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Demonstration Project for Fatigue Management Programs in the Road Transport Industry:

Summary of Findings

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Summary of Findings

DEMONSTRATION PROJECT FOR FATIGUE MANAGEMENT PROGRAMS IN THE ROAD TRANSPORT INDUSTRY

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Abstract
This document is the final summary of a series of three reports of a project on the development of model work-rest schedules that have demonstrated effectiveness for managing driver fatigue in the long distance road transport industry. The purpose of these studies was to help the industry in designing work-rest schedules to provide additional flexibility for companies and drivers to meet their operational needs but also manage fatigue most effectively. The report provides an overview of the findings of each of the three studies. The first study developed a set of fatigue-sensitive performance measures and alcohol-equivalent standards for each of them. The results also demonstrated sleep deprivation of 17 hours or more produced decrements in performance capacity equivalent to the community-accepted standard of 0.05%Blood alcohol concentration. They also showed that long distance drivers appeared to cope with the demands of sleep deprivation better than non-professional drivers. The second and third reports detailed the evaluation of four work-rest schedule, two of which complied with the current working hours regulations and two were alternative schedules that did not comply with the regulations. The evaluations were carried out on the road while drivers were doing their normal trips. The exception was one of the alternative compliance schedule evaluations which was done with professional long distance drivers in a simulation mode rather than on-road. The results of the regulated hours evaluations showed that so long as drivers were rested before their trips, the regulated regime produced increased fatigue and produced some performance decrements at the end of a work period between long 24 hour breaks. The level of effect was not significantly high however, relative to alcohol-equivalent standards. In contrast, the alternative compliance schedule evaluations demonstrated that it is possible to introduce flexibility in scheduling such as by extending the length of work periods, but only if an adequate balance is maintained between work and rest.

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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INTRODUCTION

Fatigue and fatigue management has attracted considerable interest in the long distance road transport industry over the last few years because it has been acknowledged increasingly as one of the industry's major problems. The research that has occurred because of this interest has clarified a number of aspects of the problem. Most notably it has shown that regulatory approaches that are generic and attempt to limit working hours and manage rest in a "one size fits all" approach is not necessarily the best approach (Williamson, Feyer, Coumarelos and Jenkins, 1992; Feyer, Williamson, Jenkin and Higgins, 1993; Arnold, Hartley, Penna, Hochstadt, Corry, & Feyer, 1996). Not only are such approaches difficult to implement and police, surveys of drivers and the industry indicate that regulatory approaches are unlikely to succeed because they do not accommodate the differing needs for rest between individual drivers or the differing operational needs of companies.

With the introduction by Queensland Department of Transport of an alternative compliance approach, the Fatigue Management Programme, the focus has moved to increasing the flexibility available to companies and drivers to manage fatigue in ways that suit them, rather than trying to match their work demands to the working hours regulations. The programme attempts to encourage companies to take a primary role in planning for fatigue management by developing Fatigue Management Programmes (FMP'S) for work-rest scheduling on particular routes. While this approach is clearly in harmony with the findings of the research on fatigue, it has some fundamental difficulties, most notably because there is very little information available on what constitutes effective alternative work-rest schedules in comparison to the working hours regulations. If the FMPs are to be useful, it is imperative that the work-rest schedules they allow offer no loss in the ability of drivers to manage fatigue, and preferably that they improve fatigue management.

One way of improving the effectiveness of the FMP approach is to develop a range of model work-rest schedules that have demonstrated effectiveness for managing fatigue. These models can then help in designing work-rest schedules that provide additional flexibility for companies and drivers to meet their operational needs, but still manage driver fatigue most effectively. The aim of this project was to begin to develop some model work-rest schedules by evaluating work-rest schedules that had been operating under the current regulated regime and some FMP approaches that had been allowed to begin operating under the pilot FMP scheme.

1. DEVELOPMENT OF MEASURES OF FATIGUE

The first step in this project was to develop methods for measuring fatigue that have demonstrated sensitivity for detecting fatigue and its effects, and can be interpreted on the basis of relative risks for safety (see report CR189 for full details). As there are no objective ways of measuring fatigue directly, this study chose performance measures because they reflect not just that fatigue is occurring through a decreasing capacity to perform as fatigue increases, but they can also reflect the way fatigue affects performance, which is also important for this project. The performance tests were chosen on the basis of demonstrated sensitivity to fatigue based on previous research. The tests included Simple Reaction Time (RT), the Mackworth Clock Vigilance Test, an Unstable Tracking Task, Dual Task, Symbol Digit Task, Visual Search Task, Sequential Spatial Memory Task, and a Logical Reasoning task.

The study design was to compare performance on a range of performance tests under conditions in which study participants should be tired, with performance under conditions in which they had been exposed to varying doses of alcohol. Alcohol was used as a comparison as there are community-accepted safety standards already established for alcohol effects and driving.

In addition, the study compared the effects of sleep deprivation and alcohol on professional drivers and controls who did not work as professional drivers. Previous research has suggested that professional drivers are better at controlling the effects of fatigue on performance than the rest of the population (Williamson, Feyer, Friswell and Leslie, 1994; Feyer, Williamson, and Friswell, 1995). If the methods resulting from this study are to be applicable to the long distance road transport industry, it was important to determine whether professional drivers perform differently when they are tired compared to other people.

