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Strategies to Combat Fatigue in the Long Distance Road Transport Industry

Stage 2: Evaluation of Alternative Work Practices

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Abstract

In this study measurements of a range of indicators of fatigue were collected on long distance truck drivers undertaking a 10-12 hour journey under different operational conditions. Measurements of cognitive performance, physiological state, vehicle control and subjective perceptions of fatigue were taken for a sample of 27 drivers on trips corresponding to staged driving, single driving and driving to a flexible schedule. Results indicate that a 10-12 hour trip is tiring no matter how the work is organised, and that the effects of accumulated fatigue may overshadow the effects of fatigue on a single 10-12 hour trip.

Keywords

DRIVER FATIGUE, LONG DISTANCE DRIVING, STAGED DRIVING

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EXECUTIVE SUMMARY

Fatigue is a common problem in long distance driving which affects driver performance in the long term and, in the shorter term, the amount of effort required of drivers to maintain the performance on the driving task. The aim of this study was to investigate ways of reducing on-road fatigue on long distance trips by varying work practices. The results suggest that controlling the hours of work within a trip may not be as important as controlling the overall scheduling framework within which trips occur in order to better manage accumulated fatigue. This conclusion is based on two major findings in the study. First, the results clearly indicated that a 12 hour trip is fatiguing for drivers no matter how the work was arranged for the 12 hour trip. In particular, driving to a flexible schedule, where rest was able to be taken on a needs basis rather than according to current regulations, was not different to either driving the 12 hour trip as a staged driver or as a single driver taking rest according to the regulations. It is noteworthy that the flexible driving arrangement resulted in no worse an outcome than the other arrangements. Drivers in the study only had the opportunity to drive one trip on such a flexible regime in the study, and it is quite plausible that given the opportunity to better refine a suitable regime over a number of exposures to the trip, drivers may well have been able to more effectively utilise the flexibility.

Secondly, perhaps the most striking finding of the study was that on staged trips drivers were more fatigued at the beginning of the staged trip, compared with the other two trips that they undertook, and remained so at the end of these trips. The finding that the drivers started the staged trips tired is most likely to reflect the accumulated fatigue resulting from the routine scheduling arrangements for these drivers, however, rather than the effects of staged operations per se. Due to operational constraints, the staged trip was the first trip scheduled for evaluation for the vast majority of drivers in the study. This meant that the staged trip was the trip most close in timing to the regular schedules worked by the drivers, and thereby the most vulnerable to the effects of the scheduling patterns. The finding that drivers remained more fatigued on staged trips clearly indicates that having drivers tired at the start of a trip is likely to increase the fatiguing effects of any trip.

Taken together, the implications of the findings in the present study seem clear. They suggest that the effects of accumulated or chronic fatigue may overshadow the effects of acute or short-term fatigue, at least within a 12 hour trip

A repeated measures design was used in the study, in which each subject participated in each of three work practices being trialed. In this way, differences between the work practices could be analysed independently of differences between the individuals participating in the study. The three different methods of organising work chosen for investigation in the present study were based on the results of previous surveys of long distance truck and coach drivers. The first of these was staged driving, where two drivers begin their trips from different points, then meet at a point roughly half way into their trip, exchange loads then return to their point of origin. The purported advantages of staged driving for managing fatigue are that it allows drivers to work from their home base, thereby eliminating the problem of fatigue due to sleeping in unfamiliar surroundings.

The second method was flexible driving where the driver was allowed to arrange the work rest schedule of their trip according to their own body state, regardless of the working hours regulations. This method of driving is suggested to reduce fatigue by allowing drivers to take breaks from driving when they need them due to fatigue rather than on the basis of the regulated work hours. The results of the two previous surveys of long distance drivers suggested that providing drivers with the facility of taking breaks purely on a needs basis may assist in reducing on-road fatigue.

The third method, involved single drivers travelling from point of origin to point of destination and working to current working hours regulations. This third method was included as it provided a comparison for the other two methods and was therefore titled control driving for this study.

The three work practices were compared during trips by a group of 27 drivers using all three methods over the same 10 to 12 hour route between Sydney and Melbourne. All participating drivers had the same experience of the selected route since, normally, they all drove in staged operations on this route. The repeated measures design meant that each driver was being assessed before the trip, on the road and after the trip for all three work practices. For the staged trips, all drivers exchanged loads at Tarcutta.

A range of fatigue measures were used in view of the fact that fatigue occurs on different levels and that, taken individually, these measures may not always provide exclusive evidence of fatigue. Consequently, measures were used that related to performance both on and off the road, to the body's physiological state and to the drivers own perceptions of fatigue.

Performance tests included a battery of cognitive performance tests to evaluate drivers before, during the midtrip break and at the end of the trip. Tests included the Critical flicker fusion test (CFF), a perception test which assesses the ability to detect the onset or offset of flicker in a small light presented to one eye or the other. A simple visual reaction time test was used which required the drivers to respond by button press to the onset of light. The battery also included a vigilance test which involved drivers responding to the onset of one of five small lights which were lit in a random fashion over a ten minute period. Finally, the battery included an unstable tracking task which involved drivers using a knob to adjust the position of a moving pointer to a midpoint on a computer screen. The test involved instability since it increased in difficulty as the driver became more proficient in the task.

