaire (Appendix 2) addressing demographic characteristics, general health and lifestyle factors, workload in the previous week, recent sleep, and food and drug intake.

Drivers were provided with a “Work Diary” in which to record details of their work and rest schedule during the study, and to rate their fatigue before and after longer breaks (Appendix 3). A set of written instructions for using the palmtops was also provided (Appendix 4).

Procedure

Drivers who agreed to participate in the study arrived at the testing room at the truck depot approximately 1 hour before they were due to depart on the first trip of the fortnight. The nature of the study was explained and drivers were asked to complete a consent form before participating. They were then asked to complete a background questionnaire and were taught the procedures necessary to run the palmtop tests. This was followed by a practice session of the palmtop tests. Drivers then completed their pre-study test session on the laptop computer, and were then supervised while they self-administered palmtop tests. This last session served as a performance baseline on the palmtop tests but also allowed drivers to consolidate their knowledge of palmtop operation before commencing unsupervised tests on the road. (Round the clock palmtop assistance was available by phone.) Finally, the use of the "Work Diary" was explained, and drivers completed the questions relating to the start of their first shift of the fortnight.

Drivers returning to the depot at the end of the final shift of their fortnight completed a palmtop test session, appropriate "Work Diary" entries, and the post-study laptop testing session.

Statistical Analysis

The primary analyses were conducted on FMP-participating drivers only.

In all analyses the three subjective rating scales produced similar results and were averaged to create a single rated fatigue measure. In this study missing data occurred at various times due to factors like, driver forgetfulness, technical problems with the palmtops, and practical constraints imposed by the work itself. As a result, the reported analyses included varying numbers of people, depending on the particular measures and times in the study period being examined.

Initially, comparisons were made by matched t-tests for fatigue and performance measures between the beginning and end of the study period for the laptop and palmtop test measures separately. (Analyses comparing laptop and palmtop tests are detailed in Appendix 7). Next, the influence of the work and rest schedules before the trip on baseline fatigue and performance were analysed using linear regressions in which a range of work-rest factors were entered as predictors. The predictors used were: work hours in the past seven days, number of night hours worked, number of hours between the end of the last work shift and the start of the study trip, total hours slept in this period, the hours since the end of the last sleep, and the rated quality of that sleep. A similar regression analysis was also used to estimate the influence of the work-rest experiences during the study week on fatigue and performance measures.

Changes in fatigue and performance before and after sleep breaks across the study period was examined, to assess the impact of cumulative fatigue over the rostered fortnight and to determine whether any changes occurred in the effectiveness of breaks as the shift cycle progressed. Because drivers reported different numbers of breaks however, no statistical analyses were performed on these data.

Comparisons were also made between performance on each test during the trip and performance levels standardised against alcohol. For this analysis, laptop performance was compared against the standard alcohol-equivalent performance levels at 0.05%BAC developed in the earlier laboratory study. This analysis should provide a yardstick for estimating the level of safety risk at intervals across the work week.

RESULTS

Recent work and rest history

Table 2 outlines the pattern of work in the last 7 days prior to the study. Participating drivers overall and those working under the FMP had worked an average of around 60 hours in the past seven days. All drivers had worked more than forty hours and most had worked between 40 and 60 hours. Notably, however, around one-third of drivers had worked more than 72 hours in the past week, up to a maximum of 80 hours or more for both FMP and regulated regime groups. For most drivers (63.2%) work was done in two trips and covered around 2,000 kilometres or more, up to 4,000 kilometres. For around two-thirds of drivers, the last trip took more than 32 hours up to a maximum of 96 hours. On average overall and for the FMP group, about half of the work over the last week was done at night. All of the drivers did at least some night work, ranging from a minimum of 12 hours up to 50 hours.

Across all drivers, the last work shift was around 12 - 14 hours in length although two drivers reported the duration of the last shift as between 40 and 47 hours in length. Reported length of the last shift was shorter on average for the FMP group, mainly because the longest reported last shift was 28 hours rather than 47 or 48 hours. It is likely that the drivers reporting these extreme shift lengths were actually reporting the length of their last trip. For the majority of drivers (73.7%) and FMP drivers alone (71.6%), the last shift contained 14 hours or less work. As intended in the study design, almost all of the drivers both overall and in the FMP, had been resting for at

TABLE 2: Distribution of work hours in the last 7 days for FMP study participants

HOURS WORKED	% ALL PARTICIPANTS (N=19)	% FMP DRIVERS (N=14)
TOTAL WORK HOURS:		
• ≤ 50 hours	31.6	35.3
• 51 - 60 hours	26.3	28.6
• 61 - 72 hours	5.3	0
• > 72 hours	37.1	35.5
Mean *(SD)*	62:21 *(15:50)*	60.6 *(14.58)*
Range	40-86	42-80
NIGHT WORK HOURS:		
• 0 hours	0	0
• ≤ 20 hours	10.5	7.1
• 21 - 40 hours	68.4	78.7
• > 40 hours	21.1	14.2
Mean *(SD)*	31.21 *(10.18)*	29.9 *(9.47)*
Range	12-50	12-50
LENGTH OF LAST SHIFT:		
• ≤ 10 hours	31.6	35.7
• 11 - 15 hours	36.8	28.4
• 16 - 25 hours	15.8	21.3
• 26 - 48 hours	15.8	14.2
Mean *(SD)*	14.03 *(10.86)*	12.68 *(8.32)*
Range	1-47	1-28
HOURS WORKED IN LAST SHIFT:		
• <10 hours	31.6	35.7
• 10 –14 hours	42.1	35.9
• 15 – 24 hours	21.0	28.4
• > 24 hours	5.3	0
Mean *(SD)*	11.37 *(6.72)*	10.71 *(6.43)*
Range	1-37	1-22
HOURS SINCE END OF LAST SHIFT:		
• 0-24 hours	10.5	14.2
• 24 - 48 hours	47.5	35.5
• 49 - 72 hours	31.6	35.5
• > 72 hours	10.5	14.2
Mean *(SD)*	46:26 *(30.03)*	49.33 *(34.2)*
Range	0-118.5	0-118.5

least 24 hours at the start of the evaluation period, and so had time to rest before the start of their participation in the study. The two drivers who had less than 24 hours off had already begun their first shift of the fortnight when they commenced the study. Both drivers were in the FMP programme. One had worked for 3.75 hours since his extended break and the other for 5.25 hours.

Table 3 shows details of the drivers' rest between the end of the last shift and the beginning of the study for the study participants overall and for the FMP group. There was very little difference between the FMP group and all drivers. The results showed that drivers had varying amounts of sleep, depending mainly on the length of their rest period. On average drivers had around 17 hours of sleep with the last substantial sleep being around at least 7 to 8 hours in length for almost all drivers (86.4%). The rated quality of sleep was high, with virtually all drivers rating their sleep quality in the top quartile of the sleep quality range. Drivers' ratings of how refreshed they were after their last sleep were again high, but slightly lower than their sleep quality ratings since only around half of the drivers used the top quartile of the refreshedness rating scale. Not surprisingly then, the drivers' fatigue ratings at the beginning of the study were low, indicating low fatigue. Most drivers rated themselves as being in the lowest one-fifth of the rating scale. On the day that drivers began the study, they tended to wake just before 07:00, although waking time ranged from 03:00 to 09:00 hours. Three drivers napped between their last substantial sleep and the start of the study. The nap period was quite short, being less than two hours in length.

TABLE 3: Details of rest since end of last shift for FMP study participants

	ALL PARTICIPANTS MEAN, (SD), RANGE	FMP PARTICIPANTS MEAN, (SD), RANGE
• Hrs sleep since end of last shift	17.2 (11.2) 0 – 45.5	17.7 (12.4) 0-45.5
• Hrs length of last substantial sleep	9.0 (2.3) 4-12 hrs	8.5 (2.3) 4-12 hrs
• Rated quality of last substantial sleep(/100)	84.2 (21.2) 6-100	80.8 (23.8) 6-100
• Rated refreshedness from last substantial sleep (/100)	74.9 (21.9) 3-100	73.8 (23.4) 3-100
• Nap since substantial sleep (%)	15.8	14.3
• Length of last nap (hours)	1.5 (0.5) 1–2	1.25 (0.35) 1–1.5
• Baseline fatigue ratings:		
- laptop	18.51 (12.99) 1.67-4.67	20.2 (13.7) 1.67-50
- diary *(Note: Higher ratings indicate higher fatigue)*	16.8 (10.5) 4.67-50.33	18.2 (12.4) 4.67-50.33
• Waking time on Day 1 of study	6:49 (1:26) 3:00–9:00	6:45 (1:30) 3:00-9:00

In the period leading up to the study, drivers had typically eaten three to four hours ago (mean = 3.8 hrs). Mostly they had consumed a moderate-sized meal (52.6%) and almost all drivers had not eaten since then (90.0%). The majority of drivers (63.1%) had consumed one or two caffeine-containing drinks in the five hour period leading up to the study, but some drivers (15.9%) had not consumed caffeine-containing drinks for more than 24 hours. Most drivers (83.3%) consumed alcohol in the last 48 hours, but only 22.2% had consumed it in the last 12 hours. No driver had consumed alcohol in the five hour period prior to the study.

Description of the study period

The work experiences over the study period are summarised for all drivers and the FMP group in Table 4. Figure 2 provides an overview of the average alternative compliance trip and compares it to a typical work-rest schedule worked under the regulated regime (Figure 3). The study period was approximately two weeks long (mean = 291 or 283 hours, range = 250 to 337 for all drivers or 250 to 327 hours for FMP drivers) and involved around three trips on average (mean = 3.47 or 3.42 trips, range = 1 to 6 or 1 to 5 trips for all drivers and FMP drivers respectively). In this period, around 48% of time was taken up with work and nearly half of the work time was performed at night for both overall and FMP groups.

Over the study period, all drivers and FMP drivers alone averaged around 17 breaks. When all drivers were considered, about two-thirds of the breaks taken involved sleep. FMP drivers had a similar, but slightly lower percentage of breaks involving sleep (61.7%). The median length of sleep in breaks was close to six hours for FMP and all drivers, and showed a similar range for both groups. Not surprisingly due to the long study period, all drivers in the study had at least one 24 hour break, which occurred at various times in the study. For the FMP group, the longest break ranged from just over 24 hours to 72 hours. There was a strong inverse relationship between the number of breaks and break length ($r_{(19)}=-0.73$, $p<0.001$) such that the drivers who had the longest breaks tended to break less often and vice versa.

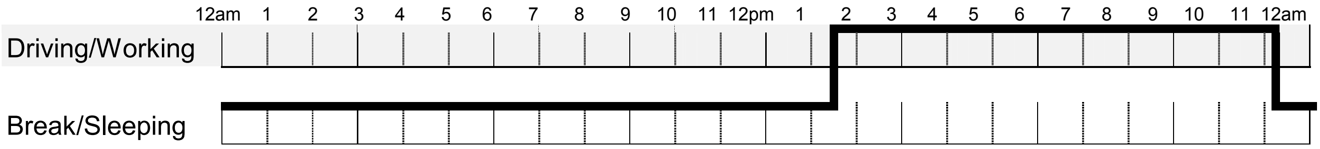
TABLE 4: Work experiences in the study week for drivers in the FMP study

	ALL DRIVERS **Mean, (SD), Range** **(n=19)**	**FMP GROUP** **Mean, (SD), Range** **(n=14)**
WORK		
• Hrs work in study period	138:64 (16:55) 108 – 173:75	137:52 (19:15) 108 - 173:75
• % study period worked	48.2	48.9
• Night hours in period	63.75 (12.28) 45:25 - 89:0	62:66 (12:90) 45:25 - 89:0
• % working hours done at night	45.9 (7.2) 36.1 - 58.2	45.6 (7.0) 36.1 - 58.2
• Median length of work period	7.57 (3.22) 3.62 – 14.0	6.83 (2.81) 3.63 – 12.75
• Median hours driving in work period	6.36 (2.55) 3.0 – 11.5	5.86 (2.27) 3.0 – 11.0
REST		
• Mean number of breaks in study period	17.1 (5.9) 9 – 31	17.5 (4.9) 11-26)
• Median length of breaks in study period	6.10 (2.99) 1.50 – 14.25	5.85 (3.00) 2.50 – 14.25
• Total sleep in study period (hrs)	74.48 (16:35) 46 – 104	70:61 (14:86) 46-98
• Median length of sleeps during breaks	6.02 (1: 22) 1:45 - 7:00	5.72 (1.10) 4:00-8:00
• Number of sleeps taken in breaks across the study period	10.5 (2.3) 5 – 14	10.1 (2.2) 5-13
• % breaks with sleep	67.46 (23.12) 29 - 100	61.68 (20.8) 29-100

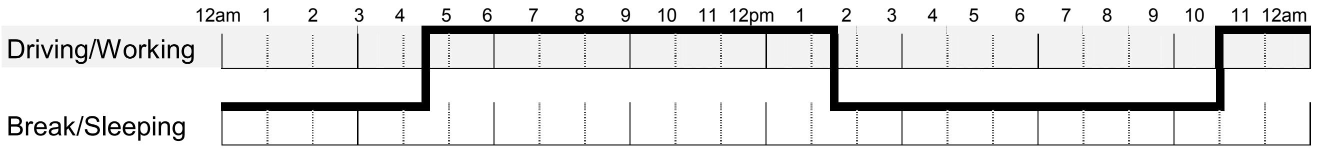
FIGURE 2: Average work-rest regime observed under the FMP

TRIP START

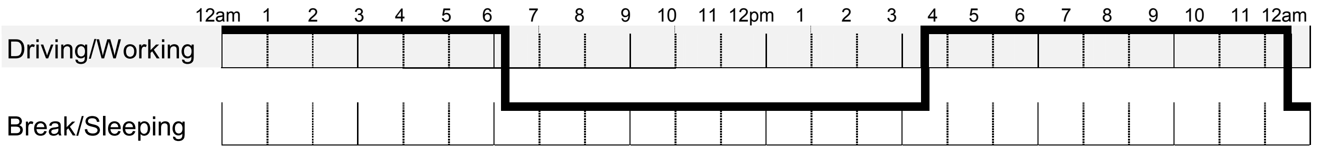
DAY 1 -



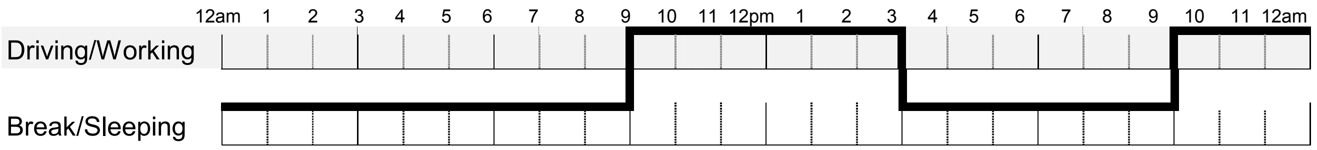
DAY 2 -



DAY 3 -



DAY 4 -



DAY 5 -

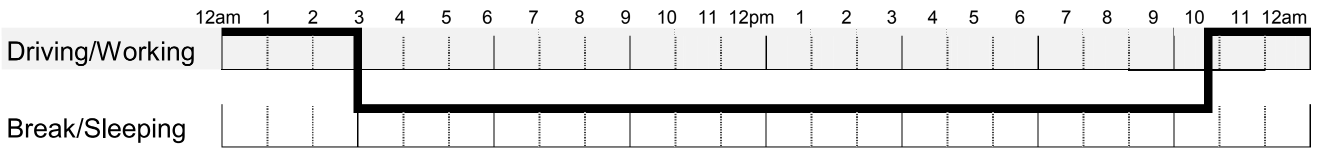
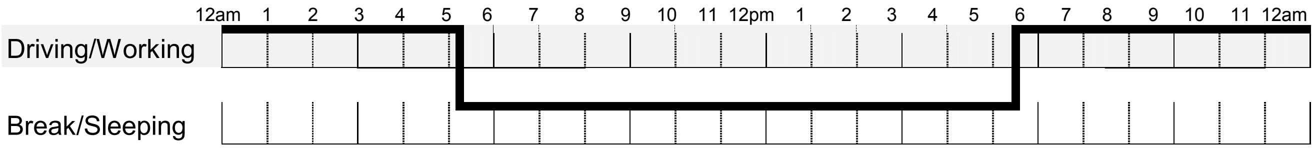
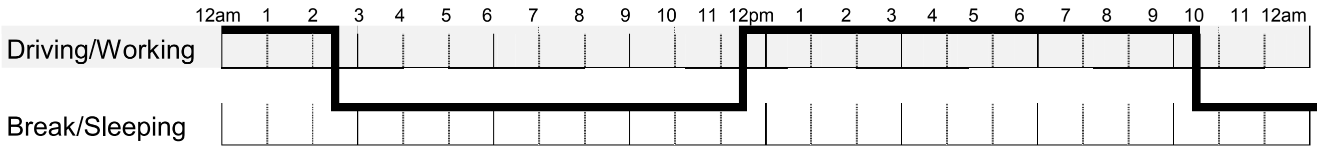


Figure 2 continued

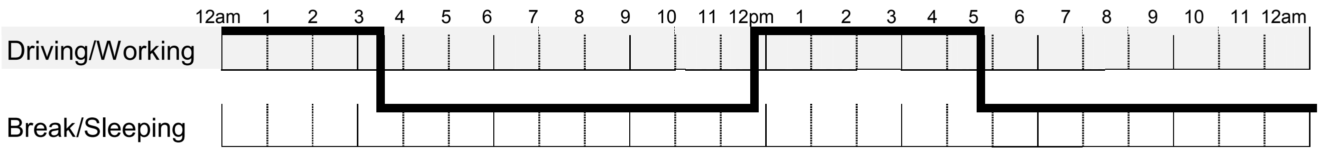
DAY 6 -



DAY 7 -



DAY 8 -

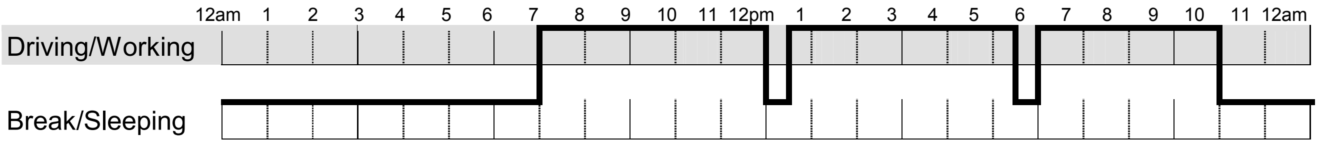


Note: This timeline represents the average work-rest regime of FMP drivers participating in the study. Only the first 11 work periods were included because this corresponded to the minimum number of breaks taken, so that the averages include the maximum possible number of drivers. The timeline was created by averaging the durations of the first 11 work periods and 10 breaks across drivers.