Fatigue was manipulated in this study by keeping participants awake for 28 hours in total. Alcohol effects were manipulated by administering four doses of alcohol calculated to achieve 0.025, 0.05, 0.075 and 0.1% BAC levels. As performance tests were administered at regular intervals under both alcohol and sleep deprivation conditions it was possible to plot changes in performance with increasing sleep deprivation and increasing blood alcohol levels. It was also possible to compare the effects of alcohol and sleep deprivation since study participants completed both study conditions. By this means the sleep deprivation effects could be interpreted in terms of a community-accepted standard for safe performance on the road.

The results indicated that virtually all tests showed deterioration in performance with increasing alcohol doses. In contrast not all tests were affected by increasing sleep deprivation (see Table 1). Specifically, Simple Reaction Time, Mackworth Clock Vigilance, Dual Task, Unstable Tracking, Sequential Spatial Memory, and the speed measures for Symbol Digit showed clear decreases in performance capacity as sleep deprivation increased. In contrast, more complex tasks like Grammatical Reasoning, the Search and Memory Task and the accuracy measure on the Digit Symbol task did not show changes in performance over the 28 hours of sleep deprivation. Interestingly, professional drivers showed a different pattern of performance to controls. On the Symbol Digit Test professional drivers performed significantly more slowly than controls from the beginning of the study, but maintained almost perfect accuracy, whereas the controls responded faster, but after around 21 hours of sleep deprivation, they were unable to maintain accuracy.

Comparing alcohol and sleep deprivation results (see Table 2) showed that 0.05% BAC equivalence occurred at between 17 and 19 hours of sleep deprivation for most tests. This means that after around 17 hours of wakefulness, performance capacity was sufficiently impaired to be of concern for safety.

This study achieved its major aim of revealing a number of tests that have known sensitivity to the effects of fatigue and that can be interpreted on the basis of a community-accepted safety standard based on alcohol effects. The tests chosen to be most sensitive to fatigue were Simple Reaction Time, the Mackworth Clock Vigilance test and the Dual Task. These tests could then be used most effectively in developing models of work-rest schedules because they are known to detect fatigue effects where they occur. Secondly, the study shed further light on the question of how much concern should be placed on the effects of fatigue. Through a careful comparison of alcohol and sleep deprivation effects, it is possible to conclude that after around 16 to 19 hours without sleep, performance capacity has deteriorated sufficiently to be of concern to the community due to an increased potential safety risk. Further details of this study can be found in Williamson, Feyer, Friswell and Finlay-Brown (in press, CR189)

TABLE 1: Summary of the results of the performance tests under alcohol and sleep deprivation conditions. Results of trend analysis where ✓ = significant linear decrement shown with increasing alcohol dose/sleep deprivation and ✕ = no significant linear decrease.

TEST	MEASURE	LINEAR TREND *ALCOHOL*	LINEAR TREND *SLEEP*
Reaction Time	*Speed (msecs)*	✓	✓
	Accuracy (misses)	✓	✓
Dual Task	*Speed (msecs)*	✓	✓
	Hand-eye coordination difficulty level	✓	✓
Tracking	*Hand-eye coordination difficulty level*	✓	✓
Mackworth Clock	*Speed (msecs)*	✓	✓
	Accuracy (No. targets detected)	✓	✓
	Accuracy (False alarms)	✓	✓
Symbol Digit	*Speed (msecs)*	✓	✓
	Speed (No. targets inspected)	✓	✓
	Accuracy (% correct)	✓	✕
Logical Reasoning	*Speed (msecs)*	✕	✕
	Accuracy (No. correct)	✓	✕
Visual Search Task	*Speed (msecs)*	✕	✕
	Accuracy (No. correct)	✓	✕
Spatial Memory	*Length of recalled series*	✓	✓
Tiredness	*Rating*	✓	✓

TABLE 2: Equating the effects of sleep deprivation and alcohol consumption. Amount of sleep deprivation required to produce performance decrements equivalent to varying levels of alcohol (BAC).

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

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

2. EVALUATIONS OF WORK-REST SCHEDULES

The second and third reports for this project (Williamson, Feyer, Finlay-Brown and Friswell, in press, CR190; Williamson, Feyer, Friswell and Finlay-Brown, in press, CR191) involved four evaluations of work-rest schedules. Two studies were evaluations of the current working hours regulations and two studies were evaluations of alternative approaches to work-rest schedules. Although the aim of this project was to develop new models of work-rest schedules, evaluations were undertaken of work-rest schedules that conformed to the current work hours regime because there is little or no scientific evidence for its effectiveness as a fatigue management device. Even though the current working hours regime has been in operation for a considerable time, there has not been an evaluation of its effectiveness for managing fatigue. Furthermore, in developing new approaches to work-rest scheduling, it is first important to know how the current approaches fare, but also, information may be obtained about how to develop new models through looking at the older versions.

All evaluations were conducted on-road, except one which involved a simulation because the length of the work periods meant that it was not possible to conduct it on the road. All evaluations used the performance measures developed in the first study. However, as these were on-road evaluations, the original laptop computer versions of the performance tests were also adapted for administration on a small palmtop computer which could be taken on-road by drivers to test themselves.