The performance tests also included an on-road performance test which involved a simple auditory reaction time task occurring at approximately two hourly intervals in the trip. Driving performance was also assessed by measuring deviations in steering wheel movement and changes in truck speed across each trip.

Physiological state was assessed by monitoring changes in the driver's heart rate across the trip. Changes in the experience of subjective fatigue were assessed using two pen and paper instruments, the Stanford Sleepiness Scale and a set of three Visual Analogue Scales. In addition a questionnaire was administered to drivers before the trip which asked about demographic details, driving experience, and the driver's general health and lifestyle characteristics. Drivers were also asked to complete a trip diary which included details of where and when they began the trip, took any breaks from driving and finished the trip, as well as their ratings of feelings of fatigue at each of these times.

The results showed that drivers experienced higher subjective fatigue at the end of the trip compared to the beginning for all trip types indicating that the experience of driving for 10 to 12 hours was tiring, no matter how the work was organised. In addition, however, drivers reported higher fatigue at the beginning of staged trips compared to the other trip types. This most likely reflects the cumulative impact of the previous week's work which was typical of the schedules routinely worked by these drivers. Fatigue levels were also higher for staged drivers at the end of the trip compared to the ratings at the end of the trip for the other trip types, suggesting that if a drivers starts the trip more tired, he is likely to be more fatigued at the end of the trip.

Analysis of the cognitive performance test results showed that changes in the level of fatigue across the trip were associated with changes in test performance. For the vigilance and unstable tracking tasks, drivers showed poorer performance when on staged trips than on either of the other trips. Performance for the CFF test also revealed poorer performance by drivers on staged trips, but only for the beginning of the trip. By the end of the trip CFF performance by staged drivers was no different from control or flexible drivers. These changes in observed performance appear to be directly related to the experience of fatigue on the trip. Examination of patterns of responses rules out practice as a possible alternative explanation for these findings. In fact the extent of the deterioration of performance may have been underestimated as there appeared to be rearousing effects of finishing the trip which created a temporary improvement in CFF performance.

Neither the simple reaction time test nor the on-road reaction time test showed differences related to type of trip or the time in the trip that the test occurred. As these are very simple tests involving little driver effort to perform, they may be somewhat more resistant to the effects of fatigue on performance, at least over a 10 to 12 hour trip.

Analysis of the patterns of heart rate change across the trip showed that the trip types differed significantly. Heart rate change and fatigue are correlated such that higher and less variable heart rate is associated with higher levels of alertness. On staged and control trips drivers showed much the same changes in heart rate across the trip. On both types of trips, heart rate decreased across the trip, indicating decreasing alertness. In contrast, when on flexible trips heart rates were much slower at the beginning of the trip, but increasing such that by the end of the trip they had much faster heart rate than the other trip types. This suggests that when on flexible trips, drivers had lower alertness, based on the heart rate measure, at the beginning of the trip but their alertness increased by the end of the trip.

Examination of the extent to which heart rate and reported fatigue were correlated for the drivers in this study showed that a positive relationship exists overall. High fatigue tended to be associated with heart rate changes indicative of low alertness. There were, however, a few anomalies in this relationship. On staged trips the expected relationship was shown across the trip between reported fatigue and heart rate. Comparing staged trips to the other trip types, however showed that the relationship did not hold for the beginning of the trip. Drivers reported higher fatigue at the beginning of staged trips, but their heart rate was no different to when they were on control trips. For control trips, at the end of the trip drivers reporting lower fatigue tended to be less alert than those reporting higher fatigue, compared to the beginning of the trip. For flexible trips, low fatigue drivers were more alert at the end of the trip than the beginning although their alertness was diminishing fairly rapidly. High fatigue drivers showed reductions in alertness over the flexible trip.

These changes in fatigue and alertness can also be linked to changes in performance. For staged trips decreases in cognitive performance and alertness-related heart rate and increases in subjective fatigue occurred compared to the other trip types. Although the pattern of changes in heart rate during flexible trips suggested variable levels in alertness across the trip depending on the overall level of alertness, no change was evident during these trips on any of the performance tests with the exception of steering. Steering became more variable across flexible trips. Control trips showed little change in performance and heart rate but subjective fatigue changes indicated decreased alertness across the trip.

This study provides some insights into the effects and causes of fatigue on long distance drivers. Analysis of the effects of fatigue in drivers showed that cognitive performance was clearly diminished by fatigue in this study, a finding that necessarily demands further attention.

Even though studies have linked general health and lifestyle to increased fatigue, the design of this study allowed us to rule out factors relating to individual drivers such as level of experience, general health and lifestyle as causes of fatigue in this group of drivers. Undoubtedly 12 hours of driving produces fatigue, but this study suggests that the fatigue does not occur because of factors like poor driver preparation, poor rest and break behaviour, driving route, or their motivation to complete the trip.

Differences between driving types were not sufficient to account for changes in fatigue or performance in this study. All drivers reported more fatigued over the trip, but not all drivers showed poorer performance. It seems that the 12 hour trip is relatively immune to any effects of differences in work practices. It is possible that studying such relatively short trips will not provide clear findings. It may be that longer trips are needed to assess the effect of the differences between these three work practices. It is certainly noteworthy that flexible trips produced no worse an outcome than either of the other two ways of doing the same trip. In fact, a more exhaustive evaluation of flexibility, where drivers have the opportunity to learn about manipulating the timing of work and rest during several trips, might reveal that flexibility is of benefit in managing fatigue.