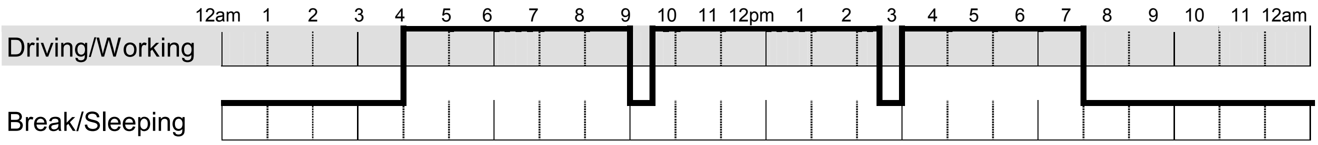
FIGURE 3: An 'average' work-rest regime under regulations

Working Hours Regulations Guidelines:

DAY 1



DAY 2



Note: These timelines represent only one interpretation of the regulations. The Working Hours Regulations offer more flexibility than is demonstrated above. For example, drivers are required to break for 30 minutes in every 5.5 hour block but it may be taken as one 30 minute break (as shown) or two 15 minute breaks under the Transitional Fatigue Management Scheme (TFMS).

Changes in fatigue ratings across the study period

The change in ratings of fatigue over the study period are shown in Table 5. The change in laptop and diary ratings of fatigue across the study period were similar. Both measures showed an increase in fatigue ratings across the study. Paired t-tests showed that this change in fatigue ratings was statistically significant over the work period for diary ratings of fatigue ($t_{(10)}$=3.43,p=0.006) and for laptop ratings ($t_{(13)}$=2.67,p=0.02).

Performance changes over the study period

Changes in performance over the work period are also shown in Table 5 for each measure of each palmtop test. The results for the palmtop Simple Reaction Time test showed no significant deterioration in performance for the measures, variability of reaction speed or number of missed signals (for standard deviation in reaction time, $t_{(11)}$=0.06,ns; for misses, $t_{(11)}$=0.12,ns). The change in reaction speed showed a trend to become slower over the study period, but this was not statistically significant ($t_{(11)}$=1.9,p=0.08). The results for the palmtop version of the Mackworth Clock Vigilance test also showed no significant change across the study period for any measure, reaction speed ($t_{(11)}$=0.98,ns), variability of reaction time ($t_{(11)}$=0.91,ns), the number of missed signals ($t_{(11)}$=1.0,ns) or the number of false alarms ($t_{(11)}$=1.21,ns).

Similar results were found for the laptop versions of these tests (Table 5). The results showed that reaction speed in the Simple Reaction Time test slowed significantly by the end of the study period ($t_{(13)}$=3.04,p=0.009). The other Simple Reaction Time measures, variability of reaction speed and

TABLE 5: Mean fatigue and performance at the start and end of the study period for the FMP driver group.

	MEASURE	START WORK PERIOD MEAN	START WORK PERIOD SD	END WORK PERIOD MEAN	END WORK PERIOD SD
LAPTOP TESTS					
• Simple Reaction Time (n=14)	*RT*	506.57	42.95	544.50	58.86
	RT variability	78.43	30.39	86.00	28.83
	# missed	0.43	0.85	0.71	0.91
• Mackworth Vigilance (n=14)	*RT*	1064.36	525.88	940.14	225.24
	RT variability	504.29	866.81	191.71	305.32
	# missed	2.29	3.17	3.29	4.08
	# false alarms	5.64	9.03	3.07	5.53
PALMTOP TESTS					
• Simple Reaction Time (n=14)	*RT*	660.08	86.17	691.25	93.51
	RT variability	120.67	32.45	120.00	36.94
	# missed	4.25	5.46	4.50	6.56
• Mackworth Vigilance (n=12)	*RT*	997.00	429.04	892.25	99.42
	RT variability	289.42	786.68	87.25	58.25
	# missed	0.67	1.23	0.92	1.00
	# false alarms	0.92	2.27	1.50	3.68
FATIGUE RATINGS					
• Laptop (n=14)		20.24	13.69	34.40	17.49
• Diary (n=11)		17.64	12.81	36.27	21.58

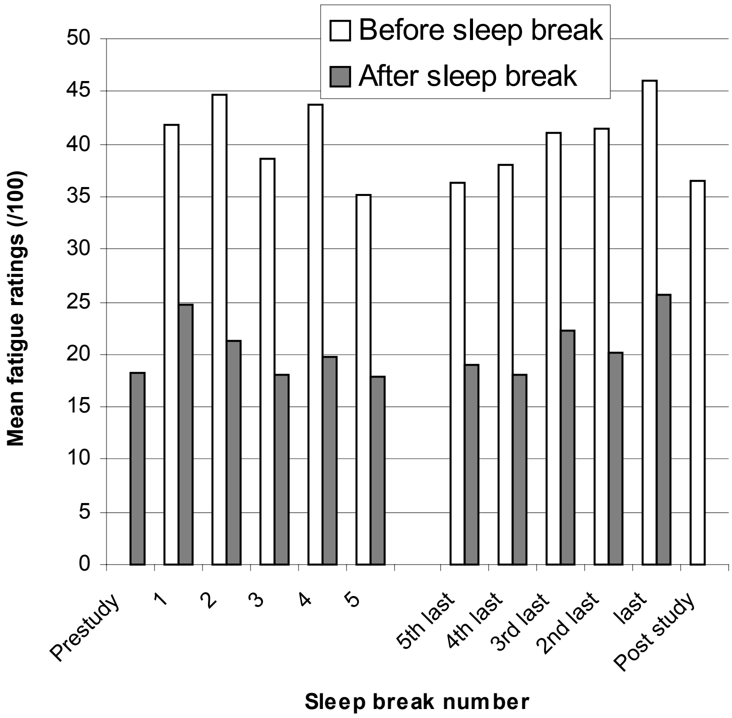
the number of misses showed no significant changes across the trip ($t_{(13)}$=0.82,ns; $t_{(13)}$=0.81,ns respectively). The results of the laptop version of the Mackworth Clock Vigilance test also showed no significant change across the study period for any of the measures, reaction speed ($t_{(13)}$=1.15,ns), variability of reaction time ($t_{(13)}$=1.70,ns), the number of missed signals ($t_{(13)}$=1.61,ns) or the number of false alarms ($t_{(13)}$=1.66,ns).

Analysis of the relative importance of the change in reaction time over the study was possible by comparing it with the 0.05%BAC equivalent performance standard developed in earlier laboratory studies. Response speed in the Simple Reaction Time test at the end of study was greater than the standardised response speed. This suggests that the deterioration in reaction speed across the study was reaching levels sufficient to compromise drivers' capacities to perform safely at the end of the study. The number of false alarms in the Mackworth test were also higher at the end of the study than the 0.05%BAC equivalence level, and although they had also increased across the study period, this was not a statistically significant change.

Figures 4 to 6 show the changes in fatigue ratings and in performance on each measure of the palmtop Simple Reaction Time and Mackworth Clock Vigilance tests across the study period. The points plotted are performance at first measurement occasion at the beginning of the study, then each measurement occasion before and after each subsequent break involving sleep ending with the last measurement at the end of the study period. As drivers took different numbers of breaks, for comparison purposes, the figures are drawn showing the first five breaks taken and the last five breaks taken as this reflects performance for the maximum number of drivers at each data point.

Ratings of fatigue showed relatively little change before sleep breaks over the first five breaks in the trip, but a steady increase in fatigue ratings before sleep breaks over the last five breaks of the trip. There was a striking improvement in fatigue levels following each sleep break throughout the study period.

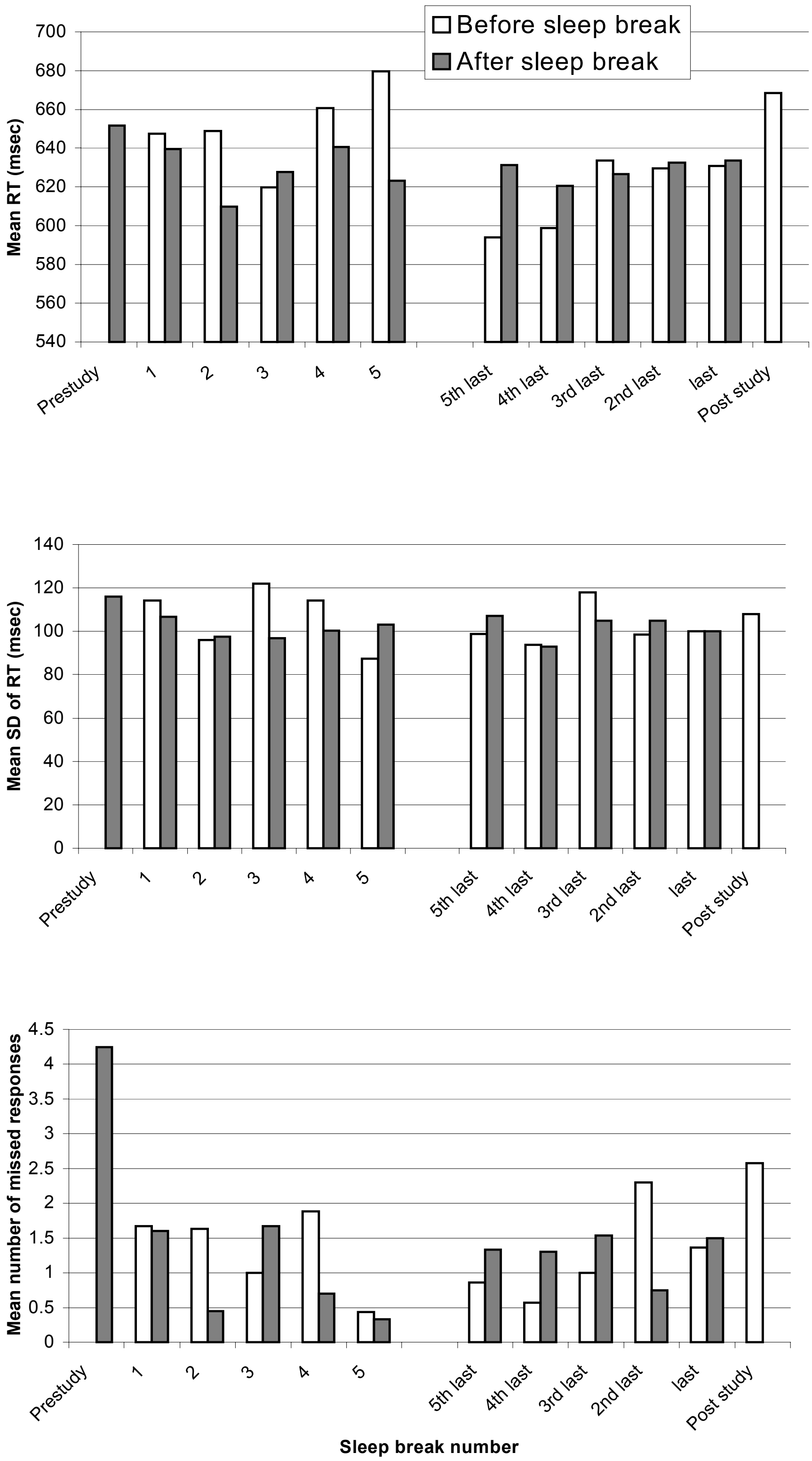
FIGURE 4: Rated fatigue before and after sleep breaks in the early and later parts of the study period



These results reinforce the finding of statistically significant increases in fatigue across the study period, but also reveal that even higher levels of fatigue had been experienced at earlier stages in the study.

For the Simple Reaction Time test, Figure 5 shows that reaction speed varied across the study period and did not show a simple linear decrease across the study period. Performance before the fourth and fifth sleep breaks in the study period was around the same level or worse than reaction speed performance at the end of the study period. Reaction speed was faster again in the tests for the last five breaks. It is again notable, however, that unlike the earlier sleep breaks where reaction speed improved after a sleep break, the last few sleep breaks made little or no improvement in reaction speed. This pattern of performance indicates that the final performance

FIGURE 5: Simple Reaction Time performance before and after sleep breaks in the early and later parts of the study period



test did not overestimate the deterioration in reaction time performance across the study. It would be expected that performance would improve following a sleep break, however, the pattern of performance suggests that sleep breaks did not always result in improved performance. For measures of variability of reaction speed, performance remained at around the same level throughout the study. As before, however, sleep breaks were less effective in the later parts of the study period. For the number of missed signals, performance at the beginning of the study was much poorer than at any other time, possibly reflecting a warm-up effect. The number of misses remained at around the same level throughout the study. The effect of sleep breaks was variable across the study period, although performance across the last five breaks tended to show more misses after the break compared to before the break.

For the Mackworth Clock Vigilance test, the graphs show that reaction speed increased considerably across the study. While examination of performance only at the beginning and end of the trip suggests that there was no significant change in reaction speed to the infrequent signals in this test, the plot of the data (Figure 6) indicates that performance in the period towards the end of the study was notably poorer than at the beginning of the study. In addition, there appeared to be little benefit from many sleep breaks across the trip as reaction speed remained the same or slowed after the sleep break for most sleep breaks in the trip. The results for the variability of reaction speed, false alarms and the number of missed signals on this test showed a similar pattern of greater variability and more misses in the later breaks and later parts of the study period, whereas the plots of the number of false alarms showed little change across the study. Overall, therefore, these results suggest that the analysis of the start and end milestones underestimated the changes in performance on the Mackworth Clock Vigilance test across the study period.

FIGURE 6: Mackworth Clock Vigilance performance before and after sleep breaks in the early and later parts of the study period

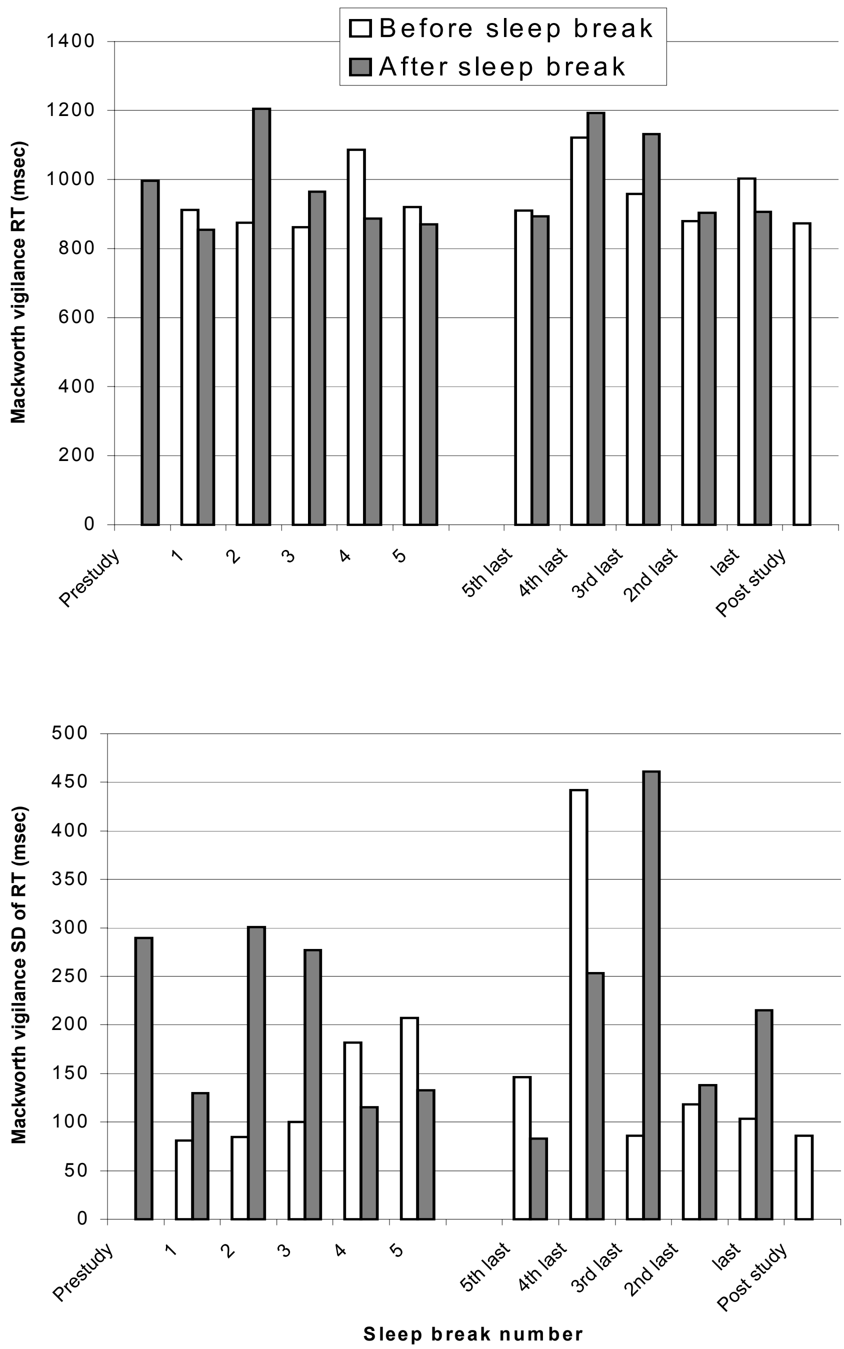
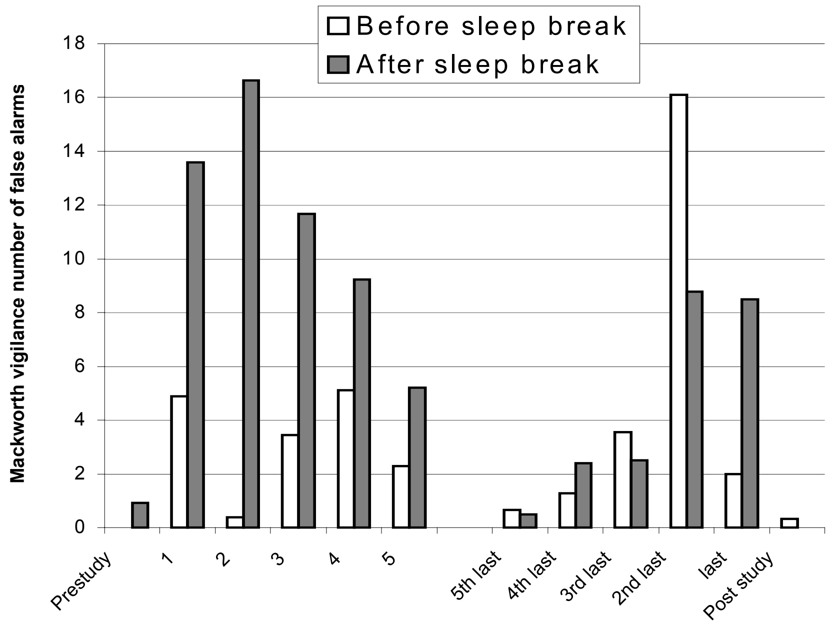
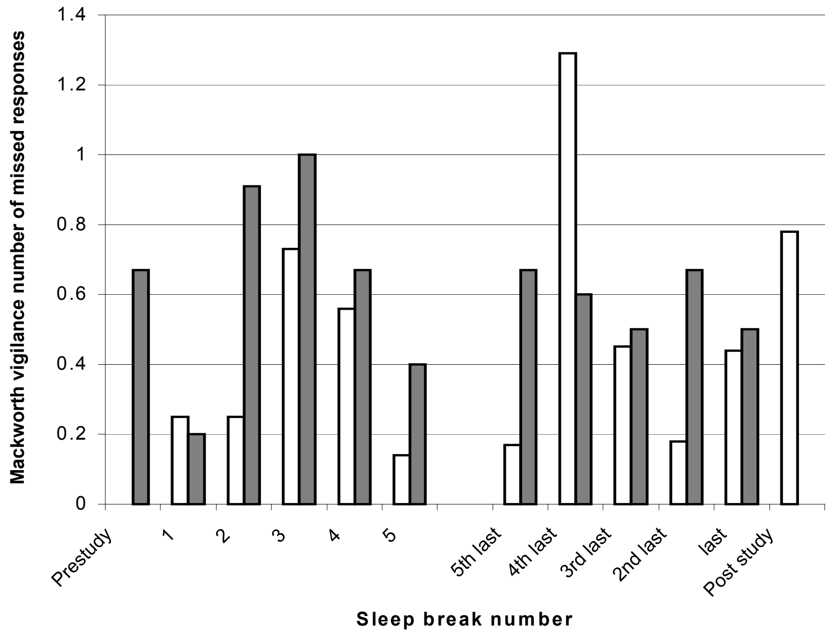