Each of the evaluation studies followed basically the same design. The design involved starting the study after the participants had been on a break of at least 24 hours in order to obtain baseline information about performance when rested. Drivers were tested using the laptop versions of the tests at times when they were in the company depot. This varied between studies, but was typically at the beginning of their first trip after the break, then on return to the depot at the end of that trip, then at the end of the last work period before they had another 24 hour break. Ratings of fatigue were also obtained at each of these test times. In addition to the laptop tests, drivers tested themselves using the palmtop versions of the tests and gave ratings of subjective fatigue immediately before they took any break from driving in which they intended to sleep and immediately after the sleep break. In this way, it was possible to obtain measures of fatigue and performance at strategic points across the work-rest schedule between two long 24 hour breaks.

2.1 Evaluations of the effectiveness of the current regulatory regime for fatigue management

The two evaluations of the current working hours regime showed similar overall results. Both studies showed relationships between work-rest variables and increased fatigue and decreased performance capacity (see Table 3), but there was little evidence that the performance decreases were large enough to constitute a significant safety risk compared to alcohol equivalent levels at 0.05% BAC. For the first evaluation of the regulated regime (*CR190, Evaluating a regulated hours regime on-road and an alternative compliance regime under simulated conditions*) fatigue ratings were significantly higher when drivers returned to the depot at the end of the first trip and at the end of the study period compared to rested levels. Despite this, there were only a few significant changes in performance capacity. The most notable were increases in the number of missed signals over the first trip in the study for the palmtop version and over the study period for the laptop version of the Mackworth Clock Vigilance test. These changes were judged to be not of major concern for safety when compared to the alcohol equivalence standard for 0.05% BAC.

The second regulated regime evaluation (*CR191, On-road evaluations of a regulated hours regime and an alternative compliance regime*), showed small, but non-significant increases in fatigue ratings across the study period and no changes in performance across the study period for any measure. For this evaluation, however, it was not possible to begin the study when drivers were at their most rested. As most drivers in this evaluation lived some distance away from their company depot, they had been driving for a considerable period, up to around six hours on average, before they arrived at the company depot for testing. Consequently, drivers were not starting from a maximally rested point at the beginning of the study. As shown in Table 4, this group had only received around 5 hours sleep on average since their last trip, compared to nearly 22 hours for the first evaluation group. It is not surprising then that there was little change in fatigue ratings or performance capacity over the study period. Importantly, when compared to 0.05% BAC equivalent levels, most measures showed that average performance were never in the region that would signal concerns for safety. The exception was the number of missed signals in the Simple Reaction Time test where performance of some drivers was around the level of concern by the end of the study. Overall, however, just as for the first regulated regime evaluation, this study showed little evidence of cause for concern due to fatigue-related performance decrements.

TABLE 3: Stepwise regression predictors of performance and fatigue for on-road evaluation studies

	Baseline			End of study		
	Company 1 Regulated	**Company 2 Regulated**	**Company 3 FMP**	**Company 1 Regulated**	**Company 2 Regulated**	**Company 3 FMP**
REST STATUS	rested	not rested	rested	not rested	not rested	not rested
SUBJECTIVE FATIGUE						
• diary ratings	.	SQ-, 0.29	.	.	.	WH+, 0.55
• laptop ratings	NH-, 0.08	SQ-, 0.24	.	.	NH+, 0.35	WH+, 0.46
SIMPLE REACTION TIME TASK						
• laptop RT	.	.	SQ-, 0.41 (BL+)	SH-, 0.16	.	.
• palmtop RT	.	WH+, 0.55 (NH+)	.	SH-, 0.09	NH+,0.34	.
• laptop SD	.	.	.	.	.	.
• palmtop SD	.	.	.	BK-, 0.12	.	.
• laptop number missed	.	.	SQ-, 0.51	.	.	.
• palmtop number missed	.	.	.	SH-,0.11	.	.
MACKWORTH CLOCK VIGILANCE TASK						
• laptop RT	SL+, 0.32 (WH-, BL+, SS+)	.	.	.	.	.
• palmtop RT	.	.	SQ-,SL-, 0.93	.	.	BK-, 0.41 .
• laptop SD	BL+, SL+, 0.44 (WH-, SS+)	.	.	.	.	.
• palmtop SD	.	SQ-, 0.34	SQ-,WH+, 0.90	.	.	.

Table 3 continued

	Baseline			End of study		
	Company 1 Regulated	Company 2 Regulated	Company 3 FMP	Company 1 Regulated	Company 2 Regulated	Company 3 FMP
MACKWORTH CLOCK CONTINUED						
• laptop number false alarms	NH+, 0.11	.	.	.	.	SH+, 0.33
• palmtop number false alarms	NH+, 0.14	.	.	.	BK-, 0.37	.
• laptop number missed	.	.	.	.	.	.
• palmtop number missed	.	.	.	.	.	SH+, 0.57
DUAL TASK						
• laptop RT	NH+, 0.11	x	x	.	x	x
• laptop SD	NH+, 0.14	x	x	.	x	x
• laptop misses	.	x	x	.	x	x
• laptop tracking	.	x	x	.	x	x