However, the present results clearly indicate that even short trips are affected by the work organisation and conditions that surround them. Factors other than experiences during a 12 hour trip must be considered as causes of fatigue in these drivers. The results of this study suggest that factors leading to chronic fatigue, such as heavy work load over the past few days may account for differences in fatigue levels of drivers. Of the three types of trips, the staged trips were most vulnerable to the effects of work in the past week due to their order in the study. The impact of aspects of work organisation was clearly revealed in the finding that on staged trips drivers were much more tired at the very start of the trip and remained so at the end of the trip. Given that drivers are fatigued by 12 hour trips, irrespective of how they are driven, it is essential that they start fresh and fit to drive. Further, it seems likely that if 12 hour trips and the work organisation surrounding them render drivers vulnerable to fatigue, the impact of work organisation on trips involving even longer hours will also be considerable.

INTRODUCTION

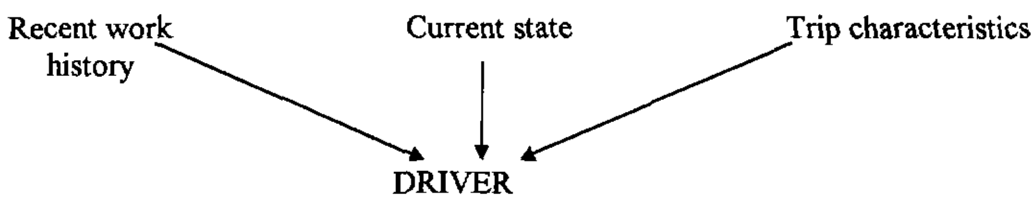
Fatigue while driving is a common problem for many long distance, professional drivers. Our previous survey of truck drivers (Williamson, Feyer, Coumarelos and Jenkins, 1992) revealed that almost half of the participants reported experiencing fatigue while driving on at least half of their trips. Furthermore, around three-quarters of the drivers reported that their driving is worse when they are tired. This finding is consistent with the often-described link between fatigue and road crashes (Haworth, Triggs and Grey, 1988; Haworth Heffernan and Horne, 1989). While it is not easy to determine when fatigue plays a role in road crashes, it is estimated that up to 60 percent of crashes occur at least partly as a result of fatigue. Clearly fatigue increases the risk of accidents in long distance drivers and, while likely to always be part of the job, it should be avoided as much as possible.

The search for the best strategies for reducing fatigue must focus on those factors known to promote it. There is good evidence that four main factors increase fatigue levels (see Figure 1). In particular, it is known that the time of day is influential in generating fatigue (Hamelin, 1987; Moore-Ede, Campbell and Baker, 1988; van Ouwerkerk, 1987). For example, Prokop and Prokop (1955) showed that falling asleep at the wheel occurred between 2 a.m. and 6 a.m. more often than at any other time. The results of the surveys of the freight and passenger sectors of the long distance road transport industry which preceded the current study (Williamson, Feyer et al 1992; Feyer, Williamson, Jenkin and Higgins, 1993) reported that fatigue was much higher during these hours than at any other time and furthermore, dawn driving was cited as one of the major contributors to fatigue by drivers in both sectors.

The duration of time on the task is also acknowledged as playing an important role in generating fatigue. Jones and Stein (1987), for example found that truck crashes were almost twice as likely in drivers who had exceeded 8 hours driving time than those driving fewer hours. Furthermore, Harris and Mackie (1972) showed that arousal levels began to decrease in drivers from around the fourth hour of driving.

In addition, the type of task is important in inducing fatigue. Research evidence implicates tasks, such as driving, which require prolonged monitoring of the physical state of stimuli as being highly vulnerable to the effects of fatigue (Davies, Schackleton and Parasuraman, 1983; Krueger, 1989; Warm, 1984) This soporific effect of long haul driving is particularly pronounced at night, when much of the long distance driving task occurs (Folkard and Monk, 1979; Monk and Folkard, 1985).

Figure 1:Possible Reasons For Fatigue While Driving



Examples of recent work history:	***Examples of current state:***	***Examples of trip characteristics:***
hours work	age	trip length
no. shifts	experience	no./timing of breaks
hours sleep	health	time of day
hours rest	lifestyle	driving conditions

Lastly, the fatigue-inducing effects of sleep loss have been shown to produce performance lapses for a range of different tasks and in a number of ways (Krueger, 1989). Sleep loss is likely to be part of the long distance driving job for much the same reasons as it is for other groups working irregular hours. The duration of sleep and its quality are highly influenced by the phase of the circadian rhythm when it is obtained, with sleep loss being a consequence of attempts to obtain sleep at times that are chronobiologically inappropriate (Dinges and Graeber, 1989). Further, those working irregular hours have been commonly reported to chronically short-change themselves on the amount of sleep that they attempt to obtain (Akerstedt, 1990; Raggatt, 1990)

To complicate matters, these factors are known to interact with one another and with other factors to enhance fatigue effects even further. Moore-Ede et. al (1988) showed, for example, that the combined effects of time of day and driving duration increased the risk of accidents markedly.