Figure 6 continued.





The relationship between work-rest experiences over the study period and fatigue and performance

The relationship between performance on both palmtop and laptop versions of the tests at the start and end of the study period and work-rest experiences before and during the study period was investigated by stepwise regressions.

Relationships at beginning of the study period

To investigate the predictors of performance at the beginning of the study, the set of variables included: the total hours worked in the seven days prior to the study period, the number of night hours worked, the time since the end of the last shift, the hours of sleep obtained since the last shift, the time since the most recent sleep and the quality of the most recent sleep.

For the palmtop tests, none of the measures for the Simple Reaction Time test had a significant predictive relationship with the work-rest variables. For the laptop version of the Simple Reaction Time test, both reaction speed and the number of missed responses were related to the estimated quality of the last sleep. (Respectively, regression equations are: RT=605.16 – 1.2 Sleep quality, $F_{(1,12)}$=9.93,p<0.008, r^2_{adj}=0.41; Misses=2.57 – 0.026 Sleep quality, $F_{(1,12)}$=14.38, p<0.003, r^2_{adj}=0.51). Drivers who rated their last sleep as lower in quality reacted more slowly and missed more responses. Variability of response speed was not predicted by prior work-rest.

For the palmtop version of the Mackworth Clock Vigilance test, reaction speed was predicted by the quality of the last sleep as well as its recency (Regression equation is RT=2444.97 – 16.27

Sleep quality – sleep lag, $F_{(2,9)}$=71.82,p<0.001, r^2_{adj}=0.93) so that lower quality and less time since the sleep predicted slower responses. Response speed variability was also increased as sleep quality fell and as the hours worked in the previous week increased (Regression equation is: SD=1431.53 – 26.91 Sleep quality + 17.80 work hours, $F_{(2,9)}$=51.40,p<0.001, r^2_{adj}=0.90). False alarms and missed responses were not related to prior work-rest. For the laptop version of the Mackworth Clock Vigilance test, however, regression analyses showed that the work-rest variables were not significant predictors of performance for any of the measures. When fatigue ratings at the start of the study period were related to prior work-rest variables using stepwise regression, none of the predictors were significant.

Relationships at the end of the study period

Stepwise regression analysis was also used to examine the relationship between performance at the end of the study period and four variables describing the amount of work and rest during the study: the total hours worked, the number of hours worked at night, the total hours slept and the number of breaks taken. Total work hours across the study period was a significant predictor for ratings of fatigue at the end the study period using both measures, diary ratings and laptop ratings (Regression equation is: for diary ratings: Fatigue=-103.64 + 0.995 total work; $F_{(1,9)}$=13.16, p<0.006; r^2_{adj}=0.55; for laptop ratings: Fatigue=-70.51 + 0.77 total work; $F_{(1,9)}$=9.37, p<0.01; r^2_{adj}=0.46), accounting for 55 and 46 percent of the variance in fatigue ratings. This result indicates that drivers who did longer total working hours reported greater fatigue.

For the palmtop version of the Simple Reaction Time test, regression analysis for performance at the end of the study showed no significant work-rest predictors for the reaction speed measure, the variability of reaction speed or for the number of missed signals. The laptop version of this test also showed no significant work-rest predictors for any of the measures at this time.

In contrast, for the palmtop Mackworth Clock Vigilance test, two measures were predicted significantly by work-rest variables. For the reaction speed measure, the number of breaks taken was the only significant predictor. Drivers who took more breaks during the study period reacted more quickly to the irregular signals in the Mackworth Clock Vigilance test (Regression equation is: Mackworth reaction speed=1190.9 – 18.64 total breaks; $F_{(1,8)}$=7.32, p=0.03; r^2_{adj}=0.41). For the number of misses, the total amount of sleep in the study period was the only significant predictor, such that drivers who obtained more sleep showed more missed signals in the Mackworth Clock Vigilance test at the end of the study period (Regression equation is: Mackworth misses=-3.60 + 0.6 total sleep; $F_{(1,8)}$=12.84, p<0.007; r^2_{adj}=0.57). For the other two measures of the Mackworth Clock Vigilance test, the number of false alarms and the amount of variability in reaction speed, there were no significant work-rest predictors of performance at the end of the study period.

For the end of study laptop version of the Mackworth Clock Vigilance test the number of false alarms was predicted by the work-rest variables. The regression analysis indicated that drivers who slept more in the study period, produced more false alarm responses (Regression equation is: Mackworth false alarms=-6.63 + 0.12 total sleep, $F_{(1,9)}$=5.81, p<0.004; r^2_{adj}=0.33). None of the other measures of the Mackworth Clock Vigilance test showed significant work-rest predictors in the regression analysis.

DISCUSSION

The results of this evaluation suggest that the alternative work-rest schedule employed in this FMP needs to be modified. This work-rest schedule differed from the regulated regime in that it allowed longer periods of active work without rest (6 hours instead of 5 hours and allowed the mandatory six hours of continuous rest to be taken in two parts instead of one. The results of the evaluation suggest that the balance between work and rest in this alternative schedule is not adequate for effective fatigue management.

In this evaluation, drivers reported increasing fatigue across the study period but the levels were never very high. The highest ratings of subjective fatigue reported by drivers were only at moderate levels compared to the overall fatigue scale available to be used. Drivers, it seems, felt that their fatigue levels increased at various times across the study period, but never rated their fatigue as excessive or even particularly high. Based on these results of these ratings, it would seem that the work-rest schedule was adequate for managing fatigue.

The major problem revealed by this evaluation, however, is the effect of the work-rest schedule on performance, particularly on reaction speed. First both laptop and palmtop versions of the Simple Reaction Time test showed significant slowing of reaction speed across the study period. Furthermore, the magnitude of the decrement in reaction speed was shown to be of concern when compared to standardised alcohol-equivalent performance at 0.05% BAC. Reaction speed at the end of the study had deteriorated sufficiently be of concern for safety through a decreased capacity to react to events on the road and this decrement can be compared with the community-accepted standard for on-road performance which was set at least in part on performance changes such as this.

In addition, performance on the Mackworth Clock Vigilance test also showed markedly slower performance at intervals across the study period. Again the levels of performance deterioration indicated a safety risk as it is likely that they were at or above the 0.05% alcohol-equivalence level on several test occasions over the study period. The results for both these tests demonstrate that this alternative work-rest schedule appears to be at a cost for drivers which influences their ability to perform safely. This conclusion is warranted because a deterioration in performance was found in this alternative schedule whereas the previous evaluation of the regulated regime did not show any significant change in performance capacity over a week of work. In both this study and the previous evaluation of the regulated working hours regime (Williamson et al., in press, CR190) ratings of fatigue increased over the study period, but only in the study of this alternative compliance approach was performance found to deteriorate significantly over the study period.

The FMP evaluation occurred over a two week rather than a one week period as for the regulated regime because the nature of the FMP trips kept drivers away for longer from their company base where testing started and ended. A possible reason for differences in performance effects between the two evaluations might be the greater length of time away from home for the FMP drivers. This would assume that driver fatigue builds up while on the road such that a two week evaluation produces poorer performance at the end of the study than a one week evaluation. The results of the FMP evaluation, however, show that drivers took regular breaks and regularly took breaks longer than 6 hours which suggests that they were able to obtain some rest. The pattern of breaks suggests that there was some variation across drivers in the way rest could be obtained. Some drivers tended toward many short breaks while others had fewer longer breaks. The percentage of breaks containing sleep was lower than for drivers in the regulated regime, therefore it is possible that rest taken on the road is not as effective in relieving fatigue as it would be if rest was taken at home. If this is the case, then one of the targets for modifying the FMP regime would be to reduce the amount of time away from home.

Further evidence for concern about this work-rest schedule arises because the evaluation showed relationships between work-rest characteristics and performance which were consistent with the effects of fatigue. The pattern of these relationships indicated that the performance decrements were related to length and quality of sleep and the number of breaks. At the beginning of the study, sleep in the rest period immediately before the study began was the single most important influence on performance. Poor sleep quality was a significant predictor of slow response time and more missed signals in the laptop version of the Simple Reaction Time test. For the Mackworth Clock Vigilance test, drivers who had comparatively little and poorer quality sleep before the study started, showed slower response speed to signals, and drivers who had worked for longest in the past seven days followed by poorer quality sleep immediately before the study started, also showed more variable reaction speed to signals. These results show that the drivers who derived least benefit from their last rest were most likely to suffer effects on their capacity to perform. Although all drivers had at least 25 hours rest before the study began and should have recovered from any build up of fatigue from the previous work period this was dependent on how effective their sleep actually was. The earlier evaluation of the regulated regime (Williamson et al., in press, CR190) which used a similar approach of beginning the study after a period of long rest also showed that performance capacity at the beginning of the study was at least partly due to how effectively sleep could reduce fatigue.

The work-rest characteristics over the study period, were also predictive of changes in subjective fatigue and performance. Drivers who did most work in this schedule rated themselves the most tired. This was also found for drivers in the first regulated regime evaluation (Williamson et al., in press, CR190) providing further evidence that long working hours are a serious risk factor for the experience of fatigue in driving. For the performance tests, there were no significant predictors for any measures of the Simple Reaction Time test, but for the Mackworth Clock Vigilance test, there was a significant predictive relationship between work variables and palmtop reaction speed. For the palmtop version, slower detection of signals in the Mackworth Clock Vigilance test was associated with having fewer breaks to rest and recover from the long working hours.

The evidence on the effectiveness of breaks also suggests that this work-rest schedule is not as effective for fatigue management as originally hoped. Many of the measures showed little or no improvement even after a sleep break, especially towards the end of the study period. This suggests that the break was not long enough or soon enough to overcome the build up of fatigue to that point. This effect was also seen over the second day of the simulated work-rest schedule study (Williamson et al., in press, CR190). Under this schedule, drivers did two consecutive 16 hour days separated by a six hour break. As in this study, it was shown that the benefit of a break for restoring performance capacity was lost by the second day of the schedule as driver fatigue increased and was not reversed by the amount of sleep available to them. Both of these studies highlight the importance for fatigue management of maintaining the appropriate balance between work and rest.

The results showed an apparently paradoxical effect on Mackworth Clock Vigilance performance at the end of the study, whereby drivers who slept the most over the study period appeared to have poorer performance, as seen by higher rates of missed signals on the palmtop version and more false alarms on the laptop test. The reason for this result is not clear and further analysis of the data did not clarify it. For example, there did not appear to be any work-related reason for the finding since drivers who slept more did not work longer over the study period or do more night work or take more breaks. Similarly, there were no apparent personal reasons for the tendency to sleep more that could have accounted for these findings in that drivers who had more sleep were not older or more tired at the beginning or end of the trip. Nor could these performance results be attributed to the effects of recent experiences at the end of the study, since the drivers who got more sleep over the study had not slept for longer in their last sleep period, had not been without sleep for longer nor had done more work in the period since they slept. In line with the suggestion that sleep taken on the road is less effective, it is possible that the poorer performance by drivers who actually slept more is due to the fact that all of the sleep was taken on-road and not at home. If this type of sleep is less effective, it is certainly possible that drivers who are trying to overcome their fatigue by getting more sleep will be the ones who show more adverse effects on performance rather than an improvement. Further research may help clarify these findings.

Taken together, these results also suggest that this alternative compliance-based work-rest schedule had adverse effects on performance and that these effects are of a sufficient magnitude to affect safety risk. Furthermore, this analysis points to the areas of most concern in the work-rest schedule. As found in earlier evaluations, the overall hours worked was important, but in addition, the amount of sleep and the number and timing of breaks taken were also shown to be important targets for reducing the fatigue-load of this work-rest schedule.

These findings therefore provide the link between performance decrements and characteristics of the work-rest schedule and help to identify what characteristics of the schedule could be modified to reduce the adverse effects on performance. Clearly the starting point would need to lie in tackling the major differences between this alternative compliance roster and the regulated regime, that is, to focus on the effects of dividing long breaks into smaller parts, which may not allow sufficient time for a long restorative sleep, and the length of work periods allowed in a single stint.

STUDY 2: EVALUATION OF A REGULATED WORKING HOURS ROSTER

This study was an evaluation of a work-rest schedule currently in use under the regulated working hours regime. The evaluation was basically the same design as the previous evaluations in this series. The aim, as before, was to examine changes in fatigue and performance over a representative period of work and rest.

METHOD

Design

Long distance truck drivers were studied across a regular working week. All of the drivers were working under NSW working hours regulations. That is, they were limited to 14 hours of work (12 of driving) in each 24 hour period. In any 24 hour period, drivers were also required to take one continuous break of not less than 6 hours, and 30 minutes of break time in every 5.5 hours of work. Drivers were not permitted to work more than 72 hours per week, and were required to take at least one continuous break of not less than 24 hours in that period. It should be noted that the regulations prescribe the work-rest limits and that, in this study, the actual rosters sampled were quite varied within these limits.

An attempt was made to commence measurement upon each driver's return to work after a break of 24 hours or more. However, this was difficult to achieve as many of the drivers employed by the company began their working weeks from their homes in regional centres, before reporting to the

Sydney depot where the study was based, so that the company found it difficult to integrate the demands of the study with their daily work scheduling. This meant that the specific duration of the study period also varied between drivers as a function of their roster, and the timing of their return to Sydney.

As in the previous study of FMP drivers, two cognitive psychomotor tasks (sustained attention and reaction speed) were presented via palmtop computers at the start and end of the study period, and drivers were asked to self-administer the tests at the start and end of every break from work during the study period which contained sleep. In addition drivers were also asked to test themselves at the start and end of non-sleep breaks spanning an hour or more. Drivers in the previous study were not asked to complete tests at these times, and in the current study compliance with this aspect of the procedure was not high – 36% of subjects did not keep records or test themselves around non-sleep breaks.

Consistent with Study 1, the accuracy of the palmtop test data was assessed by administering longer versions of the two tests on laptop computers at the start and end of the study.

In conjunction with the performance tests, drivers were asked to rate their subjective fatigue at the start and end of every break from work of one hour or more during the study period, and to provide some details about any sleep they may have taken during the break.

General background information was also collected on the drivers' health and lifestyle, and on their work pattern and activities in the period leading up to the study.

Subjects

Fifteen professional long-distance truck drivers, employed by a Sydney-based company specialising in refrigerated transport agreed to participate in the study. One of these subjects terminated his participation during the first work period of the study week. Table 6 summarises the characteristics of the remaining 14 people.

All of the drivers were men with an average of 19 years professional driving experience. The minimum was 8 years. Nearly half had more than 20 years' experience.

The majority of the subjects (71%) were aged between 30 and 49 years and most (71%) were living in a continuing relationship. All but one of the group had ceased formal education at or before Year 10. The group had little or no prior computing experience.

All of the drivers drank caffeinated drinks at an average frequency of 6.4 drinks per day. The majority of subjects (93%) drank alcohol rarely (29%) or once a week (50%). Fifty seven percent of drinkers tended to consume 4 or more drinks per occasion. Less than one third (29%) of the sample currently smoked.