KEY

x	Analysis not conducted	
.	No significant regression predictors or correlated variables	
( )	Variable is correlated with performance but is not a significant predictor in the regression analysis	
+ or **-**	Positive or negative relationship between performance and work/rest	
values	Proportion of variance in performance explained by significant predictors (adjusted r^2)	
Predictor variables:	**BK**	Number of breaks taken during the study
	BL	Length of last break before the study
	NH	Number of hours worked at night (18:00-06:00) in the 7 days before baseline or during the study
	SH	Number of hours spent sleeping during the study
	SL	Hours elapsed between most recent sleep prior to commencing the study and baseline
	SQ	Rated quality of most recent sleep
	SS	Number of hours spent sleeping between end of prior shift and baseline
	WH	Number of hours worked in the 7 days before baseline or during the study

TABLE 4: Comparison of sleep prior to the study between on-road evaluation studies

	COMPANY 1 REGULATED	COMPANY 2 REGULATED	COMPANY 3 FMP
• Total sleep since last shift	21.88 (14.19)	4.93 (7.39)	17.68 (12.40)
• Length of last substantial sleep	7.57 (1.91)	5.89 (2.31)	8.52 (2.32)
• Time since last substantial sleep	8.12 (6.12)	10.63 (9.49)	6.46 (4.09)
• Length of last nap	2.15 (1.25)	1.08 (0.63)	1.25 (0.35)
• Time since last nap	2.12 (1.45)	5.08 (3.88)	1.80 (0.18)
• Length of last sleep	6.25 (3.07)	5.34 (2.99)	7.41 (3.28)
• Time since last sleep	5.13(4.87)	9.07 (9.72)	4.90 (3.28)

It must be pointed out though, that drivers were comparatively well rested at the beginning of the study in the first regulated hours evaluation, and the evaluation only reflects the effects of one cycle of the current regime on drivers who had low fatigue levels to begin with. Further research is needed to look at how the regulated regime manages fatigue over the longer term. Nevertheless, the results indicate that provided drivers obtained the rest prescribed in the regulated regime, the approach is managing fatigue effectively. Both evaluations showed, however, that performance capacity deteriorates and fatigue levels increase in relation to factors like increasing hours of work (especially night hours), short breaks and breaks that only allow short or poor quantity sleep (see Table 3). While fatigue and performance capacity seems to be maintained within safe limits under the regulated regime, these findings indicate that where drivers or companies take the work-rest schedules beyond the current limits, they are likely to be increasing the risk of performance decrements sufficient to compromise safety.

2.2 Evaluations of alternative compliance (FMP) approaches

Two studies evaluated alternative compliance approaches that involved extending at least one of the aspects of the working hours regulations. One study, described in CR190, (*Development of measures of fatigue: Using an alcohol comparison to validate the effects of fatigue on performance*.), involved a simulation of a proposed FMP work-rest regime. The second study, described in CR191 (*On-road evaluations of a regulated hours regime and an alternative compliance regime*), involved an on-road evaluation of an FMP which had been implemented under the pilot phase of the FMP.

The main characteristic of the approach used in the simulation study was the extension of the daily working hours limits from a maximum of 14 hours in a 24 hour period to up to 16 hours in a 24 hour period. The overall schedule covered 60 hours. The longer hours were balanced by beginning and ending the schedule with a 6 hour break and having a mandatory 6 hour break at some point in the intervening 48 hours. Short breaks of at least 15 minutes were also required after every 3 hours of work. The evaluation was conducted as a simulation because it had not yet been authorised to be trialed on the road as part of the pilot FMP.

The simulation involved the drivers who would normally have done the trip if it were allowed on-road. As for the previous evaluations, drivers began the study after they had at least 24 hours rest break. The drivers spent the time of the simulation in a laboratory set up in a motel. To simulate the demands of driving the drivers spent the time they would have been driving doing driving games on computers. They took breaks in the same way they would have if they had been on the road. Sleep breaks were taken in nearby rooms in the motel. The same performance tests and subjective fatigue ratings were used at the beginning and end of the trip and at regular intervals throughout the trip.