All these factors are important in making decisions about the best methods for reducing the problems due to fatigue. In a country the size of Australia, however, with its vast distances between main population centres, it may not be possible to avoid fatigue. Any strategies for controlling fatigue will only reduce, but not eliminate it completely from the experience of long distance driving. This also means that in choosing fatigue-reduction strategies, it is essential to consider the setting in which the strategies are likely to be used.

This was one of the major purposes of the two surveys which preceded this study (Williamson, Feyer et.al, 1992; Feyer, Williamson et al, 1993). For both surveys, the main aim was to determine the nature of the pressures on drivers from different sections of the long distance transport industry, their impact on the experience of fatigue and whether any specific methods for reducing fatigue were being used by any groups in the industry that could be applied in other settings within the industry.

The results of the surveys highlighted a number of factors which deserved further investigation, either because they were promising as strategies to reduce fatigue or because they were being used as fatigue-reducing strategies but did not appear to be entirely successful.

First, the results suggested that staged driving may be only partially successful as a fatigue-reduction strategy. Staged driving involves trips in which two drivers begin their trips from separate origins, meet at a central point in the trip and either exchange loads or exchange trucks, then return to their own point of origin. Theoretically, the advantages of staged driving are that drivers work from their home-base, reducing the need to sleep away from home and thereby reduce the amount of sleep loss, and consequently the amount of fatigue experienced in any trip and across trips.

Evidence from the surveys supported this concept of the benefits of staged driving since staged drivers reported the fatigue least often, compared to other types of drivers, and were least likely to rate fatigue as a substantial personal problem In contrast, however staged drivers reported that they started to experience fatigue much earlier in the trip than the other types of drivers. In addition, staged driving was a favoured work practice mainly for drivers who were currently doing it. Just over half of the drivers with recent experience preferred staged driving to single driving, whereas only about one-quarter of those who had not driven staged for more than 12 months actually preferred this form of driving over single trips. This suggests that staged driving does not suit all drivers. In view of the theoretical benefits of this way of organising work for reducing fatigue, it would be of value to investigate further the effects of staged driving ,as it is currently implemented, on the experience of fatigue.

Second, the surveys suggested that increasing the degree to which drivers have flexibility over the arrangement of the work-rest schedules within a trip may be of significant benefit for reducing fatigue. The results showed that drivers who were less constrained in organising the internal structure of their trips such as two-up drivers and independent owner drivers, reported fatigue as a personal problem least often, and reported experiencing fatigue later in their trips than other types of drivers. Less constraint was also seen in these drivers taking much longer breaks which were more likely to be for purposes of rest, rather than for work-related reasons compared to other drivers. Drivers with greater flexibility were also characterised by doing much longer trips, covering many more hours than the other types of driving. Clearly flexibility has some benefits for driver fatigue which allows them to overcome the problems of very long periods of driving. This strategy, clearly, may be of help to drivers doing other types of driving as well. This possibility should be evaluated.

In this study, therefore, two alternative ways of arranging work were evaluated for reducing the effects of fatigue while driving. Staged driving and flexible work scheduling were evaluated on the road. The latter referred to allowing drivers to arrange the timing of work and rest within a trip according to their needs rather than according to prescribed regulations. The ability of these operational practices to reduce the effects of fatigue were compared with the fatigue experienced by drivers doing single driving, point of origin to point of destination trips, under current regulations.

The principal approach of the present study was to collect on-road data assessing the driver's level fatigue during a 10 to 12 hour trip to document the impact of different working conditions. How one assesses fatigue among drivers, however, has been a major issue of the literature (Dinges and Graeber, 1989). It is clear from the difficulty that many researchers have noted regarding its definition, that, in order to be measured, fatigue needs to be operationalised as level of alertness manifest in capacity to function (Dinges and Graeber, 1989; Haworth et al, 1988). Collection of data bearing on level of alertness requires a multifaceted approach, since fatigue is evident in a variety of outcomes for drivers including control of the vehicle, capabilities for information processing, physiological arousal and subjective feelings of fatigue.

Changes in driving performance with changes in the driver's level of alertness are the most direct measure of the effects of loss of alertness and fatigue. Overall, commonly used direct measures of vehicle control such as steering (Brookhuis and de Waard, 1993; Mackie and Miller, 1978; Seko, Kataoka and Senoo, 1986), speed (Ranney and Gawron, 1987) and maintaining lateral road position (Blaauw, 1982, Brookhuis and de Waard, 1993) have revealed the loss of fine control with prolonged driving. Evaluation of steering control has been one of the most favoured measures because it is considered sensitive to changes in the driver's functioning (Mackie and Wiley, 1991) and because of its obvious relevance as a measure of driver functioning. The presumption is that, in the absence of change in road topography, the alert driver makes a comparatively large number of fine steering adjustments to the demands of the driving task, and relatively few large ones, except when deliberately changing lanes or passing other traffic (Mackie and Wylie, 1991). From both simulator and on-road studies, it appears that with prolonged driving, steering wheel movement becomes increasingly variable, with the proportion of fine steering movements decreasing and the proportion of coarse movements increasing.