TABLE 6: Demographic details of subjects

DEMOGRAPHIC FACTOR			**%OF SUBJECTS (N=14)**
SEX			
• Male			100.0
AGE			
• 20 - 29 years			7.1
• 30 - 39 years			35.7
• 40 - 49 years			35.7
• 50 - 59 years			21.4
RELATIONSHIP STATUS			
• Married/Defacto			71.4
• Divorced/Widowed/Separated			14.3
• Single			14.3
EDUCATION LEVEL			
• High school years 7 - 10			92.9
• High school years 11 - 12			7.1
PC EXPERIENCE			
• No previous experience			64.3
• A little experience			35.7
• Frequent PC user			0.0
SOCIAL DRUG HABITS			
• Cigarettes	- Non-smoker		57.1
	- Ex-smoker		14.3
	- Current smoker	%	28.6
		Average no./day *(SD)*	36.63 *(18.32)*
• Alcohol	- Non-drinker		7.1
	- Current drinker		92.9
• Caffeine		%	100.00
		Average no./day *(SD)*	6.42 *(4.03)*
DRIVING EXPERIENCE			
• Years of driving experience	- 5 - 10 years		14.3
	- 10 - 20 years		42.9
	- Over 20 years		42.9
		Range (years)	8-32

Materials and measures

i. Performance testing

The tests and testing equipment used were identical to those employed in the previous study.

ii. Documentation

Similar to the previous study, all subjects completed an informed consent form (Appendix 5) and a background questionnaire (Appendix 2) addressing health and lifestyle factors, recent workload, sleep, and food and drug intake. Drivers were provided with a "Work Diary" in which to record details of their work and rest schedule during the study, and to rate their fatigue before and after breaks (Appendix 6) and a set of written instructions for using the palmtops (Appendix 4).

Procedure

Volunteer drivers arrived at the testing room at the truck depot approximately 1 hour before they were due to depart on a trip. Once the nature of the study had been fully explained, drivers were asked to give formal consent before participating. They then completed a background questionnaire and were given instruction in the use of the palmtop computer, followed by a practice session of the palmtop tests. Drivers then completed a baseline test session on the laptop computer, followed by a self-administered baseline palmtop session. This last session also allowed drivers to consolidate their palmtop knowledge before commencing unsupervised tests on the road. (Round the clock assistance was, nonetheless, obtainable by phone.) Finally, the use of the "Work Diary" was explained, and drivers completed the questions relating to the start of the first work period of the study.

Drivers returning to the depot at the end of their final shift of the study period completed a palmtop test session, appropriate "Work Diary" entries, and the final laptop testing session.

Statistical Analysis

Because the three subjective rating scales produced similar results they were averaged to create single rated fatigue measures for the diary and for the laptop versions of the scales.

Comparisons of fatigue and performance measures between the beginning and end of the study period were conducted using t-tests. Performance at these occasions was also examined in relation to performance levels standardised against alcohol. Comparing the performance of drivers in this study with performance expected under 0.05% BAC, should provide a yardstick for estimating the level of safety risk at points in the study period.

The influence of the work and rest schedules before the trip on baseline fatigue and performance were analysed using stepwise linear regressions in which a range of work-rest factors were entered as predictors. The predictors used were: work hours in the past seven days, number of night hours worked, number of hours between the end of the last work shift and the start of the study period, total hours slept in this period, the hours since the end of the last sleep, and the rated quality of that sleep. A similar stepwise regression analysis was also used to estimate the influence of the work-rest experiences during the study period on fatigue and performance measures at the end of the study. The predictor variables were the total work hours between the start and end of the study, the amount of night work done over the period, the amount of sleep obtained over the period, and the total number of breaks taken.

The main evaluation of this work-rest schedule was carried out on a selected period of work from the data collected. As the actual schedules varied considerably between drivers, it was necessary to attempt to find a comparable period for each driver. The periods selected were the longest period of work in the roster which had no long rests within it, but which followed a period of long rest. Comparisons were then made on fatigue and performance measures at a series of three test milestones across the work: at the start of the first block of work, the end of the first block of work, and the end of the last block of work in the selected period. A repeated measures analysis of variance on one factor (test occasion) was performed for each measure. Multivariate Fs are reported unless they differ from the univariate Fs, in which case both are reported.

Missing data occurred throughout the study for a variety of reasons including driver forgetfulness, low motivation, technical problems with the palmtops, and practical constraints imposed by the work itself. This means that the reported analyses include varying numbers of people, depending on the particular measures and times in the study period being examined.

Comparisons between the laptop and palmtop test measures and between the laptop and diary fatigue ratings were also conducted and are presented in Appendix 7.

RESULTS

Recent work and rest history

The pattern of work and rest undertaken by the participants in the seven days leading up to the study is summarised in Table 7. Most drivers (84.62%) felt that the week was typical of their usual work schedule and load. However two subjects had spent a part of the week on leave, thereby reducing their overall hours. These were the only participants who reported working less than 50 hours, but their hours were, nonetheless, above 40. Typically, the drivers worked 63 hours in the week preceding the study.

Most of the drivers (78.57%) felt that their hours were usually distributed approximately equally between days (06:00am to 18:00pm) and nights (18:00pm to 06:00am), but 3 drivers reported working predominantly at night. Table 7 shows that in the 7 days prior to the study, an average of 43 hours, or 68.29% (SD=14.99) of reported work hours had occurred at night.

Immediately prior to commencing the study, about half of the drivers had a break of at least 6 hours, but the remainder started their participation during an ongoing shift, and so had no break immediately prior to the initial testing session. Most of these were drivers who started their shift in regional towns and drove to the company depot in Sydney before commencing participation in the study. These drivers had worked between 2 and 8 hours before the beginning of the study.

TABLE 7: Distribution of work hours in the 7 days prior to the study (N=14)

HOURS WORKED	N	% OF SUBJECTS
TOTAL WORK HOURS:		
• 50 hours	3	21.43
• 51-61	4	28.57
• 62-72 hours	5	35.71
• > 72 hours	2	14.29
	Mean *SD*	63.39 *13.45*
	Range	41.50 - 90.00
NIGHT WORK HOURS:		
• 30-39 hours	5	35.71
• 40-49 hours	6	42.86
• ≥ 50 hours	3	21.43
	Mean *SD*	42.82 *10.49*
	Range	30.00 - 70.00
TOTAL DURATION OF LAST SHIFT:		
• < 10 hours	8	57.14
• 10 - 14 hours	1	7.10
• 15 - 24 hours	5	35.71
	Mean *SD*	10.00 *6.61*
	Range	1.50 - 21.00
HOURS WORKED IN LAST SHIFT:		
• < 10 hours	8	57.14
• 10 - 14 hours	5	35.71
• 15 - 24 hours	1	7.10
	Mean *SD*	8.20 *4.84*
	Range	1.50 - 16.00
HOURS SINCE END OF LAST SHIFT:		
• 0 hours	4	28.57
• 1-6 hours	2	14.29
• 7-12 hours	4	28.57
• 13 - 24 hours	1	7.14
• > 48 hours	3	21.43
	Mean *SD*	19.20 *27.94*
	Range	0 - 87.50

Regardless of the time elapsed since the last work period, the length of the last shift was typically less than 10 hours, most of which (about 8 hours) was spent working.

Table 8 shows details of the drivers' sleep leading up to the start of the study and their subjective fatigue at baseline. As many drivers had already started their work shift when the study began, their last substantial sleep (as defined by the drivers) typically occurred 11 or so hours before the start of the study and averaged approximately 6 hours in length. Drivers generally rated this sleep as of good quality and reported feeling quite refreshed on waking.

TABLE 8: Details of rest since end of last shift (n=14)

	MEAN	RANGE	MEDIAN	SD
LAST SUBSTANTIAL SLEEP				
• Length (hours)	5.89	2.00 - 10.00	5.00	2.31
• Hours since waking	10.63	0.00 - 36.50	10.75	9.49
• Rated quality (/100)	73.96	41.00 - 100.0	83.00	20.69
• Rated refreshedness (/100)	65.57	19.00 - 90.00	67.50	21.65
LAST NAP SINCE SUBSTANTIAL SLEEP (N=3)				
• Length (hours)	1.08	0.50-1.75	1.00	0.63
• Hours since waking	5.08	1.25 - 9.00	5.00	3.88
• Rated quality (/100)	34.67	5.00 - 50.00	49.00	25.70
• Rated refreshedness (/100)	45.17	8.00 - 80.00	47.50	36.06
BASELINE FATIGUE RATINGS (/100)				
• Laptop	37.62	5.00-81.67	41.67	21.11
• Diary	32.89	7.33 - 93.33	32.50	20.90
(Note: Higher ratings indicate higher fatigue)				

Three subjects had napped since their last substantial sleep. Their naps were approximately one hour long and occurred approximately 5 hours prior to the start of the study. Average rated sleep quality and refreshedness after naps were noticeably lower than after more substantial sleeps. Almost all drivers reported moderate fatigue levels at the start of the study although there was a considerable range of ratings.

Drivers had typically eaten a light (35.71%) or moderate (57.14%) meal approximately 5.5 hours before the start of the study. Only 3 drivers reported consuming snacks since their last meal. On average drivers had consumed 2.5 caffeine-containing drinks prior to starting the study, with the last being approximately 1.5 hours before commencement. The period between last alcohol intake and study commencement was typically 5.4 days, and the minimum period was 8.5 hours

Description of the study period

Table 9 summarises drivers' overall pattern of work and rest during the study period. The length of the study period averaged approximately 7 days (=168 hours). Clearly, however, the periods of participation varied quite markedly across drivers from 4.73 to 12.05 days. This variation resulted from differences in the point in the roster cycle at which drivers commenced the study, the timing of their subsequent breaks of 24 hours or more, and the timing of their return visits to the Sydney depot. Regardless of the overall length of their study period, drivers typically spent almost half (45%) of it working. In turn, approximately half (51%) of this work time occurred at night (18:00pm to 06:00am). Individual work periods (bounded by longer rest of one hour or more) were around 7 hours long and incorporated 5 to 6 hours of work, of which approximately 5 hours was driving.

TABLE 9: Work experiences in the study period

	N	Mean	SD	Range
WORK				
• Total length of study period (hrs)	14	166.96	45.72	113.50 - 289.25
• Hours worked	12	70.90	17.71	43.50 - 99.00
• % of study period worked	12	45.18	6.99	38.33 - 58.06
• Night hours worked	14	38.73	17.67	19.40 - 84.55
• % working hours done at night	12	51.33	11.35	30.55 - 71.26
• Median length of work periods (hrs)	14	7.11	4.02	2.88 - 16.50
• Median hours work per work period	14	6.58	3.43	2.87 - 13.00
• Median hours driving per work period	14	5.56	2.79	2.63 - 12.50
REST				
• Mean number of breaks	13	9.62	3.59	6.00 - 16.00
• Median length of breaks	14	5.66	3.30	1.50 - 13.50
• Total hours sleep during breaks	14	37.89	9.20	26.00 - 57.75
• Median length of sleeps	14	4.21	1.59	1.87 - 8.00
• Total number of sleeps	14	6.93	1.54	4.00 - 10.00
• % breaks with sleep	13	76.36	16.43	58.33 - 100.00

Across their study period, drivers averaged 9 to10 longer rest breaks of one hour or more, and approximately three quarters of them involved sleep. Breaks tended to be about 5 hr 40 mins long, but there was marked variability in the length of breaks taken by each person over their study period. Sleeps averaged just over 4 hours in length.

Regressions between performance and subjective fatigue on the one hand, and work and rest variables

i. Relationships at the beginning of the study period

The relationship between prior work-rest variables and fatigue at the beginning of the study were examined using a stepwise regression. The beginning of the study was chosen for this analysis as it was the point that provided the most complete data in this evaluation. A set of six work-rest variables was used, which included the number of hours worked in the last seven days, the number of hours worked at night in the last seven days, the time in hours between the end of the last shift and the current one, the amount of sleep since the end of the last shift, the time since the last sleep and the drivers' ratings of sleep quality. This variable set was chosen as it included the work-rest variables most likely to influence fatigue and performance and because it had been used in the previous on-road evaluation of current working hours regulations. Ratings of fatigue at the beginning of the study were significantly predicted by the rated quality of the last sleep before the start of the study. Drivers who reported better sleep in the last sleep period also reported lower fatigue at the beginning of the study (Regression equation is: Fatigue = 64.55-0.46 sleep quality; $F_{(1,12)}=6.38, p<0.003$; $r^2_{adj}=0.29$). None of the other variables were significant predictors of fatigue at the beginning of the study.

The relationship between work rest variables and performance at baseline were also examined using the same variables in a stepwise regression. The analysis of the relationship between work-rest experiences at baseline and the palmtop version of the Simple Reaction Time test showed that the number of work hours in the past seven days was a significant predictor of reaction speed in this test and accounted for a large proportion of variance (Regression equation is: RT = 412.95+

3.70 work hours; $F(1,11)=15.52, p<0.002$, $r^2_{adj}=0.55$). This result showed that reaction time slowed significantly with increasing work hours over the last seven days. No other variables were significant predictors of Simple Reaction Time speed. Similar analysis for the standard deviation and misses measures of the Simple Reaction Time test showed no significant predictors amongst these work-rest variables.

For the Mackworth Clock Vigilance test, the only measure that was predicted significantly by aspects of the work-rest schedule in the past week was standard deviation of reaction time which demonstrated that drivers who reported obtaining better quality sleep in their last sleep period showed more consistent reaction time results (Regression equation is: SD=185.51-1.36 sleep quality; $F(1,11)=7.26, p<0.02$, $r^2_{adj}=0.34$). None of the other measures from the Mackworth Clock Vigilance test, reaction time, false alarms or missed signals were predicted significantly by any of the work-rest variables used.

ii. Relationships at the end of the study period

A similar stepwise regression analysis was carried out to look at the influence of work-rest predictors on fatigue and performance at the end of the study period. For this analysis the predictor variables were the total work hours between the start and end of the study, the amount of night work done over this period, the amount of sleep obtained over the period and the total number of breaks taken. The results showed no significant predictors for ratings of subjective fatigue, showing that any changes in fatigue at this time were due to factors other than the work-rest variables used in this study.

For the palmtop version of the Simple Reaction Time test, the reaction speed measure was significantly predicted by the total amount of night work done during the study period (Regression equation is: Reaction speed = 466.13 + 4.04 night work; $F_{(1,10)}=6.70$, $p<0.03$; $r^2_{adj}=0.34$). This result shows that drivers who did more night work had slower reaction times at the end of the study period. Neither of the other two Simple Reaction Time measures, variability of reaction speed and number of missed signals, were predicted significantly by the work-rest characteristics of the past work period. The number of missed signals, however, was significantly correlated with the total number of night hours worked ($r_{(12)}=0.51$, $p<0.045$) suggesting that drivers who did more night work were also more likely to miss signals.

For the palmtop version of the Mackworth Clock Vigilance test, the only measure that was predicted by any of the work-rest variables was the number of false alarms for which the total number of breaks taken was a significant predictor (Regression equation is: False alarms=1.23 - 0.09 Number of breaks; $F_{(1,10)}=7.45$, $p<0.02$; $r^2_{adj}=0.37$). This result indicates that the rate of false alarms was higher in drivers who did not have many breaks over the study period.

Comparison of test results with 0.05% BAC standard

Table 10 presents performance on the laptop version of the tests at the start and end of the study period. None of the measures on either the Simple Reaction Time test or the Mackworth Clock Vigilance test showed any significant difference between the two test occasions when compared using paired t-tests (Simple Reaction Time task: RT $t(13)=0.75$, ns; SD $t(13)=0.13$, ns; misses $t(13)=1.84$, $p=0.09$; Mackworth task: RT $t(13)=1.11$, ns; SD $t(13)=1.11$, ns; false alarms $t(13)=1.76$, ns; misses $t(13)=0.77$, ns). There was a non-significant trend for the number of missed signals on the Simple Reaction Time task to increase between pre and post study, but this appeared to be due to a small number of drivers, rather than a general increase across the group. These results might be expected given the variation in work and rest that preceded each testing occasion for the different drivers.

Of more interest, is the comparison of these performance levels with the levels expected when blood alcohol is high enough to cause concern (0.05% BAC). As Table 10 shows, performance levels were well within the 0.05% BAC estimates on both tests at both occasions, except for the number of missed responses on the Simple Reaction Time task at the end of the study period where performance was at the 0.05% BAC level. As noted above, however, this result is due to a small subset of the drivers so that although most of the drivers were performing within safe limits some were not. The number of false alarms in the Mackworth Vigilance test did not differ across the study period and were also not different from the alcohol equivalent standard. This finding is difficult to interpret as it is not always clear why false alarms occur. For example they can occur because a driver is very alert and keen to do well and responding too often, or because the driver is trying to increase the amount of stimulation available in an otherwise boring task.

TABLE 10: Mean laptop performance at the start and end of the study (n=14) with predicted performance at 0.05% BAC

Task and measure	Time in study	Mean	SD	Mean predicted performance at 0.05% BAC
SIMPLE REACTION TIME				
• *RT*	Start	509.07	40.19	534
	End	520.43	46.23	
• RT variability	Start	81.86	33.98	94.79
	End	83.21	37.26	
• # missed	Start	0.21	0.43	1.17
	End	1.21	1.97	
MACKWORTH CLOCK VIGILANCE				
• RT	Start	865.71	109.64	1094
	End	933.79	246.81	
• RT variability	Start	84.07	45.92	304.3
	End	262.29	610.42	
• # missed	Start	2.29	2.61	4.09
	End	3.07	3.32	
• # false alarms	Start	2.00	2.32	1.63
	End	1.21	2.36	

Analysis of selected periods

In this evaluation, it was intended to begin studying each driver from the first trip after they had taken at least a 24 hour break. This was not possible as many drivers began their trips from their homes in regional centres rather than from the company depot. In order to evaluate the effects of the work-rest schedule on fatigue and performance in this group of drivers, it was necessary to find a common work period for all drivers. On inspection of the work patterns, the best period available for all drivers was the longest period of work uninterrupted by a long break of 24 hours or more. For selection, this period of work also needed to be bounded by measurement occasions (involving performance tests and fatigue ratings) so that the effect of the long work period could be evaluated. This period was selected as it should reveal the effects of a sustained period of work by drivers under this roster. Several drivers (N=4) did not have sufficient complete data to be included in this part of the analysis, so the numbers of people involved was reduced.

i. Description of work and rest in the selected periods

Table 11 summarises the characteristics of the selected periods. All drivers had a substantial break of between 26 hours and 60 hours before the selected period. As a number of drivers had to come into the company depot from regional areas about half of the drivers had done some work since their long break before being tested at the start of the study period. For these drivers, this meant that they had worked for long enough to have one or two breaks before the study started.