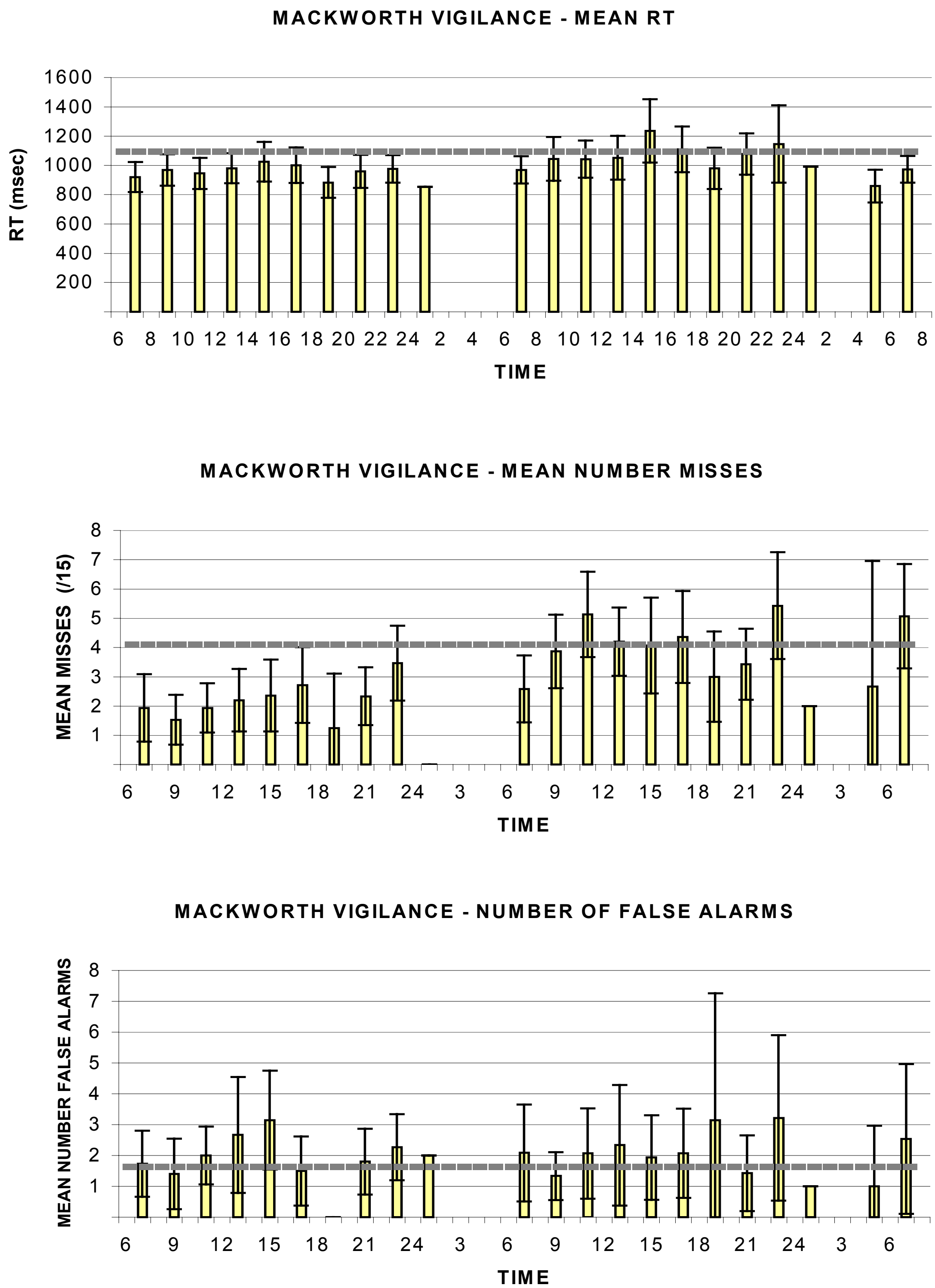
The results of the simulation showed that drivers were able to manage fatigue effectively over the first 16 hours of the schedule, indicating that if rested at the beginning of the trip, extending working hours to as much as 16 hours does not seem to present a problem for fatigue management (see Figure 1). The problem occurred during the second 16 hour working period. The ability of drivers to manage fatigue and maintain performance deteriorated significantly by the middle of the second 16 hour period. In fact performance levels at this time were considerably poorer than the 0.05% BAC alcohol equivalence standard. It seems that the 6 hour break was insufficient to allow recovery and recuperation from the demands of the previous long day such that performance levels could not be maintained at safe levels for the second full 16 hour work period. By the third day of the simulation, after another 6 hour sleep break, performance deteriorated even more rapidly.

This simulation demonstrated clearly that the work-rest schedule was too demanding for drivers to manage fatigue effectively. The main problem with this alternative schedule appeared to be that the amount of sleep and rest time was not enough to allow full recovery from the previous long work period. This meant that fatigue built up across work periods and performance capacity suffered in inverse proportion to the amount of rest that had been obtained.

The results highlight a number of relevant points for improved work-rest scheduling. First that long work periods up to 16 hours can be done without compromising safe performance provided that drivers are sufficiently rested before they begin. Second they show the importance of balancing work and rest proportionately. Long work periods need to be balanced by longer rest periods. This study did not address the issue of the length of rest needed to recover sufficiently from a 16 hour work period. It only showed that a 6 hour break was not sufficient. Third the results show the utility of simulation approaches to work-rest evaluation. While on-road evaluations are clearly more valid because they are looking at driver performance in the actual driving situation, simulations allow greater control over the design of the evaluation, and can therefore be useful in their own right.

The second evaluation of an alternative approach to work-rest scheduling could be conducted on-road because it was in operation as part of the pilot FMP. This work-rest schedule differed from the regulated hours regime by allowing for longer sustained periods of work at a stretch and splitting of the mandatory breaks between them. The regulated hours allow only five continuous hours of work before drivers take a break of at least 30 minutes. In this alternative schedule, drivers could work up to six continuous hours and only needed to take breaks in 15 minute periods, although they needed to take 30 minutes in total in every six hour period. The FMP also allowed drivers to divide the mandatory six hour continuous break into shorter sections. In all other ways, the work-rest schedule was the same as the regulated regime.

FIGURE 1: Mackworth Clock Vigilance results for FMP simulation study, showing 95% confidence intervals. The broken line on each graph shows the performance level at 0.05% BAC



Drivers were studied over a longer period than in the other evaluations as the cycle of the FMP schedule lasted for 11 to 12 days rather than 5 to 7 days as in the other on-road evaluations. In most other ways, the evaluation of this FMP schedule was similar to the regulated regime. Table 5 shows a comparison of the characteristics of the study period for the two evaluations of the regulated regime and for the on-road evaluation of the FMP schedule. The only major difference between the trips for the regulated regime evaluation and the FMP evaluation trips was that in the FMP schedule, a lower percentage of breaks involved sleep. In all other aspects, the characteristics of the study period were similar in this study to the evaluations of the regulated regime.