On the other hand, perhaps one of the most vexatious problems in assessing fatigue has been that deterioration in performance capacity occurs well before changes in driving performance (Dinges and Graeber, 1989) That is, fatigue may be quite profound but not necessarily have caused a detectable performance decrement, and yet have increased the potential for driver error considerably. High levels of skill in the driving task among professional long distance drivers might be expected to allow them to compensate during routine driving despite considerably reduced capacity due to fatigue. In a series of studies examining vulnerability to the effects of long-term driving, Lisper (1977) demonstrated that inexperienced drivers were far more sensitive than experienced drivers.

Despite an absence of discernible effect on driving performance, fatigue nevertheless may cause serious loss of physiological arousal and slowed sensorimotor function (Dinges and Graeber, 1989, Mascord and Heath, 1992). These fundamental physiological, perceptual, motor and cognitive components underlying all performance, including safe driving, have also been directly assessed.

Physiological measures have had considerable intuitive appeal. Such measures are considered to be free of social/psychological factors that are seen as part of self report, performance and behavioural measures, although this is seldom the case (Dinges and Graeber, 1989, Wilson, 1991). More importantly, physiological measures can provide an index of cerebral arousal (Brookhuis and de Waard, 1993), the dominant framework within which human performance has been considered (Coles and Sirevaag, 1987). The theory proposes that there is a dimension of arousal, with the individual moving from sleep to relaxation to alertness to frantic excitement as arousal increases (Hebb, 1955). The relationship between arousal and performance is described by an inverted 'U', such that the level of arousal at which the individual is alert and performance is optimal lies somewhere between the extremes of the dimension (Hebb, 1955).

Changes in levels of arousal have been regarded as precursors of behavioural change (Brookhuis and de Waard, 1993), with measures of physiological status seen as providing indices of changes in the level of arousal, and thereby possible early markers of fatigue. Reliable relationships have been observed between a range of measures of cerebral arousal and operator performance in relation to driving, with the most prominent being measures of heart rate (ECG) and measures of brain electrical activity (EEG).

Examination of brain electrical activity suggests that it may be a useful marker of increased sleepiness among drivers (Kecklund and Akerstedt, 1993; Mackie and Miller, 1978) and has revealed that one of the major effects of sleepiness is the imposition of brief periods of unwanted light sleep, called microsleeps, into periods of apparent wakefulness (Dinges and Graeber, 1989). In general, with prolonged driving of a train or a car in conditions of monotony, the driver's cortical activation level has been shown to diminish rapidly both across time (Brookhuis and de Waard, 1993; Torsvall and Akerstedt, 1987) and during night driving (Kecklund and Akerstedt, 1993). These findings are consistent with the decreases in arousal level that one would expect with time at the wheel, and in particular, during night driving.

Similarly, measurement of heart rate and heart rate variability have also been seen as an index of arousal. Generally, heart rate has been observed to steadily decline during extended driving (Brookhuis and de Waard, 1993; Fagerstrom and Lisper, 1977; Harris and Mackie, 1972; Lisper, 1977) and variability of the interbeat interval has been observed to steadily increase (Aasman, Mulder and Mulder, 1987; Brookhuis and de Waard, 1993; McDonald, 1984). More in-depth analysis of increased heart rate variability by means of spectral decomposition of inter-beat-interval has revealed that the middle range 0.10 Hz component of the power spectrum is increased with duration of driving under monotonous conditions (Brookhuis and de Waard, 1993; Coles and Sirevaag, 1987; Mascord and Heath, 1992; McDonald, 1984) This pattern of findings is entirely consistent with the expectation that with underload, habituation to an unstimulating environment and increases in boredom at the low arousal end of the spectrum, heart rate slows, and variability of heart rate increases. It has been noted that variability of heart rate can change even if the overall rate does not (Coles and Sirevaag, 1987; McDonald, 1984), making it imperative that each subject is used as his own control (Roscoe, 1993). Thus changes in heart rate indicate relative rather than absolute changes.

The relationship between the pattern of changes in heart rate and interbeat variability observed with extended driving have also been related to cognitive processing changes. Cognitive processing has been distinguished as involving contributions from two fundamental modes of processing, automatic and controlled (Shiffrin and Schneider, 1977). Controlled processing involves conscious attention and mental effort and is used to maintain information in short term memory, retrieve information from long term memory and for decision-making. Automatic processing, on the other hand occurs with little attention and mental effort, that is automatically. The latter is characteristic of performance of highly practiced tasks. As the amount of automatic processing increases, relative to the amount of controlled processing, the same pattern of changes have been observed in heart rate as under conditions of fatigue, namely a decrease in heart rate and an increase in heart rate variability, including an increase in the spectral power of the 0.1 Hz component of inter-beat-interval (Aasman et al, 1987; Egelund, 1982; Vicente, Thornton and Moray, 1987). When mental effort is increased, heart rate measures reveal a pattern more like those found in alert individuals (Vicente et al, 1987), with rate increasing and variability decreasing. These findings suggest that heart rate measures are likely to be highly sensitive to the early signs of fatigue during driving, where highly skilled drivers are likely to become increasingly reliant on automatic processing to maintain driving performance as capabilities for mental effort are reduced due to fatigue. The findings also suggest, however, that heart rate measures may reveal the additional mental effort required to maintain performance when individuals are fatigued (de Vries-Griever and Meijman, 1987).