The amount of work done during the selected period varied considerably between drivers, ranging from just less than 24 hours to covering nearly six days. Consequently the number of hours worked also varied considerably, although most drivers worked for more than 60% of the selected period, with three drivers working for more than three-quarters of the period. All drivers did at least one third of their work in this period at night, with many doing much more night work. The length of work periods and number of hours worked in each work period during the selected period was slightly higher than reported for the whole study period, although the number of hours spent driving per work period did not differ. During the selected period, the distribution of rest and sleep showed a similar pattern to the rest of the study period.

TABLE 11: Characteristics of selected periods

	N	MEAN	SD	RANGE
PRIOR WORK AND REST				
• Length (hours) of last long break (>24 hours)	6	41.79	13.06	26.50 – 59.50
• Hours work since last long break	9	6.00	5.92	0.00 – 14.50
• Hours breaks since last long break	9	4.75	7.54	0.00 – 21.25
WORK DURING PERIOD				
• Total length of period (hrs)	10	84.24	40.80	18.75 - 139.00
• Hours worked	10	49.47	22.70	16.50 - 82.00
• % of period worked	10	62.73	16.19	38.30 - 88.00
• Night hours worked	10	23.48	11.38	7.5 - 42.75
• % working hours done at night	10	48.87	15.46	30.16 - 77.00
• Median length of work periods	10	8.51	5.34	3.00 - 19.00
• Median hours work per work period	10	8.33	4.85	3.00 - 15.75
• Median hours driving per work period	10	5.51	2.40	2.75 - 9.00
REST DURING PERIOD				
• Mean number of breaks	10	6.20	4.61	1.00 - 13.00
• Median length of breaks	10	5.00	3.26	1.50 - 10.25
• Total hours sleep during breaks	9	19.83	9.71	5.00 - 38.00
• Median length of sleeps	9	4.22	1.13	2.00 - 5.25
• Total number of sleeps	10	4.3	2.75	0 - 8
• % breaks with sleep	10	72.22	31.86	0.00 - 100.00

ii. Description of milestones within selected periods

To examine gross changes in fatigue and performance across the selected periods, three functional milestones, or test occasions, were selected. These were: the start of the first work period in the selected period, the end of the first work period in the selected period, and the end of the last work period of the selected period. In this way, change due to a single work period and change due to a continuous sequence of work periods could be examined.

Table 12 presents information summarising the characteristics of the milestone occasions. The first and last work periods were similar in terms of length, but the hours spent working and driving during the last work period tended to be slightly longer than in the first work period. Similarly, the amount and quality of sleep and the ratings of refreshedness after the sleep preceding the last work period was slightly less than in the first period.

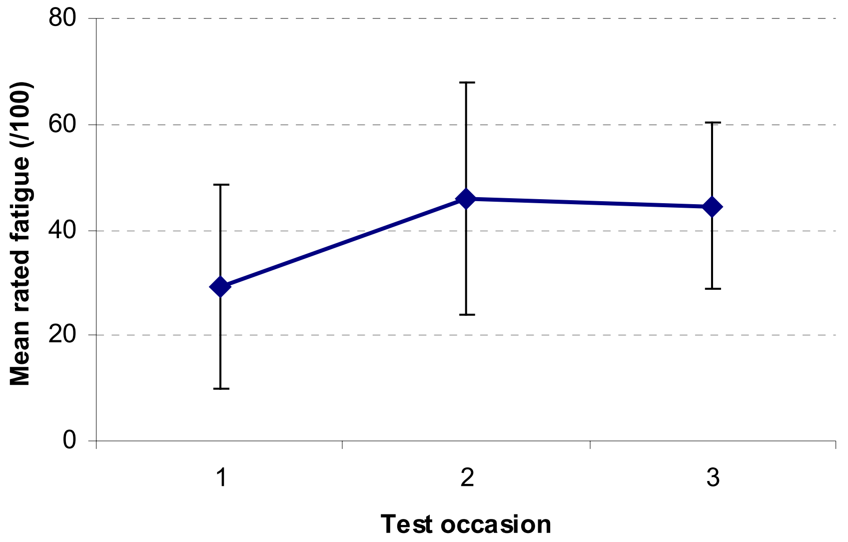
iii. MANOVAs of performance and subjective fatigue at functional milestones

MANOVA analyses with one repeated measures factor (test occasion) were conducted on the subjective fatigue ratings at the 3 milestones, as well as on the various performance measures derived from the Simple Reaction Time and Mackworth Clock Vigilance tasks. Mean fatigue levels at the 3 test occasions are illustrated in Figure 7. While there was an increase in mean subjective fatigue levels across the first work period to levels which remained at the end of the last period, statistical testing revealed that changes across the three occasions were not significant ($F_{(2,6)}$=0.54, p=0.61).

TABLE 12: Characteristics of milestone occasions in the selected measurement periods

	N	MEAN	SD	RANGE
WORK				
• Length (hours) of:				
- 1st work period	10	8.20	6.75	1.00 – 23.25
- last work period	10	8.92	5.97	2.00 – 19.00
• Hours spent working during				
- 1st work period	9	7.67	6.15	1.00 – 20.00
- last work period	10	9.42	5.68	2.00 – 16.50
• Hours spent driving during:				
- 1st work period	9	5.11	4.09	1.00 – 15.00
- last work period	10	7.29	4.80	2.00 – 14.00
REST				
• Hours since end of prior work period at:				
- start of 1st work period	10	15.35	17.71	0.50 – 48.00
- start of last work period	10	6.73	6.09	0.75 – 17.0
• Hours of sleep preceding:				
- 1st work period	10	6.50	7.84	0.00 – 18.00
- last work period	9	4.08	2.78	0.75 – 9.00
• Rated quality of sleep (/100)				
- 1st work period	5	77.70	14.97	51.00 – 86.00
- last work period	7	66.29	24.88	31.00 – 94.00
• Rated waking refreshedness (/100)				
- 1st work period	5	84.20	9.50	68.00 – 92.00
- last work period	7	62.07	26.84	27.00 – 96.00

FIGURE 7: Mean fatigue ratings at milestones in selected periods with 95% confidence intervals



Results for the Simple Reaction Time task measures (Figure 8) and Mackworth Clock Vigilance task measures (Figure 9) showed very little change across the first work period or to the end of the selected work period. Mean reaction speed (RT) and variability in reaction speed (SD) on the Simple Reaction Time task were almost identical at the three test occasions, and did not differ statistically ($F_{(2,6)}$=0.06, p=0.95 for RT and $F_{(2,6)}$=0.28, p=0.77 for SD). Mean number of missed responses on this test dipped slightly at the end of the first work period, and increased again at the end of the last work period but the changes were not statistically significant ($F_{(2,6)}$=2.15, p=0.20). Reaction speed, variability in reaction speed and the number of missed responses on the Mackworth Clock Vigilance task all showed minimal change across the three test occasions, which was reflected in the non-significant statistical tests ($F_{(2,5)}$=0.46, p=0.66, $F_{(2,5)}$=0.13, p=0.88, and $F_{(2,5)}$=0.80, p=0.50 respectively). The mean number of false alarm responses appeared to peak at the end of the first work period but, again, the effect was not significant ($F_{(2,5)}$=2.41, p=0.19).

FIGURE 8: Simple Reaction Time performance at milestones in selected periods with 95% confidence intervals

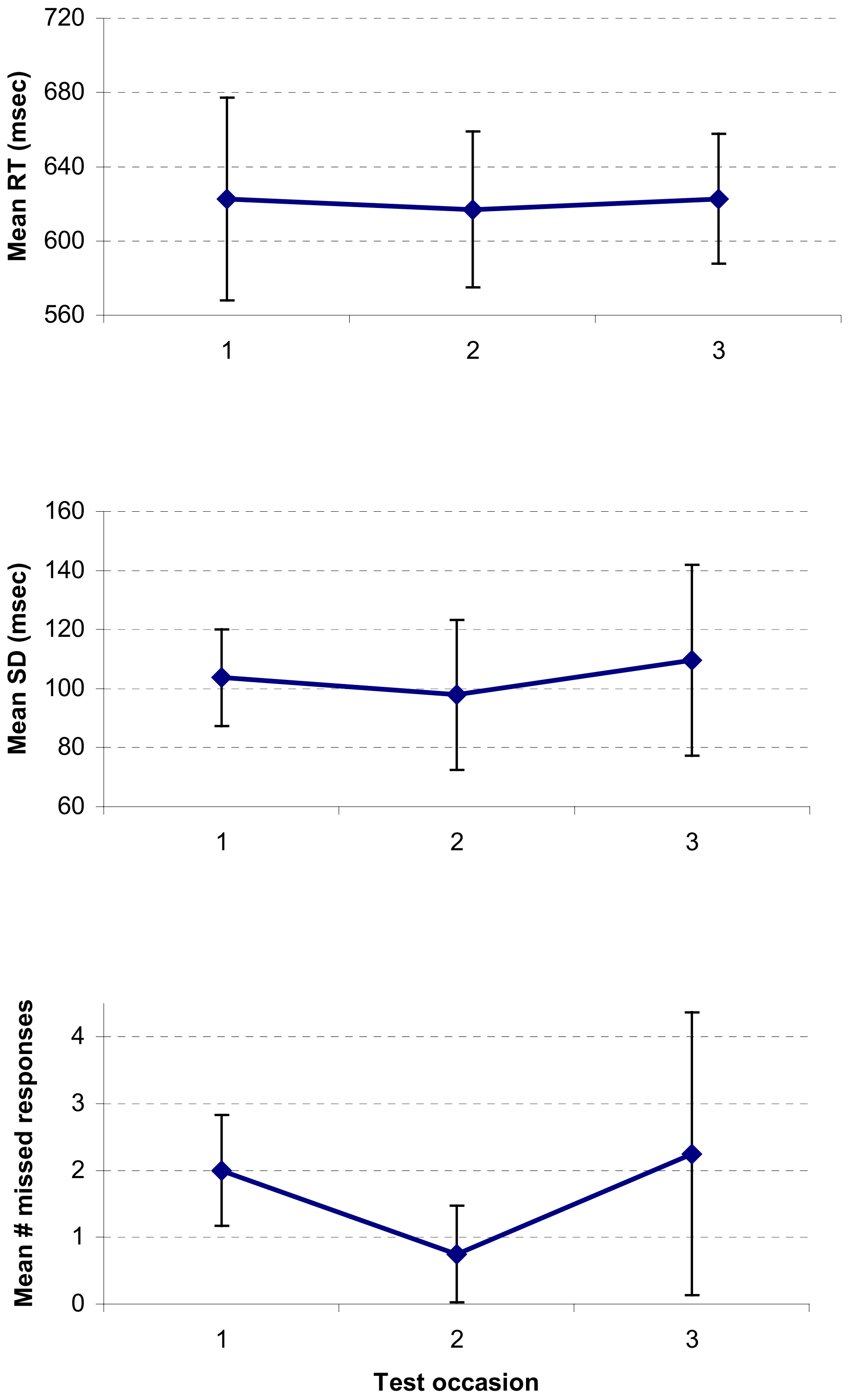
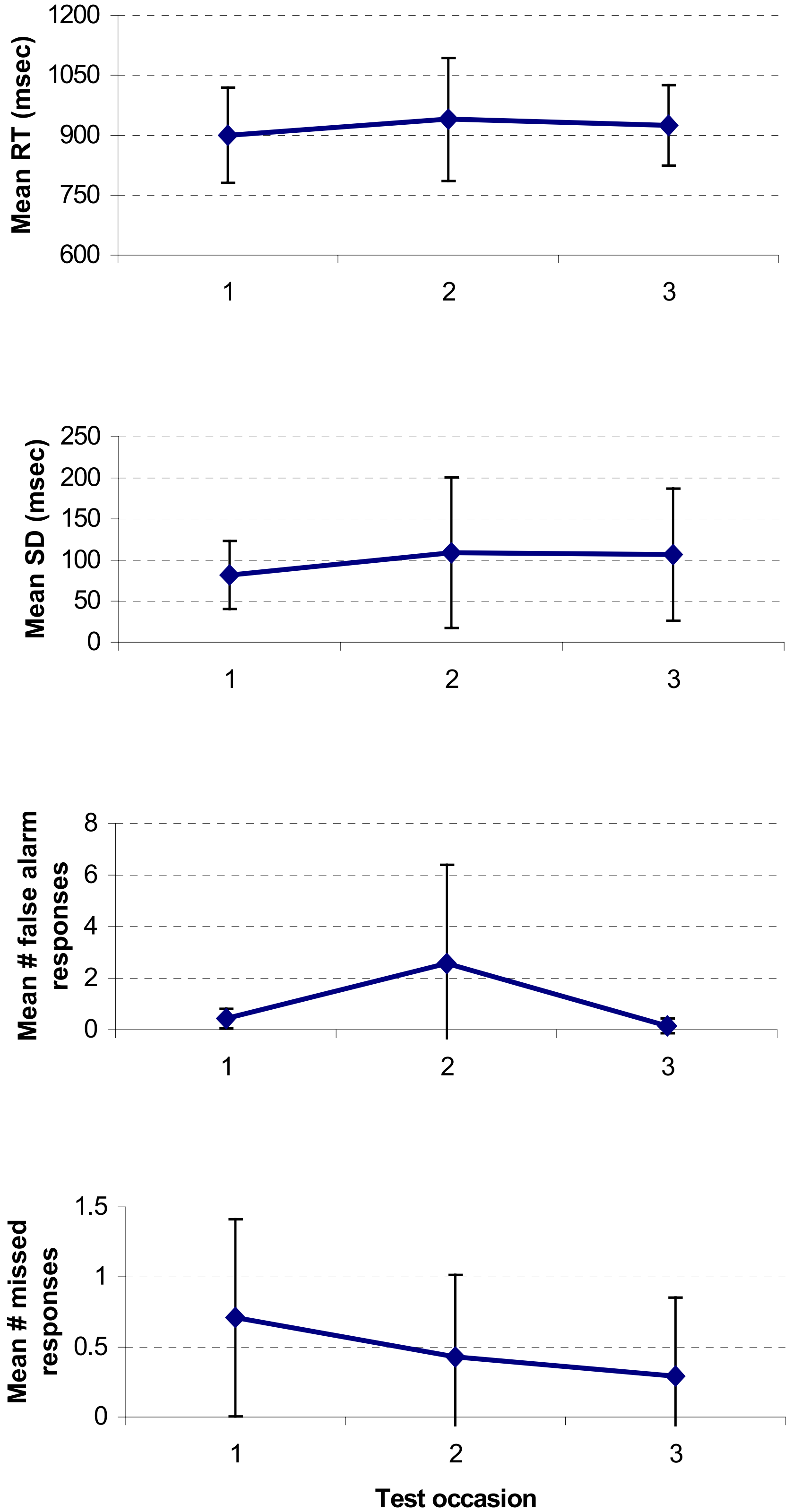


FIGURE 9: Mackworth Clock Vigilance Performance at milestones in selected periods with 95% confidence intervals



DISCUSSION

The results of this study showed little evidence of significant increases in fatigue or deterioration in performance capacity over a selected period of work on this company roster. Fatigue ratings showed only minor, non-significant changes from the beginning of the study period across the first work period for the remainder of the study period. Similarly, Simple Reaction Time and Mackworth Clock Vigilance test measures also showed only slight changes across the study milestones

It was difficult, however, to achieve the comparisons of interest in this study; that is of the relationships between work and rest, fatigue and performance in drivers doing this roster. In particular, the study design was attempting to look at drivers after they had the longest rest break in the usual schedule, then to follow any changes in performance capacity and subjective fatigue over the work period before their next long break. This was the study design used in the previous study of regulated working hours (Williamson et al., in press, CR190). Unfortunately, this was achieved for fewer than half of the drivers. Many of the drivers were based a considerable distance from the company depot. This meant that after a long break of 24 hours or more, these drivers had to drive as many as seven hours between their home and the company depot to begin work. This meant also that the first measurement occasion of the study often occurred after a considerable period of work rather than rest. Therefore, at the starting point for the study drivers were not particularly rested and there was no time in the study that could be used to estimate how drivers perform when they are rested. Since the beginning and end of the study period were relatively similar in that they occurred after work rather than rest, it is not very surprising that no significant changes were found in fatigue or performance capacity. It is possible, however to make estimates of how drivers' performance in this roster compares with the alcohol equivalent standards for performance established in the earlier laboratory study (Williamson, et al., in press, CR189). For the Mackworth Clock Vigilance test, the main measures were well within the estimated performance standard indicating that performance capacity on this roster could be regarded as within safe margins of risk. For the Simple Reaction Time test, response speed and variability in response speed were also clearly inside the limits estimated for 0.05% BAC. However, at the end of the study, the number of missed responses was high enough for a subgroup of drivers to be of concern.

Just as in the previous study of the regulated working hours regime, the regression analysis showed similar relationships between features of the work-rest schedule and fatigue and performance for this roster. Drivers who did the longest working hours and longest night hours showed slowed reaction time in the Simple Reaction Time test. This is an important finding, first because working hours accounted for 55 percent of the variance in reaction speed, indicating a strong relationship between them, and second because this finding confirms earlier work. This result shows again that long periods of work will produce adverse effects on performance if the work periods are long enough. In a similar vein, the value of breaks was important for producing good performance in the Mackworth Clock Vigilance test. Where drivers had fewer breaks or poorer quality sleep in their breaks, their ability to maintain consistent and accurate performance on the Mackworth Clock Vigilance test was adversely affected.