TABLE 5: Comparison of study period characteristics between on-road evaluation studies

	COMPANY 1 REGULATED	COMPANY 2 REGULATED	COMPANY 3 FMP
STUDY PERIOD:			
• Length of study period (hrs)	115.81 (14.41)	166.96 (45.72)	283.32 (26.10)
WORK:			
• Number of trips	4.38 (0.79)	5.03 (1.51)	3.42 (1.38)
• Hours worked	65.4 (12.6)	70.90 (17.71)	137.52 (19.15)
• % of study period worked	56.06 (8.87)	45.18 (6.99)	48.91 (8.05)
• Hours worked at night	32.3 (9.2)	38.73 (17.67)	62.66 (12.90)
• % work hours at night	50.1 (13.0)	51.33 (11.35)	45.57 (6.97)
• Median length work periods	9.68 (4.47)	7.11 (4.02)	6.83 (2.81)
• Median work per work period	8.63 (3.85)	6.58 (3.43)	6.23 (2.58)
• Median driving per work period	7.17 (3.07)	5.56 (2.79)	5.86 (2.27)
REST:			
• Number of breaks	6.9 (2.4)	9.62 (3.59)	17.50 (4.90)
• Median break length	6.35 (3.73)	5.66 (3.30)	5.85 (3.00)
• Total sleep in study period (hrs)	27.2 (6.5)	37.89 (9.20)	70.61 (14.86)
• Median length of sleeps	6.1 (1.4)	4.21 (1.59)	5.72 (1.10)
• % of breaks with sleep	75.4 (24.2)	76.36 (16.43)	61.46 (21.00)

The results of this evaluation showed that fatigue ratings increased across the study indicating, not surprisingly, that drivers grew more tired the longer they had been away. Even so, the absolute levels of rated fatigue, were not very high even at the end of the study. Most strikingly, however, reaction speed showed a deterioration across the study to levels that were suggestive of an increased safety risk based on the 0.05% BAC equivalent standard for performance (see Figures 2 and 3). There were also indications in the Mackworth Clock Vigilance test that performance was poorer than the 0.05% alcohol equivalent at some periods over the study. Furthermore, as the study progressed, the effectiveness of breaks diminished so that performance was worse after the break involving sleep than before the break. Just as in the simulation study, it seems that this alternative schedule is presenting too much demand on drivers without providing sufficient time to rest and recuperate.

The analysis suggested that the major sources of problem for fatigue management in this roster were long working hours, the availability of breaks, and the quality and length of sleep that could be obtained in this roster (See Table 3). These factors therefore present the most likely targets for improving this alternative compliance approach.

FIGURE 2: Reaction Time Task performance before and after sleep breaks early and late in the study period for drivers working under an FMP