In addition to cortical arousal, driving performance also involves perceptual, motor and cognitive processes. Deterioration of performance of tasks involving these processes, both in terms of an increase in errors and a slowing of processing, has been demonstrated to be a function of sleep loss (Babkoff, Mikulincer, Caspy, Kempinski and Sing, 1988; Dinges and Graeber, 1989; Monk and Folkard, 1985), time on task (Rosa and Colligan, 1992) and also time of day (Babkoff et al, 1988; Dinges and Graeber, 1989; Monk and Folkard, 1985), with the combined effects of these factors potentiating deterioration of performance (Babkoff et al, 1988; Spencer, 1987). Moreover, deterioration in performance has been found to be associated with subjective reports of fatigue (Rosa and Colligan, 1988). The failure of basic perceptual, motor and cognitive processes underlies impairment in more complex real-world activities like driving performance, and the individual processes themselves are likely to demonstrate deterioration in advance of impairment in overall safe driving performance. Knowledge of information processing function provides an index of capacity for such aspects of driving as hazard recognition, evasive action and capabilities for response under emergency conditions.

Deterioration in underlying information processing capabilities cannot be measured directly during driving. Tasks that are long and monotonous, that require skilled psychomotor performance but are not particularly complex, that require continuous attention, provide little feedback of results and offer minimal incentives are considered to be more likely to be sensitive to the effects of fatigue (Dinges and Graeber, 1989). However, to obtain performance measures on such tests, drivers need to be stopped during prolonged driving, and/or measured at the beginning of periods of driving. One difficulty with the need to interrupt prolonged driving is that the performance impairing effects of fatigue can fluctuate from moment to moment, and can be reduced for brief periods of time by motivation and changed environmental stimulation.

Interpolation of a subsidiary reaction time task while driving has been used as an alternative approach by several investigators to assess changes in information processing capabilities while driving (e.g. Brown, 1967; Harms, 1991; Laurell and Lisper, 1978). The theoretical basis of the dual task technique is that capacity to process information is limited (Wickens, 1984) and measuring how well a person can perform two or more tasks simultaneously allows inferences to be made about how much processing is required for the main or primary task. With the onset of fatigue, the primary task requires more processing effort to be invested in order for performance to be maintained at acceptable levels, leaving less available processing capacity for other tasks. Changes in secondary or subsidiary task performance can provide an estimate of available mental processing capacity as a consequence of changes in processing committed to performance of the main task. There are two basic theoretical requirements for a subsidiary task. It should not interfere with performance of the primary task, and the operator must be devoting sufficient attention to the primary task for the remaining processing capacity to be a test of the limits of processing (Kantowitz, 1992).

The results of studies reporting use of the dual task technique to assess changes in information processing capabilities while driving has been mixed McDonald, 1984). Brown (1967), for example, reported that length of time driving on a test circuit did not affect verbal reaction time to a light signal or a mental time interval estimation task. In contrast, Lisper and colleagues (Laurell and Lisper, 1978; Lisper, Laurell and Stenning, 1976; Lisper, Laurell and van Loon, 1986) have consistently shown that reaction time using a foot pedal response to an auditory signal deteriorated with driving time. Corroborating the utility of the technique for evaluating effort required for the driving task, Harms (1991) reported that the time taken to complete a mental calculation task increased for drivers when they drove in a high workload environment (village areas) compared with when they drove in a low workload environment (highway).

Overall, it seems that fatigue is associated with the changes in physiological status and performance which accompany changes in arousal and alertness. While such operational definitions offer measurable phenomena, in practice, fatigue remains an essentially subjective experience and it is appraisal in terms of their subjective state that drivers presumably factor into the decision to take rest (MacDonald, 1984). A variety of self-report techniques have been used to collect information about fatigue and sleepiness (e.g. Brown, 1982; Hoddes, Zarcone, Smythe, Phillips and Dement, 1973; Johns, 1991; 1992; Mackie and Miller, 1978) In general, such self-reports have been shown to covary with physiological indices of loss of cortical activation during driving (Kecklund and Akerstedt, 1993), periods of sleep deprivation (Babkoff, Caspy and Mikulincer, 1991), circadian rythmicity (Feyer, Williamson et al, 1993; Mackie and Miller, 1978; Williamson, Feyer et al, 1992) and periods of driving (Mackie and Miller, 1978).

Clearly driver fatigue is manifest in a variety of outcomes, suggesting that its evaluation requires a multifaceted approach. In particular, it is clear that fundamental changes may occur in subjective feelings, physiological status and cognitive processing, as well as aspects of driving performance. For the present study, the evaluation involved on-road and off-road monitoring of the driver's level of fatigue, alertness and arousal using measures of each of these dimensions. Specifically, subjective ratings, on-road and off-road measures of cognitive functioning, heart rate and interbeat variability and aspects of driving performance were included. The aim of the study was to evaluate objectively the impact on driver fatigue of staged driving and allowing the driver flexibility to schedule the structure of trips.