Overall, the results of this evaluation suggest that fatigue and performance capacities are being maintained within safety limits in this roster. However, the difficulties encountered in this evaluation highlight some of the problems of performing applied work in the long distance road transport industry. Since such a high proportion of the drivers' time is taken up with work and the frequency of long breaks is quite low, it can be very difficult to get to drivers at the right point to begin a study. This means that the part of the evaluation that attempted to compare drivers when they were rested and working was not a success. It is not possible therefore to conclude that fatigue and performance were managed effectively in this roster. The fact that ratings of fatigue were low and performance was at, or below, the 0.05% BAC equivalent standard suggests that the roster is allowing adequate rest to balance work. We should be cautious in these conclusions, however, as there is again clear evidence from this evaluation, as from the previous one, that long hours of work affect the capacity to perform safely.

GENERAL DISCUSSION

These evaluations showed again that by studying the effects of work-rest characteristics on fatigue and performance capacity, it is possible to reveal which schedules are better approaches to fatigue management and which aspects of existing ones might be focussed on to improve the schedule. The evaluation of the regulated regime showed little apparent adverse effects on performance capacity across the regulated regime. This confirmed the findings of the earlier evaluation of the regulatory approach. However it must be recognised that in this second evaluation, operational constraints meant that many drivers were not really rested at their first test occasion. Therefore the finding of no change across the study period is most likely because there was little consistency across drivers in their work-rest schedules from the beginning of the study to the end. On the other hand, the relationships found between work-rest schedules and performance in the second regulatory regime evaluation suggest that aspects of this regime, such as the amount of work and night work, can be modified to reduce the experience of fatigue, even on these trips in which fatigue is relatively low and there are few effects on performance.

Interestingly, in both evaluations in this report, subjective fatigue was never reported to be particularly high. This finding is similar to that found in the earlier on-road evaluation of regulated hours where subjective fatigue levels also reached only moderate levels even at the end of the work week when drivers had not had a 24 hour break for at least six days. This was also found in the simulated FMP evaluation where drivers did two successive 16 hour trips with only a six hour break in between them. In all of these studies most drivers only used the lower to middle section of the fatigue scale to rate their fatigue even after working for significant lengths of time. In all of these studies drivers reported that their fatigue increased across the study period, but their ratings suggest that they never felt that they were excessively fatigued. These results may be interpreted in the light of the findings of the earlier laboratory study which demonstrated that professional truck drivers were able to adjust their performance in a Symbol Digit test by protecting their accuracy by maintaining a slower but steady speed of work. In making subjective judgements of their fatigue levels, it seems that drivers may be doing a similar thing: pacing or adjusting their judgements of fatigue so that they have some reserves left. Fatigue judgements increased significantly over the study period where they had only short breaks, but there was still considerable room in the fatigue rating scale to allow for higher ratings even at the end of the study period.

A further anomaly in these studies is that the results of all tests using the palmtop tester are likely to have underestimated the effects on performance because of an intermittent fault in the palmtop testers. This fault meant that the results for poorer performers were systematically lost for the Mackworth Clock Vigilance test, in particular because the palmtop tester tended to fail when drivers showed prolonged lapses in their performance and took longer than about three minutes to respond on a test trial. This, coupled with the fact that drivers who missed, or failed to complete a test occasion, might be expected to be those who felt too tired, indicates that this evaluation tended to be conservative in estimating the effects of these work-rest schedules on performance and on subsequent safety. This means that the decrements in performance capacity found in the alternative compliance or FMP approach evaluated in this report are likely to be higher than reported here. These factors give further credibility to the conclusion that this alternative schedule needs to be redesigned.

Overall these evaluations have been very valuable for identifying whether the status quo or regulated working hours regime is as safe as has been assumed up until now. They have also been useful for identifying whether or not some of the alternative approaches have adverse effects on performance and on fatigue and which aspects of the alternative approaches need to be improved to be effective. Lastly these evaluations have confirmed the validity and sensitivity of the techniques used to estimate performance capacity for demonstrating which work-rest schedules may be most useful for managing driver fatigue. In this way, these evaluations have achieved the aim of providing some useable models of work-rest schedules and informed guidance on which aspects of work-rest schedules may enhance productivity and reduce fatigue most effectively.

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APPENDIX 1: CONSENT FORM FOR STUDY 1

ON ROAD EVALUATION STUDY
1999

Driver fatigue is a major safety issue in the long distance road transport industry in Australia mainly because of the long distances that have to be travelled. As you know, one of the options currently being explored to manage fatigue better is a move away from regulated working hours to more flexible Fatigue Management Programs (FMPs). The study we are conducting at will examine how your FMP plan affects driver's fatigue. The study is also part of a larger project attempting to identify the best ways of managing work and rest for the long distance road transport industry generally, in order to minimise driver fatigue. The study involves looking at drivers' experiences of fatigue on a range of work-rest schedules. By doing this we hope to have some real evidence about what does and does not work for most drivers. This information, we hope, will help the industry design better and more flexible ways of arranging work and rest schedules.

What is involved?

On the first day of participation, drivers will be asked to do two tests on a laptop computer (total 17 minutes) at the Gatton depot prior to their trip, and to complete a short questionnaire providing some background information about your lifestyle, health, and recent work and sleep patterns. The tests are simple tasks similar to computer games and measure concentration and reaction speed. Drivers will then be given a palmtop computer to take with them for the fortnight. You will be asked to do shorter versions of the two tests (total 7 minutes) on the palmtop computer at the beginning and end of each day's work and at the start and end of each sleep break taken during trips. We will ensure that drivers have some practice using the palmtop computer before leaving on their first trip, and 24-hour help will be available by phone should they need it. We would also ask that drivers complete a simple diary during the fortnight to record how fatigued they feel at the start and end of each work period. Finally, at the end of the fortnight, we would ask drivers to complete the laptop tests again at the Gatton depot. The precise timing of these tests will depend on the drivers' schedules.

All the information you provide will be confidential. In fact, once all the information has been collected, we will not be keeping your name at all.

Your participation in this project is voluntary and you are free to withdraw at any time without penalty or prejudice. Please note that your decision to participate will have no bearing on your employment and your personal results will not be shown to your employer.

If you have any questions about the study please do not hesitate to contact Ann Williamson, Samantha Brown or Rena Friswell on (02) 9385 1646.

If you wish to complain about any aspect of the conduct of this research project please contact Mrs Margaret Wright, Executive Officer, Ethics Secretariat, University of New South Wales on (02) 9385 4234.

ON ROAD EVALUATION STUDY
1999

You are invited to participate in the evaluation of the effects on fatigue and performance of your shifts. If you wish to participate, please complete the consent form below.

Consent Form

I, ____, agree to participate in the evaluation of the effects on fatigue and performance of my shifts.
I acknowledge that I have read the statement above outlining the study, 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 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 without prejudice.

______________________________ ______________________________
(Signature of participant) (Signature of witness)

__________________ __________________
(Date) (Date)

APPENDIX 2: BACKGROUND QUESTIONNAIRE FOR STUDIES 1 AND 2

Code Number:

PARTICIPANT

BACKGROUND INFORMATION

ON ROAD EVALUATION STUDY

1999

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

Today's date: ______________

Current time: ______________ am / pm ?

1. 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: *(Please circle)* M F

2. Are you:

	Please tick
married or living in a defacto relationship?	( )
widowed, separated or divorced?	( )
single?	( )

3. How long have you been driving a truck for a living? ________ years

4. 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	( )

5. How much experience have you had using personal computers?

	Please tick
None	( )
A little	( )
Frequent user	( )

6. 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

7. Do you smoke cigarettes?

No ( )

Given up ( )

How long ago did you give up? _______________ years/months

Yes ( )

How many do you smoke on average per day? ___________ cigarettes

8. 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?

____

9. 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	( )
Never	( )

If you do drink alcohol, how many standard drinks do you usually drink at one time? (*Please tick)*

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***

10. When you are sleeping, how often do you:

		Please tick
Snore loudly ?	always	( )
	often	( )
	sometimes	( )
	rarely	( )
	never	( )
Stop breathing ?	always	( )
	often	( )
	sometimes	( )
	rarely	( )
	never	( )
Move around a lot ?	always	( )
	often	( )
	sometimes	( )
	rarely	( )
	never	( )

11. Do you have difficulty getting to sleep ? Yes ( )

No ( )

12. Do you have difficulty staying asleep once you are asleep ?

Yes ( )

No ( )

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

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

14. Have you had your adenoids removed ? Yes ( )

No ( )

Please continue

over page

15. 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	_____

16. Do you usually work: *(Please tick)*

Mostly days? (6:00 to 18:00) ( )

Mostly nights (18:00 to 6:00)? ( )

Days and nights about equally? ( )

17. Was the last week a typical working week for you? Yes ( )

No ( )

If No, what was unusual about it? *(e.g., on holidays, sick, on light duties etc)*

____

18. In the last 7 days (not counting today):

How many hours did you work? _________ hours

How many of these were at night (i.e. 18:00 to 6:00)? _________ hours

How many trips did you drive? _________ trips

How long was your *last trip* in terms of:

Kilometres? _________ km

Total duration? _________ hours

Hours spent working? _________ hours

19. When did your last work shift end?

Time: ____________ am/pm Day: ___________ Date: ____________

How long was your *last work shift* in terms of:

Total duration? _________ hours

Hours spent working? _________ hours

20. In total, how much sleep have you had since then? _________ hours

21. How long was your last *substantial* sleep ? _________ hours

22. When did this sleep end?

Time: ____________ am/pm Day: ___________ Date: ____________

23. How would you rate the quality of this sleep?

(Please draw a cross at the point which most closely describes the quality of your sleep)

Very poor quality |————————————| *Very good quality*

24. How did you feel when you awoke from this sleep?

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

Not at all refreshed |————————————| *Very refreshed*

25. Have you had any naps since your last substantial sleep ?

Yes ( )

No ( ) **If No**, go to question 28

If Yes, please record the length of the nap and the time you woke up in the table below. *(If you have had more than 2 naps, please record the others on the back of this page.)*

	Length of nap	***End of nap***	
	hours : minutes	**date**	**time**
Nap 1	:		am/pm
Nap 2	:		am/pm

26. How would you rate the quality of your *last* nap ?

(Please draw a cross at the point which most closely describes the quality of your sleep)

Very poor quality |———————————————| *Very good quality*

27. HOW DID YOU FEEL WHEN YOU AWOKE FROM YOUR LAST NAP ?

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

Not at all refreshed |———————————————| *Very refreshed*

28. When did you last eat a meal?

Time: ____________ am/pm Day: ___________ Date: ____________

Was this meal *(Please tick)*: Light ( )

Moderate ( )

Large ( )

Have you snacked since then? Yes ( )

No ( )

29. If applicable, when did you last have a caffeinated drink? *(eg. Coffee, tea, coke)*

Time: ____________ am/pm Day: ___________ Date: ____________

How many caffeinated drinks have you had today? ___________ drinks

30. If applicable, when did you last have an alcoholic drink?

Time: ____________ am/pm Day: ___________ Date: ____________

How many alcoholic drinks did you have on that occasion?

___________ drinks

31. Are you currently taking any medication? Yes ( )

No ( )

If Yes, what? ____

APPENDIX 3: EXCERPTS FROM ON-ROAD DIARY FOR STUDY 1

Code:

On Road Diary

On Road Evaluation Study

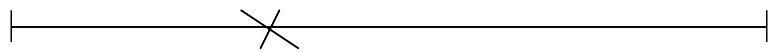
1999

Instructions

On the following pages, we would like you to record details of your work periods over the next fortnight cycle, and to rate how tired you feel at the beginning and end of every work period. This means making ratings at the start and end of every break you take longer than half an hour, and at the start and end of every day. It is important that you try to make the ratings at the very start and finish of the work period. There is one page for each work period.

To make the ratings, simply put a mark somewhere on each scale line to show how you feel. For example, on the scale of happiness below, if you were only a bit happy you might put the mark as shown

Very happy *Very sad*



Remember you need to fill in this diary for ALL BREAKS but only do the handheld tests at the start and end of SLEEP BREAKS (including the start and end of each day).

WORK PERIOD 1

WORK START TIME: __________ am or pm Date: _________

Did you do the handheld tests at the start of this work period?
(Please tick) Yes ( )
No ( )

Please rate how you feel now on the following scales

Fresh |————————————| *Tired*

Clear-headed |————————————| *Muzzy-headed*

Very alert |————————————| *Very drowsy*

How long was your break? ______________ hours

Did you sleep during your break ? Yes ( )
No ( )

If Yes,
How long was your sleep? ______________ hours

How would you rate the quality of this sleep?

Very poor quality |————————————| *Very good quality*

How did you feel when you woke?

Not at all Refreshed |————————————| *Very Refreshed*

WORK END TIME: __________ am or pm Date: _________

During this work period, how long did you spend:

Driving? ___________ hours

Doing other work? ___________ hours

Please rate how you feel now on the following scales?

Fresh |————————————| *Tired*

Clear-headed |————————————| *Muzzy-headed*

Very alert |————————————| *Very drowsy*

Did you do the handheld tests at the end of this work period?

(Please tick) Yes ( )
No ( )

WORK PERIOD 35

WORK START TIME: _________ am or pm Date: ________

Did you do the handheld tests at the start of this work period?
(Please tick) Yes ( )
No ( )

Please rate how you feel now on the following scales

Fresh *Tired*

Clear-headed *Muzzy-headed*

Very alert *Very drowsy*

How long was your break? _____________ hours

Did you sleep during your break ? Yes ( )
No ( )

If Yes,
How long was your sleep? _____________ hours

How would you rate the quality of this sleep?

Very poor quality *Very good quality*

How did you feel when you woke?

Not at all Refreshed *Very Refreshed*

WORK END TIME: _________ am or pm Date: ________

During this work period, how long did you spend:

Driving? __________ hours

Doing other work? __________ hours

Please rate how you feel now on the following scales?

Fresh *Tired*

Clear-headed *Muzzy-headed*

Very alert *Very drowsy*

Did you do the handheld tests at the end of this work period?

(Please tick) Yes ( )

No ( ) End of week

How many trips did you drive this week? ________ trips

How would you describe your workload this week?

(please tick)

Much less than usual ( )
Less than usual ( )
About the usual level ( )
Greater than usual ( )
Much greater than usual ( )

Overall, how would you describe your fatigue levels this week?

(please tick)

Much less than usual ( )
Less than usual ( )
About usual ( )
Greater than usual ( )
Much greater than usual ( )

Do you have any other comments that you would like to make about your work or your fatigue this week?

____

____

____

____

____

____

____

Many thanks for your participation

APPENDIX 4: PALMTOP COMPUTER INSTRUCTIONS FOR STUDIES 1 AND 2

Instructions for using handheld testers

(Please refer to diagrams of the handheld tester on the back of this page.)

1. **Gently plug the keypad in**to the handheld tester**,** with the bump on the plug pointing up.

2. Press the **ON button** on the **handheld tester.**

If the tester is ready for use, the last line of writing on the screen should be: E:\PIPS>

3. Use the **keyboard on the handheld tester** to **type:**

TEST then leave a **space** by pressing the long **'space' key** at the bottom of the keyboard, and then type **your subject code** as shown on the front of your On Road Diary.

Make sure there is a **space** between the word TEST and your subject code.

If you make a **mistake while typing**, use the **'backspace' key** to erase the problem and then re-type.

If you do not press any keys on the handheld tester for several minutes, the screen will go blank. If this happens, just press the ON button to bring the screen back to where you left it.

4. Press the **ENTER** key on the **keypad.**

If a "bad command" message appears on the screen followed by the E:\PIPS> message, simply redo step 3.

5. The tester will now ask you whether you have **changed the batteries today.**

Press the **1 or 2** keys on the **keypad** to answer **no or yes**.

If you have not changed the batteries, the program will ask you to turn the tester off and to replace the batteries. See instructions below and diagram over the page for changing batteries. Once you have changed the batteries, you should start from step 2 again.

If you have already changed the batteries, the program will start the tests. Simply follow the instructions on the screen

6. When the tests are finished the **E:\PIPS> message** will return.

7. Press the **ON button** on the **handheld tester** again to **switch** the machine **OFF.**

8. **Unplug** the **keypad** from the tester.

Changing the batteries.

1. Make sure that the handheld tester is **switched OFF** and the **keypad** is **unplugged.**

2. Turn the machine upside down and push the battery cover off.

3. Replace the old AA batteries with new ones.

4. Slide the battery cover back on, taking care that it closes properly

5. Please **keep the used batteries** in the bag provided

If you have any problems using the tester, call Sam Brown, or Rena Friswell, or Ann Williamson on 02 9385 3806.

APPENDIX 5: CONSENT FORM FOR STUDY 2

ON ROAD EVALUATION STUDY
1999

Driver fatigue is a major safety issue in the long distance road transport industry in Australia mainly because of the long distances that have to be travelled. This study is attempting to identify the best ways of managing work and rest for the long distance road transport industry in order to minimise driver fatigue. It involves looking at drivers' experiences of fatigue on a range of work-rest schedules. By doing this we hope to have some real evidence about what does and does not work for most drivers, taking into account the operational needs of the companies they work for. This information, we hope, will help the industry design better and more flexible ways of arranging work and rest schedules.

What is involved?

We are interested in evaluating linehaul drivers at your company across a 'normal' week of work. The evaluation will involve as many drivers as are willing to participate. On the first day of participation, drivers will be asked to do two tests on a laptop computer (total 17 minutes) and to complete a short questionnaire at the Sydney depot just prior to starting a trip if possible. The tests are simple tasks similar to computer games and measure concentration and reaction speed. Drivers will then be given a palmtop computer to take with them for the week. They will be asked to do shorter versions of the two tests (total 7 minutes) on the palmtop computer at the beginning and end of any long break from work of around an hour or more during the week. We will ensure that drivers have some practice using the palmtop computer before leaving on their first trip of the study week, and 24-hour help will be available by phone should they need it. We would also ask that drivers complete a simple diary during the week to record how fatigued they feel at the start and end of each break. Finally, at the end of the week, we would ask drivers to complete the laptop tests again at the Sydney depot. The precise timing of the Sydney tests will depend on the drivers' schedules.

All the information you provide will be confidential. In fact, once all the information has been collected, we will not be keeping your name at all.

Your participation in this project is voluntary and you are free to withdraw at any time without penalty or prejudice. Please note that your decision to participate will have no bearing on your employment and your personal results will not be shown to your employer.