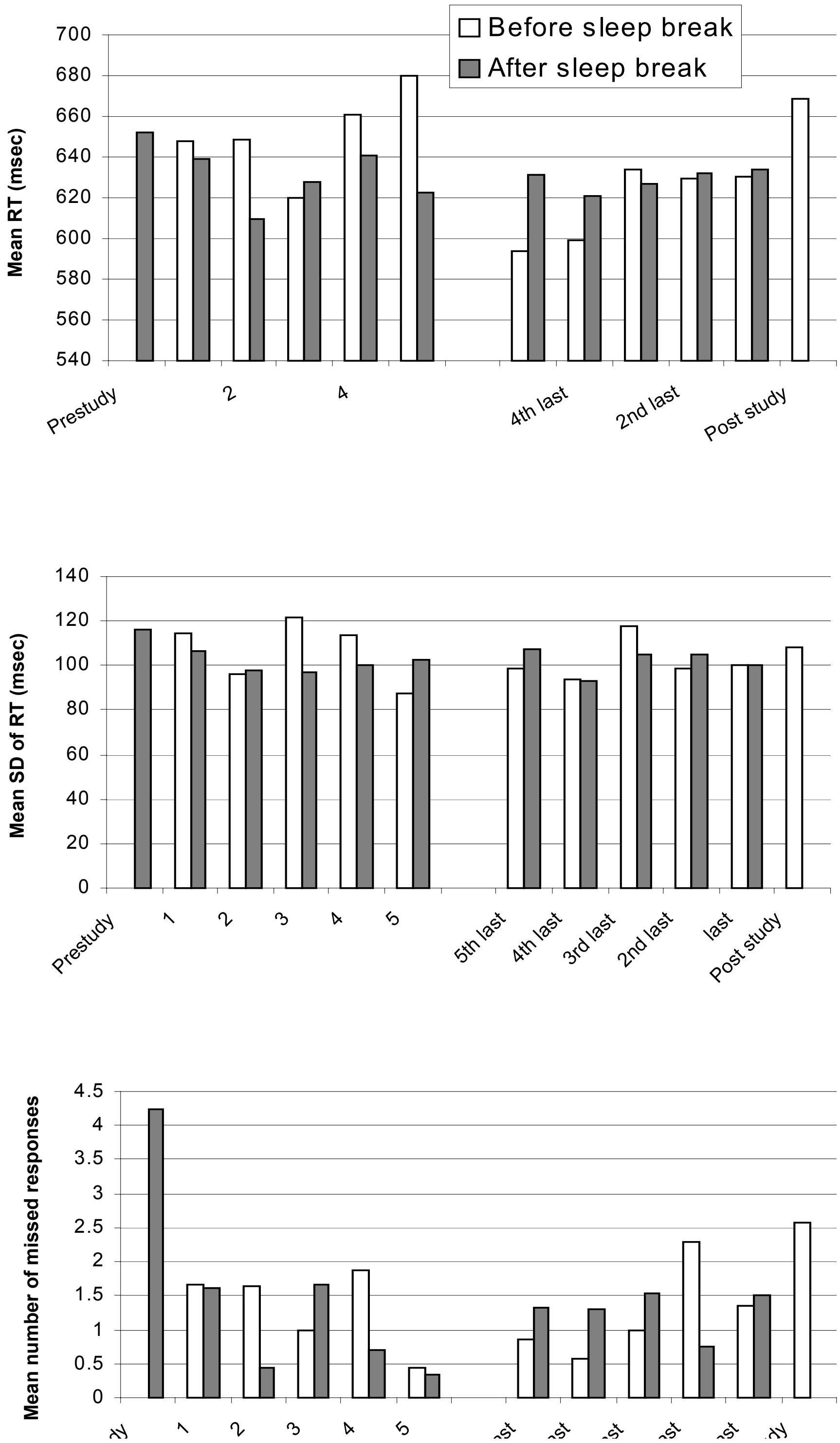
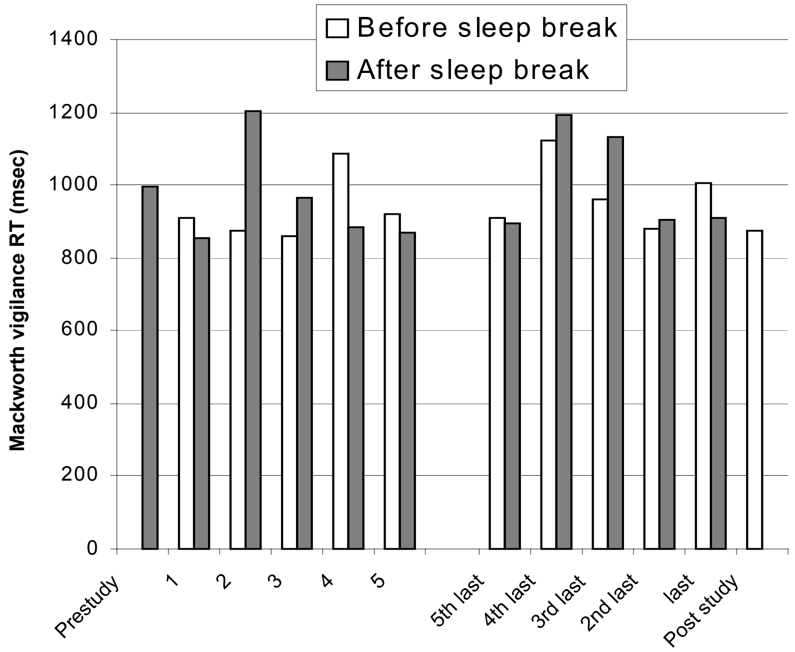


FIGURE 3: Mackworth Clock Vigilance performance before and after sleep breaks early and late in the study period for drivers working under an FMP