METHOD

Subjects

In all, 27 drivers participated in the study. Of these, 19 were drawn from one company and 8 were drawn from a second company. Both companies are categorised as large under the classification scheme used in our previous work, each operating more than 50 trucks. All drivers were regular drivers of staged operations. Just over half (14) of the drivers originated from Sydney and the remainder originated from Melbourne.

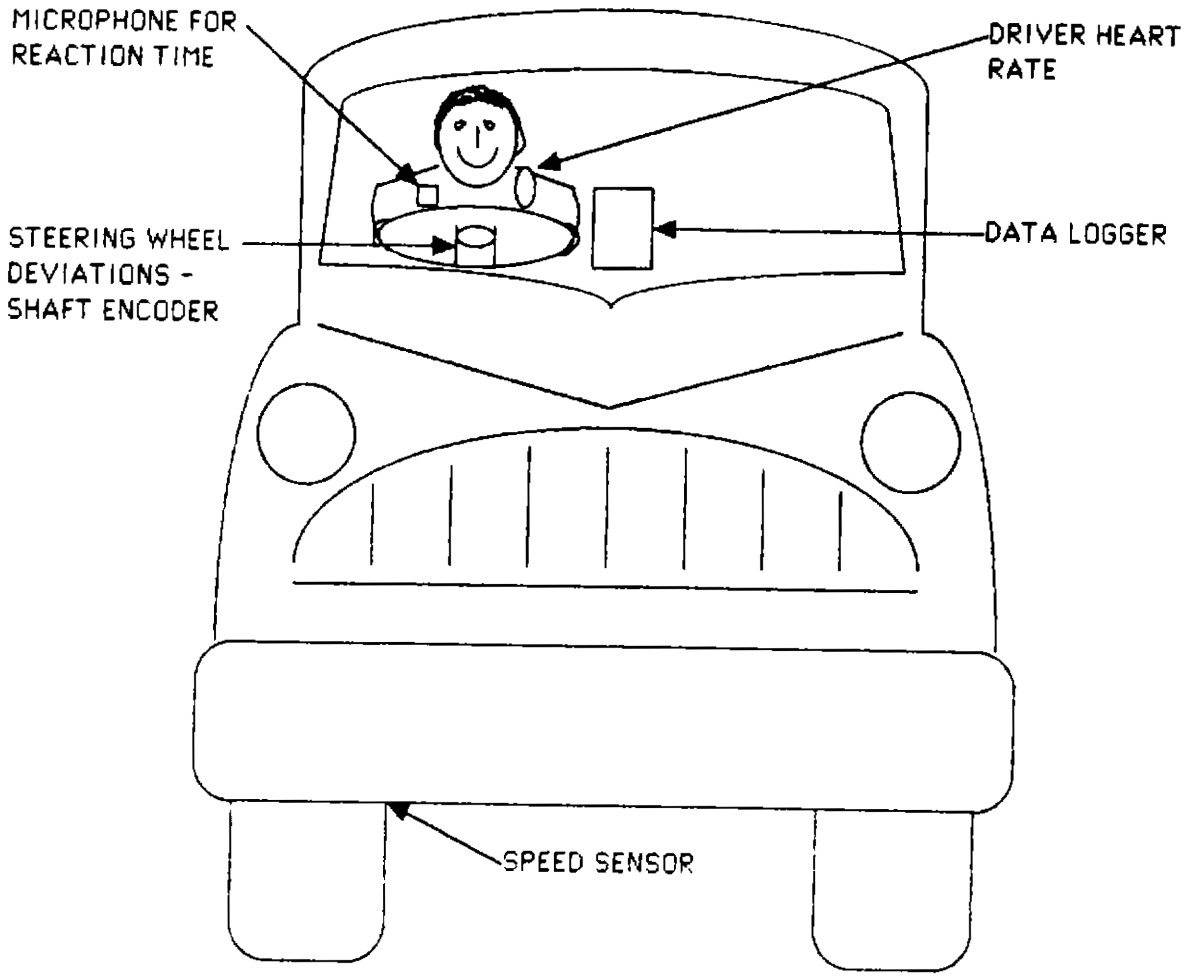
Measures used in the study

In order to assess the impact of the trial trips on driver fatigue, an extensive range of inter-related variables, both before and during the trip, were included in the study. Driver functioning during the trip was evaluated using a range measures sensitive to changes in the level of alertness. These included measures of physiological functioning, cognitive functioning, driving performance, and subjective evaluations of fatigue. Detailed information was also obtained about driver health and the pattern of work within which each trial trip occurred, in order to assess their influence on driver functioning on each trip. Details of each of these measures is provided below.

1. On-board recording apparatus

This study involved the monitoring of drivers' cognitive and physiological functioning, as well as monitoring of their driving performance, in on-road measures obtained under operational conditions (see Figure 2). The equipment was designed to obtain data in real time without interfering with the driving task, and allowing the driver to use his regular vehicle. The equipment was designed in collaboration with two technical experts. Bob Short Model Makers designed and manufactured the fixtures used to attach the various sensors to the vehicle, and A.R. Technology designed and manufactured the data acquisition system.