If you have any questions about the study please do not hesitate to contact Ann Williamson, Samantha Brown or Rena Friswell on (02) 9385 1646.

If you wish to complain about any aspect of the conduct of this research project please contact Mrs Margaret Wright, Executive Officer, Ethics Secretariat, University of New South Wales on (02) 9385 4234.

ON ROAD EVALUATION STUDY
1999

You are invited to participate in the evaluation of the effects on fatigue and performance of standard regulated shifts. If you wish to participate, please complete the consent form below.

Consent Form

I, ____, agree to participate in the evaluation of the effects on fatigue and performance of standard regulated shifts.

I acknowledge that I have read the statement above outlining the study, 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 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 without prejudice.

______________________________ ______________________________
(Signature of participant) (Signature of witness)

___________________ __________________
(Date) (Date)

APPENDIX 6: EXCERPTS FROM ON-ROAD DIARY FOR STUDY 2

Code:

ON ROAD DIARY

ON ROAD EVALUATION STUDY

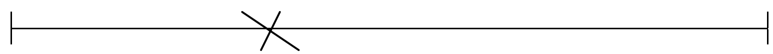
1999

Instructions

On the following pages, we would like you to record details of your work periods over the next full week cycle, and to rate how tired you feel at the beginning and end of every work period. This means making ratings at the start and end of rest and meal breaks, overnight breaks or breaks between trips. It is important that you try to make the ratings at the very start and finish of the work period. There is one page for each work period.

To make the ratings, simply put a mark somewhere on each scale line to show how you feel. For example, on the scale of happiness below, if you were only a bit happy you might put the mark as shown

Very happy *Very sad*



WORK PERIOD 1

WORK START TIME: __________ am or pm Date: _________

Did you do the handheld tests at the start of this work period?
(Please tick) Yes ( )
No ( )

Please rate how you feel now on the following scales

Fresh |————————| *Tired*

Clear-headed |————————| *Muzzy-headed*

Very alert |————————| *Very drowsy*

How long was your break? ______________ hours

Did you sleep during your break ? Yes ( )
No ( )

If Yes,
How long was your sleep? ______________ hours

How would you rate the quality of this sleep?

Very poor quality |————————| *Very good quality*

How did you feel when you woke?

Not at all Refreshed |————————| *Very Refreshed*

WORK END TIME: __________ am or pm Date: _________

During this work period, how long did you spend:

Driving? ___________ hours

Doing other work? ___________ hours

Please rate how you feel now on the following scales?

Fresh |————————| *Tired*

Clear-headed |————————| *Muzzy-headed*

Very alert |————————| *Very drowsy*

Did you do the handheld tests at the end of this work period?

(Please tick) Yes ( )
No ( )

WORK PERIOD 30

WORK START TIME: _________ am or pm Date: ________

Did you do the handheld tests at the start of this work period?
(Please tick) Yes ( )
No ( )

Please rate how you feel now on the following scales

Fresh *Tired*

Clear-headed *Muzzy-headed*

Very alert *Very drowsy*

How long was your break? _____________ hours

Did you sleep during your break ? Yes ( )
No ( )

If Yes,
How long was your sleep? _____________ hours

How would you rate the quality of this sleep?

Very poor quality *Very good quality*

How did you feel when you woke?

Not at all Refreshed *Very Refreshed*

WORK END TIME: _________ am or pm Date: ________

During this work period, how long did you spend:

Driving? __________ hours

Doing other work? __________ hours

Please rate how you feel now on the following scales?

Fresh *Tired*

Clear-headed *Muzzy-headed*

Very alert *Very drowsy*

Did you do the handheld tests at the end of this work period?

(Please tick) Yes ( )
No ( )

End of week

How many trips did you drive this week? ________ trips

How would you describe your workload this week?

(please tick)

Much less than usual ( )
Less than usual ( )
About the usual level ( )
Greater than usual ( )
Much greater than usual ( )

Overall, how would you describe your fatigue levels this week?

(please tick)

Much less than usual ( )
Less than usual ( )
About usual ( )
Greater than usual ( )
Much greater than usual ( )

Do you have any other comments that you would like to make about your work or your fatigue this week?

____

____

____

____

____

____

____

Many thanks for your participation

APPENDIX 7: COMPARISONS OF PALMTOP AND LAPTOP PERFORMANCE DATA, AND LAPTOP AND DIARY FATIGUE RATINGS

In both studies, laptop and palmtop performance tests were administered together on two occasions (at the start and at the end of the study period). Consequently, the two types of test administration could be compared using MANOVA analyses with two repeated measures factors - test occasion (start v end of study), and type of test administration (laptop v palmtop). Each performance measure on the Simple Reaction Time (RT) task and on the Mackworth Clock Vigilance task was analysed in this way. To equate the Mackworth measures for differences in the duration of the laptop and palmtop tasks, the number of missed stimuli on each version of the test was converted to a percentage of the total number of stimuli presented, and the number of false alarm responses made on the laptop tests was divided by 3 to give an indicative value for a 5 minute period.

STUDY 1

The mean scores and statistical test results for the performance tests are summarised in Figures 10 and 11 and in Table 13 respectively for all subjects. All three measures of performance on the Simple Reaction Time task were affected by the type of test administration, with palmtop responses being slower, more variable and less accurate than laptop responses. Response speed also showed an effect of test occasion, such that responses were slower at the end of the study than at the start for both laptop and palmtop tests. These differences were stable, however,

FIGURE 10: Mean performance on the Simple Reaction Time task in study 1 as a function of type of tester and test occasion (with 95% confidence intervals)

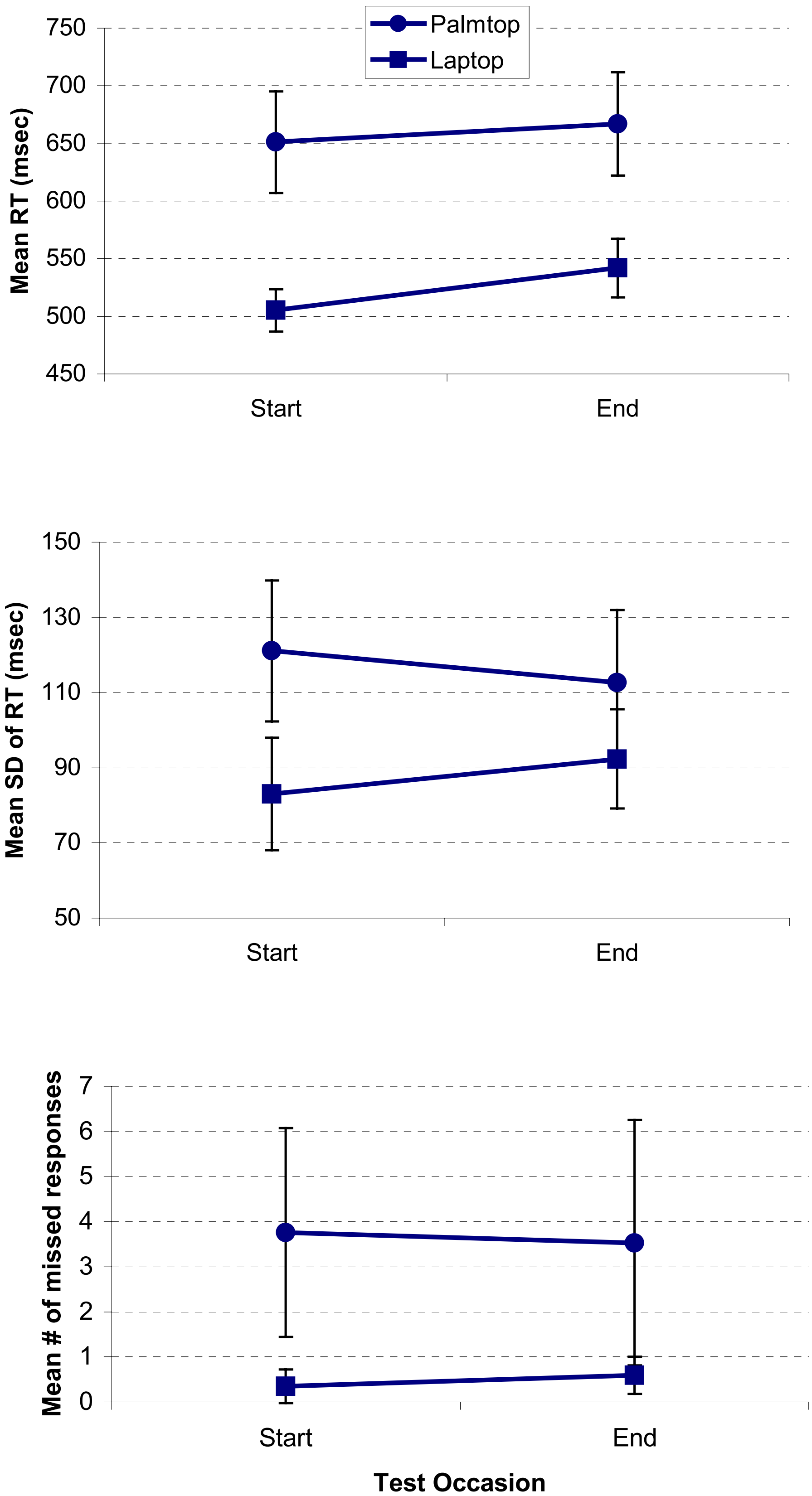


TABLE 13: Outcome of statistical comparisons between laptop and palmtop tests at the start and end of study 1.

TEST MEASURE	EFFECT	STATISTICAL TEST RESULT
REACTION TIME TEST		
• RT	Type of tester	**$F_{(1,16)}$=50.54, p<0.001**
	Occasion	**$F_{(1,16)}$=5.23, p=0.03**
	Interaction	$F_{(1,16)}$=1.87, p=0.19 ns
• SD	Type of tester	**$F_{(1,16)}$=8.73, p=0.009**
	Occasion	$F_{(1,16)}$=0.004, p=0.95 ns
	Interaction	$F_{(1,16)}$=1.19, p=0.19 ns
• # Missed	Type of tester	**$F_{(1,16)}$=9.24, p=0.008**
	Occasion	$F_{(1,16)}$<0.001, p>0.99 ns
	Interaction	$F_{(1,16)}$=0.12, p=0.74 ns
MACKWORTH CLOCK VIGILANCE TASK		
• RT	Type of tester	$F_{(1,15)}$=0.60, p=0.45 ns
	Occasion	$F_{(1,15)}$=1.94, p=0.18 ns
	Interaction	$F_{(1,15)}$=0.02, p=0.90 ns
• SD	Type of tester	$F_{(1,15)}$=1.47, p=0.24 ns
	Occasion	$F_{(1,15)}$=2.41, p=0.14 ns
	Interaction	$F_{(1,15)}$=0.01, p=0.93 ns
• # False alarms	Type of tester	$F_{(1,15)}$=3.81, p=0.07 ns
	Occasion	$F_{(1,15)}$=2.48, p=0.14 ns
	Interaction	$F_{(1,15)}$=2.48, p=0.14 ns
• % Missed	Type of tester	$F_{(1,15)}$=0.16, p=0.70 ns
	Occasion	$F_{(1,15)}$=1.82, p=0.20 ns
	Interaction	$F_{(1,15)}$=0.03, p=0.86 ns
		NB: ns = not statistically significant

as indicated by the non-significant interactions between occasion and type of administration.

None of the measures on the Mackworth Clock Vigilance task showed significant effects of type of test administration, test occasion or the interaction between these factors.

Ratings of subjective fatigue at the start and end of the study period were completed on the laptop computer using a mouse and also using pen-and-paper scales (Figure 12). MANOVA analysis comparing type of administration showed that ratings were unaffected by the manner in which they were recorded but were significantly higher at the end of the study than at the start ($F_{(1,15)}$=0.01, p=0.91 and $F_{(1,15)}$=18.66, p=0.001, respectively). The interaction between type of administration and rating occasion was also not significant ($F_{(1,15)}$=0.27, p=0.61). The absence of any administration effect means that comparisons between the pen-and-paper ratings made in the current study and computer-derived ratings from previous "benchmarking" studies are likely to be valid.

STUDY 2

The mean scores and statistical test results for the performance tests are summarised in Figures 13 to 14 and in Table 14 respectively. For the Simple Reaction Time (RT) task, all three measures of performance were affected by the type of test administration, with palmtop responses being slower, more variable and less accurate than laptop responses. These differences were stable over test

FIGURE 11: Mean performance on the Mackworth Clock Vigilance task in study 1 as a function of type of tester and test occasion (with 95% confidence intervals)

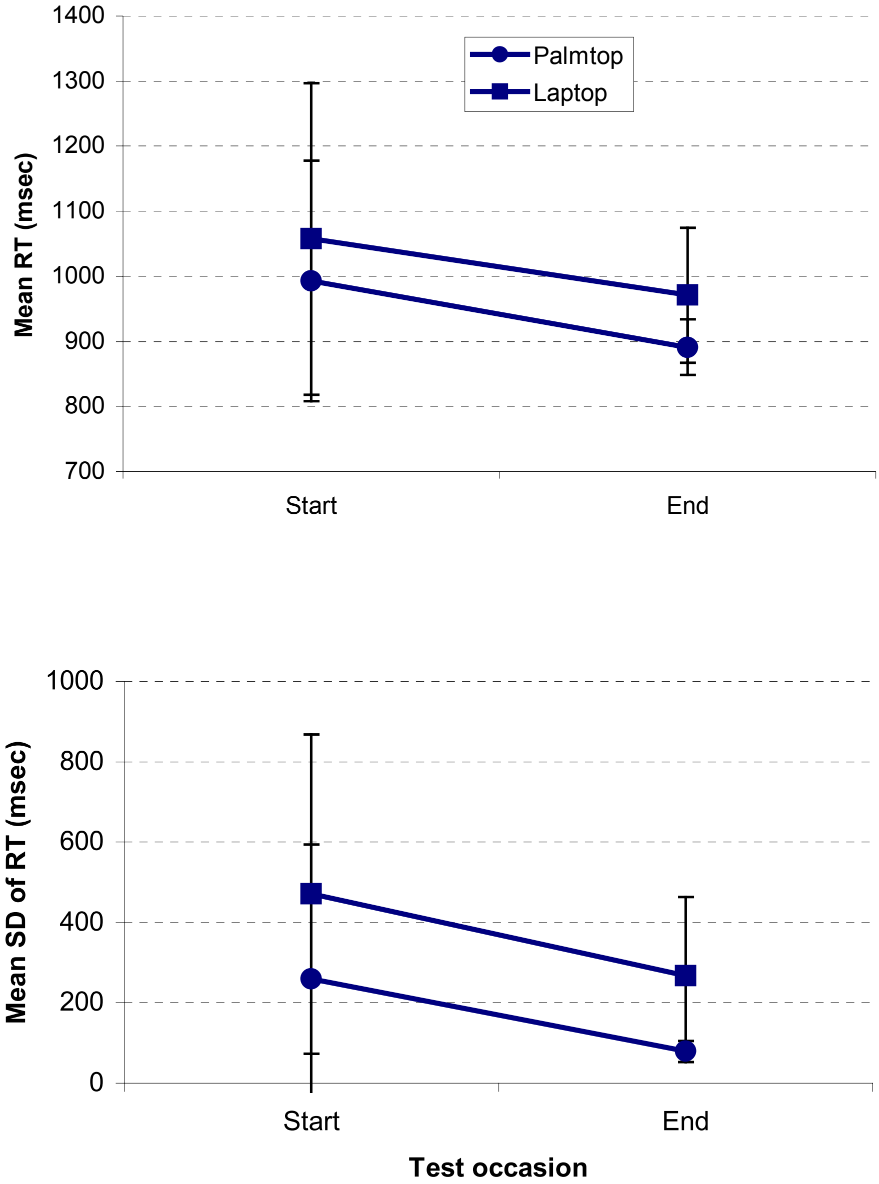
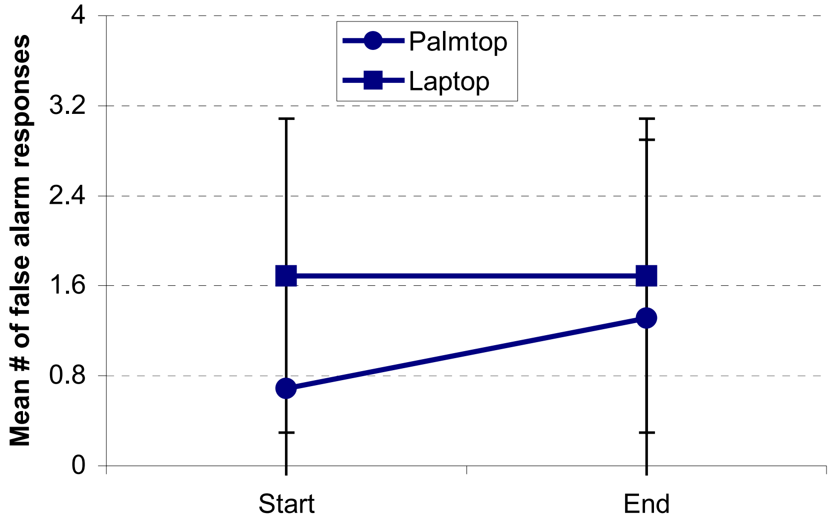


Figure 11 continued



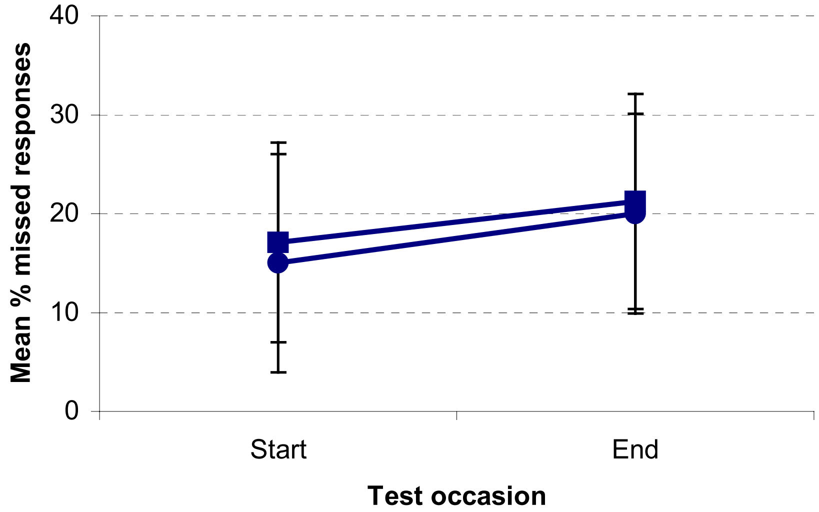
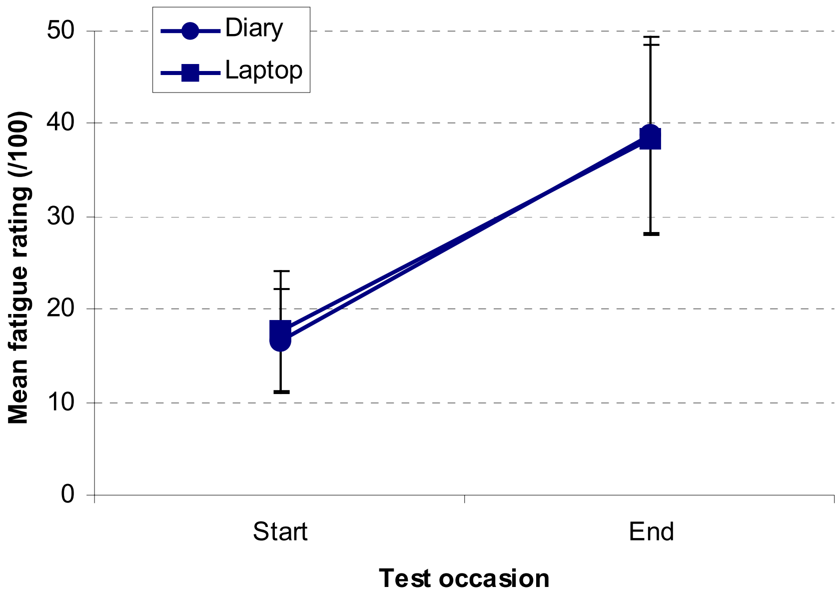


FIGURE 12: Mean fatigue ratings in study 1 as a function of type of administration and test occasion (with 95% confidence intervals)



occasions as demonstrated by the non-significant effect of occasion and the non-significant interaction effect between occasion and type of administration.