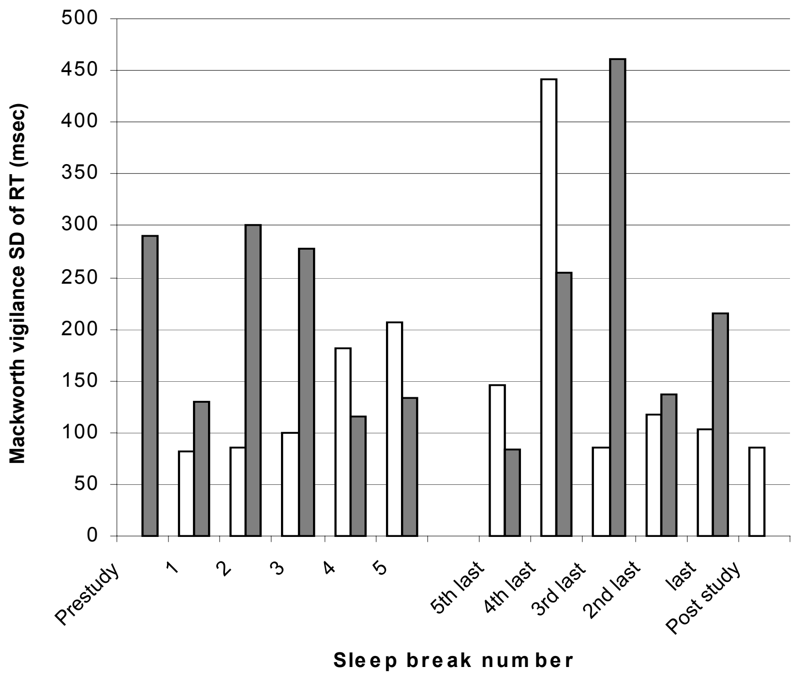
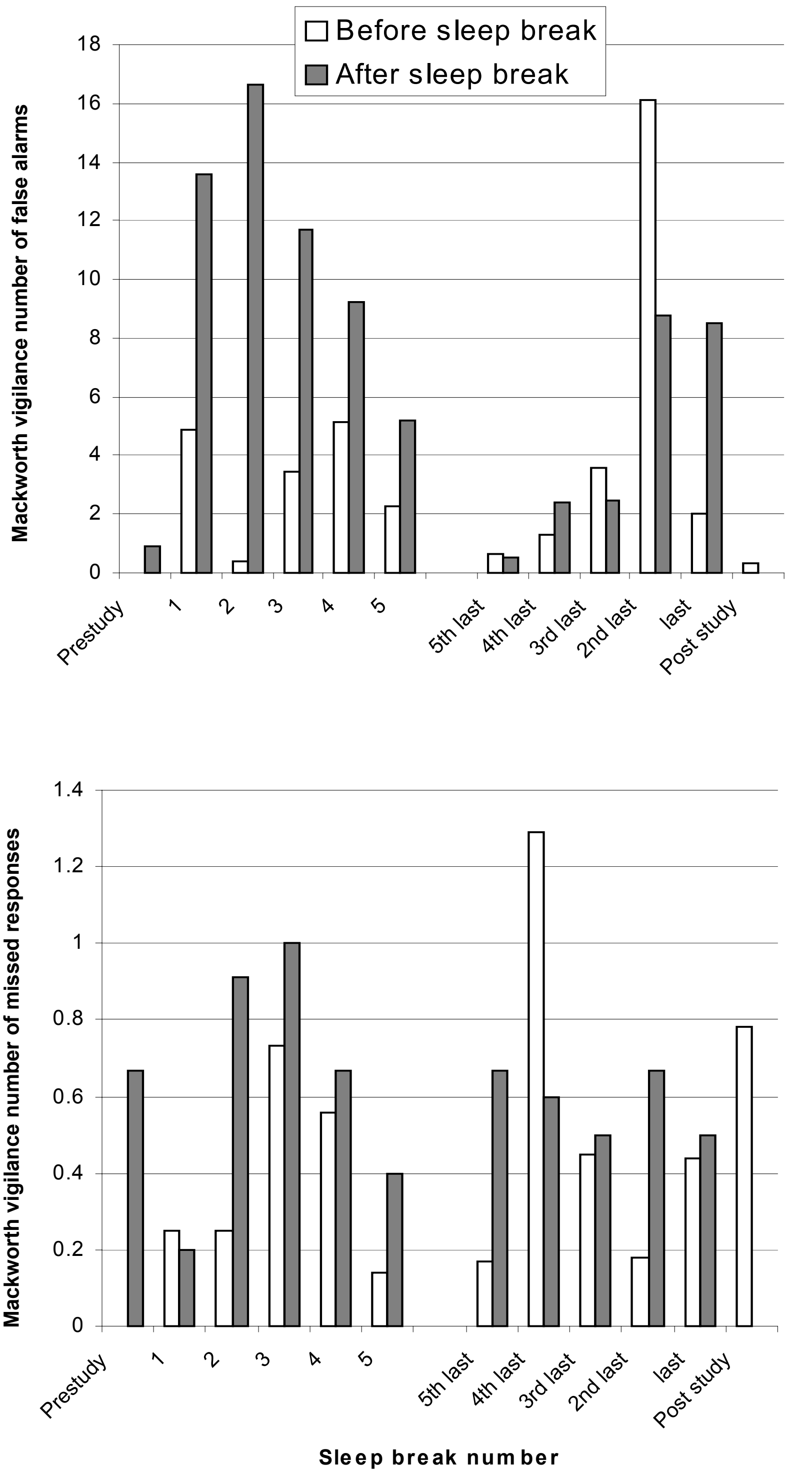


Figure 3 continued



CONCLUSIONS

This project has demonstrated that evaluation of work-rest schedules using standardised and sensitive methods for measuring fatigue is an effective approach to fatigue management. The results have identified work-rest schedules which have demonstrated capacity to manage fatigue as well as identifying the features of work-rest schedules which need to be modified to ensure that fatigue is maintained at the lowest possible levels.

Evaluation of the current working hours regime suggests that provided drivers are rested to begin with, one full cycle of the regulated regime does not produce fatigue or performance capacity decrements that are of concern for safety. There is considerable evidence however that performance decrements increase significantly as the schedule becomes more demanding. This is a warning signal for the development of alternative approaches to ensure that schedules are designed that do not simply increase the demands on drivers. The evidence from both evaluations of alternative FMP approaches reinforces these conclusions as the results for both alternative compliance schedules suggested that they increased the demands on drivers, but did not balance them sufficiently with rest in order to allow recuperation and recovery from accumulated fatigue. These results do not mean that the working hours regulatory regime is the only satisfactory approach to managing fatigue. The results show clearly that it is possible to increase trip length to 16 hours, say, and still maintain good performance levels. It is not possible, however, to continue to do 16 hour trips without a longer break than is usually allowed, even in the regulated regime.

The challenge for the road transport industry now is to use information like this and build on it to provide better guidance to drivers and companies on how to trade-off work and rest safely. These evaluations show that greater flexibility in scheduling is possible, but that it needs to be evaluated carefully. The development of model work-rest schedules that have been evaluated is clearly one way of assisting the industry down the path of better fatigue management.

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