None of the measures on the Mackworth Clock Vigilance task showed any significant effects of type of test administration, test occasion or the interaction between these factors.

Ratings of subjective fatigue at the start and end of the study period were completed on the laptop computer using a mouse and also using pen-and-paper scales (Figure 15). MANOVA analysis, comparing type of administration and rating occasion,

FIGURE 13: Mean performance on the Simple Reaction Time task in study 2 as a function of type of tester and test occasion (with 95% confidence intervals)

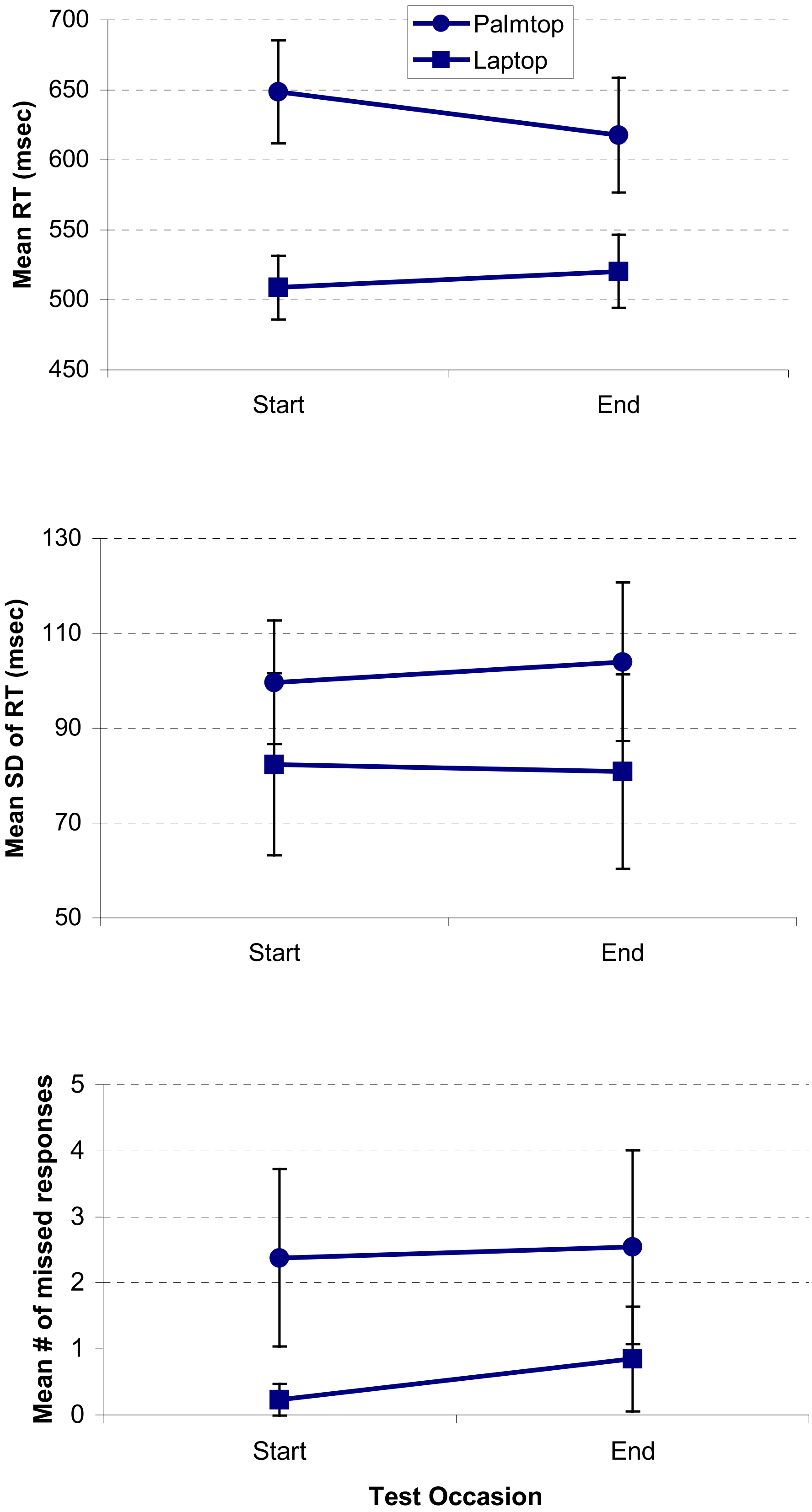


TABLE 14: Outcome of statistical comparisons between laptop and palmtop tests at the start and end of the study 2.

TEST MEASURE	**EFFECT**	**STATISTICAL TEST RESULT**
REACTION TIME TEST		
• RT	Type of tester	$\mathbf{F_{(1,12)}=50.67,\ p<0.001}$
	Occasion	$F_{(1,12)}=0.24$, p=0.63 ns
	Interaction	$F_{(1,12)}=2.80$, p=0.12 ns
• SD	Type of tester	$\mathbf{F_{(1,12)}=5.17,\ p=0.04}$
	Occasion	$F_{(1,12)}=0.05$, p=0.84 ns
	Interaction	$F_{(1,12)}=0.12$, p=0.74 ns
• # Missed	Type of tester	$\mathbf{F_{(1,12)}=13.76,\ p=0.003}$
	Occasion	$F_{(1,12)}=0.45$, p=0.51 ns
	Interaction	$F_{(1,12)}=0.18$, p=0.68 ns
MACKWORTH CLOCK VIGILANCE TASK		
• RT	Type of tester	$F_{(1,12)}=0.62$, p=0.45 ns
	Occasion	$F_{(1,12)}=1.53$, p=0.24 ns
	Interaction	$F_{(1,12)}=0.33$, p=0.58 ns
• SD	Type of tester	$F_{(1,12)}=0.85$, p=0.37 ns
	Occasion	$F_{(1,12)}=1.48$, p=0.25 ns
	Interaction	$F_{(1,12)}=0.87$, p=0.37 ns
• # False alarms	Type of tester	$F_{(1,12)}=0.78$, p=0.40 ns
	Occasion	$F_{(1,12)}=0.38$, p=0.55 ns
	Interaction	$F_{(1,12)}=0.38$, p=0.55 ns
• % Missed	Type of tester	$F_{(1,12)}=0.30$, p=0.60 ns
	Occasion	$F_{(1,12)}=0.93$, p=0.36 ns
	Interaction	$F_{(1,12)}=0.01$, p=0.91 ns
		NB: ns = not statistically significant

FIGURE 14: Mean performance on the Mackworth Clock Vigilance task in study 2 as a function of type of tester and test occasion (with 95% confidence intervals)

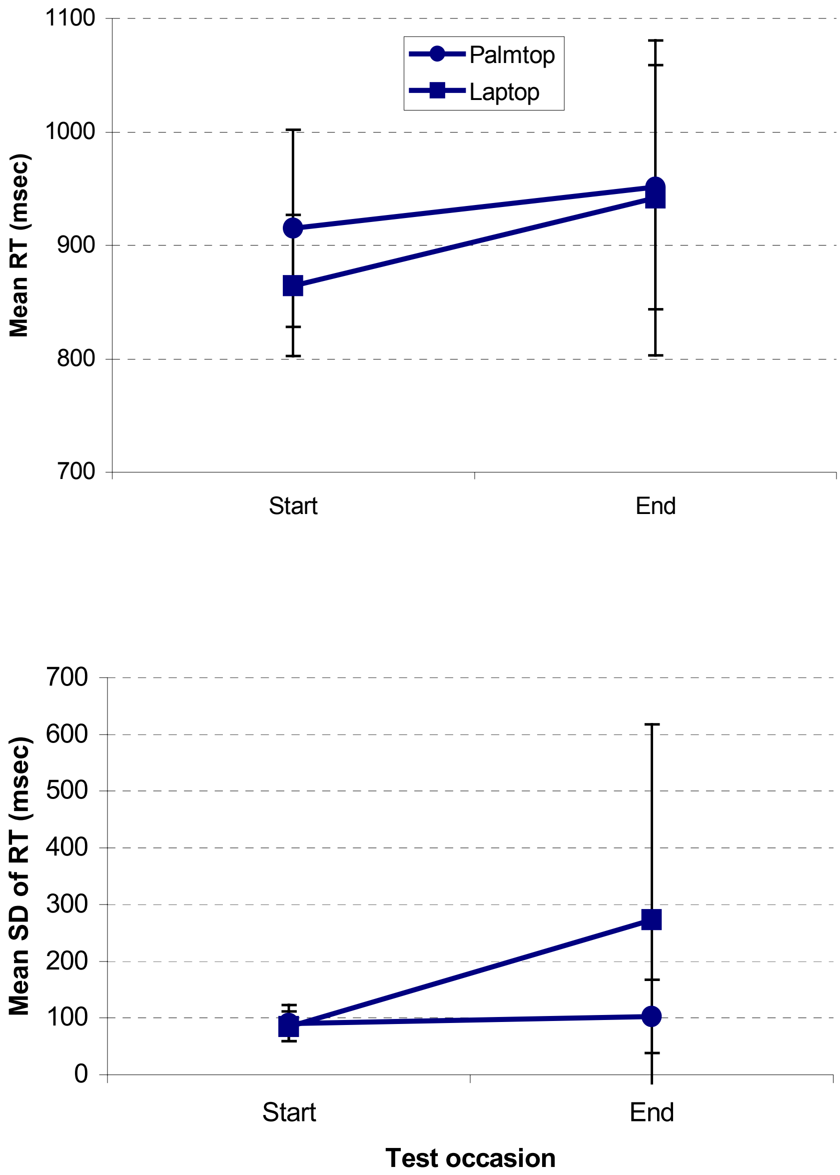
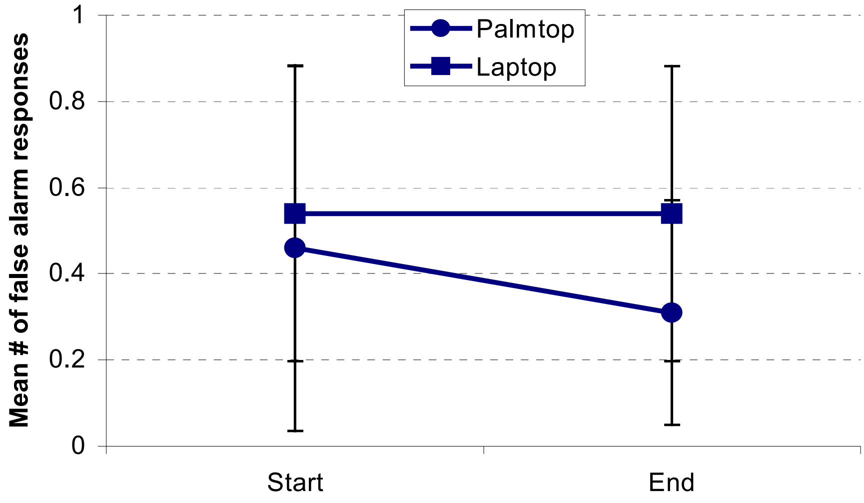
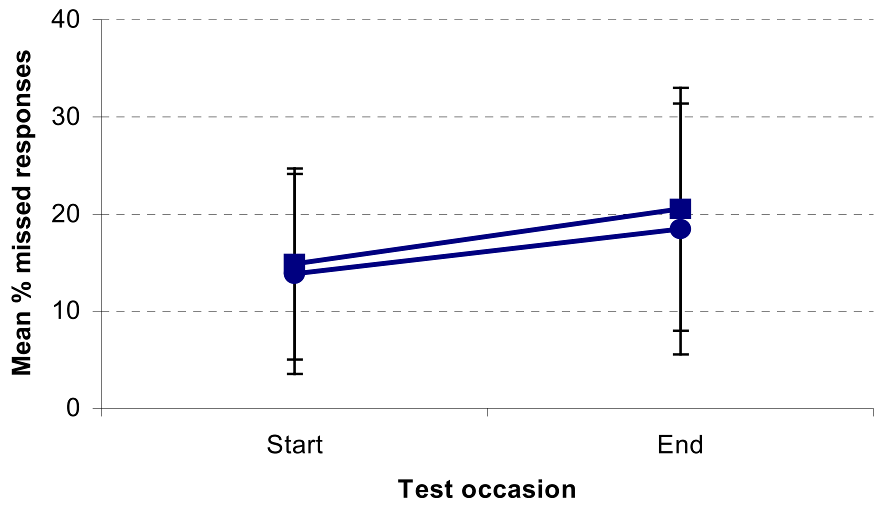


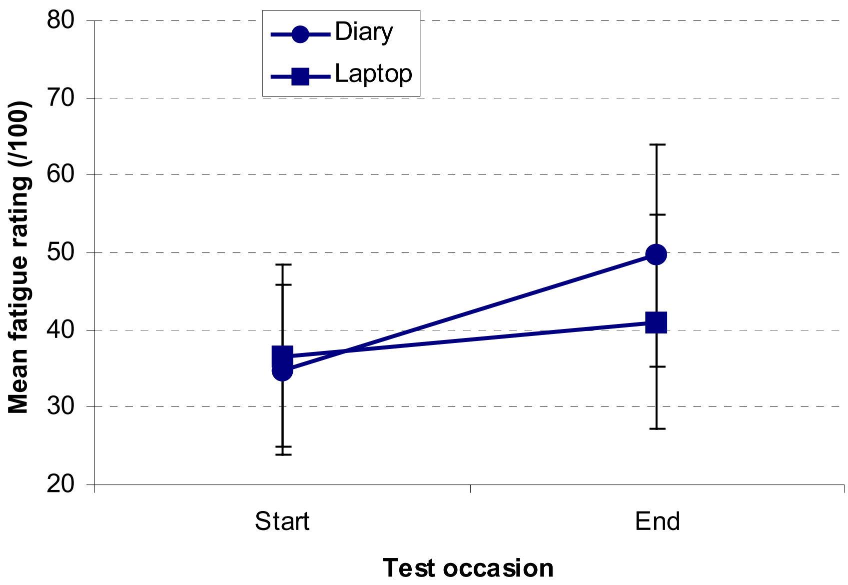
Figure 14 continued





showed that ratings were unaffected by either of the factors ($F_{(1,12)}$=1.01, p=0.33 and $F_{(1,12)}$=1.38, p=0.26, respectively), or by their interaction ($F_{(1,12)}$=1.36, p=0.27), thus legitimising any comparisons between the pen-and-paper ratings and computer-derived ratings from previous "benchmarking" studies.

FIGURE 15: Mean fatigue ratings in study 2 as a function of type of administration and occasion (with 95% confidence intervals)



DISCUSSION

As shown in the previous evaluation study (Williamson et al., in press, CR190), both versions of the tests yielded similar patterns of results. There were no significant interaction effects and only a main effect for test occasion for simple reaction indicating that performance showed the same overall patterns throughout the study. The major differences between the two test types was that the palmtop versions were always slower and more variable than laptop versions. This result was also found in the previous evaluation.

It is important to establish the differences between palmtop and laptop versions of the tests if they are to be used as alternative forms of the same test. These results show that performance on the palmtop tests will always be more variable and therefore will not have the same degree of power as laptop tests to detect differences where they exist. It is not surprising that the palmtop tests show greater variability as they have been shortened from their original laptop form which will have the effect of increasing variance of the measures. In addition, it is not possible to achieve the same degree of control over the test circumstances when the palmtop versions are used on the road compared to the laptop versions which are supervised by research staff. For the Simple Reaction Time test, variability would also be increased as the nature of the response has been changed from detection of a simple change in the colour of the circle in the laptop version to a detection of a change from a continuous to broken line defining the circle in the palmtop test.

Overall these results show that the two versions can be used as alternates for one another provided that it is recognised that the palmtop version will be less powerful in detecting differences. For this reason, there is still justification for using both tests in any further evaluations of work-rest schedules.