Figure 2: On-road test equipment



The system consists of a central data logger to which all external devices were attached (see Figure 3). The data logger is externally powered by a 24 volt battery which is designed to receive trickle charging from the truck via a connection to the cigarette lighter. In this way, the power source for the logger is automatically being charged whenever the truck powered is applied. The logger contains all the circuits for collecting data from the various input sensors and for storing the data in its internal memory. For data storage, 2 megabytes of Flash Eprom memory is provided, which is sufficient for approximately 15 hours of continuous recording within the parameters of the inputs. The on-board memory in the logger is non-volatile, that is it retains the stored data even after the power to the unit is turned off. Stored data from the logger can be up-loaded to a standard IBM PC, and individual inputs or selected portions of the data can be selected for analysis, using purpose-specific software provided with the logger by A.R. Technology.

The logger contains 6 input channels, only 4 of which were used in this study. Two were used to collect continuous on-road information about driving performance, one was used to collect continuous information about the driver's physiological functioning, and one was used to collect episodic information about the driver's cognitive functioning.

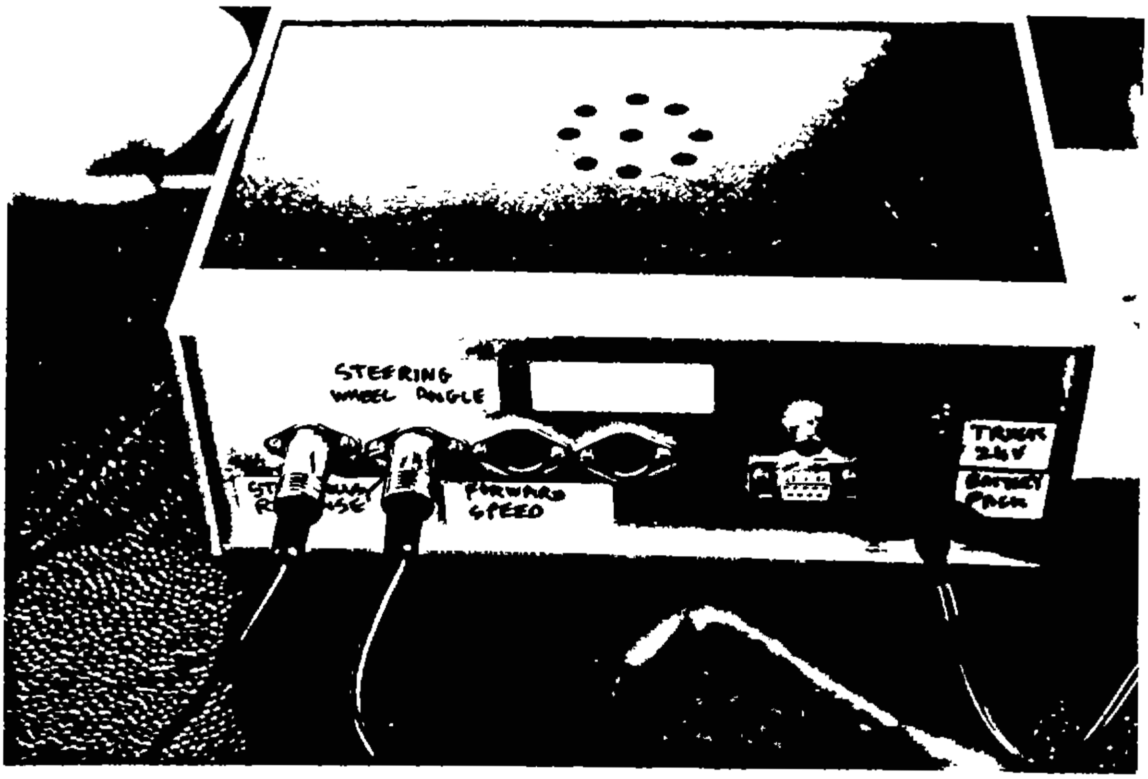
(i) Steering wheel position

The input to this channel is a quadrature-modulated digital pulse from a rotary shaft encoder (Omron E6B-CW3ZC). This device is a high resolution (resolution = 360 pulse/revolution) bi-directional multi-turn potentiometer designed to sense absolute shaft angle. It allows the direction of shaft rotation to be measured, and has a zero index to confirm a start reference point. Wheel angle in rotary pulse encoder units was sampled 10 times per second, with an accuracy of within 0.5 of one degree. Shaft encoder units can be converted to angle in degrees as follows:

angle= (value/65536)(encoder resolution)*(gearing ratio),*

yielding a final calculation of *value*0.05263*. Thus a change of 30 encoder units involves a change of 1.58 degrees.

Figure 3: On-board data logger



The shaft encoder was fixed to the steering column by a mechanical device. This consisted of a rigid metal bracket which was fully adjustable due to a series of sliding bolts and pivots (see Figure 2). Since the drivers' regular truck and driving position was part of the study design, such flexibility was essential in all equipment used to fix sensors to the vehicle. The transducer used to obtain input from the steering wheel consisted of a split-circle bracket attached to surround the steering column (see Figure 4). Circumference screws held the steering column bracket in place and made it possible to adapt it to different-sized steering columns. This collar provided the track for a length of plastic tubing which also circled the track located at the top of the shaft encoder. As the steering column rotated, the collar bracket surrounding it also rotated and through the connection of the plastic tubing resulted in corresponding rotations of the shaft encoder.

(ii) Forward speed

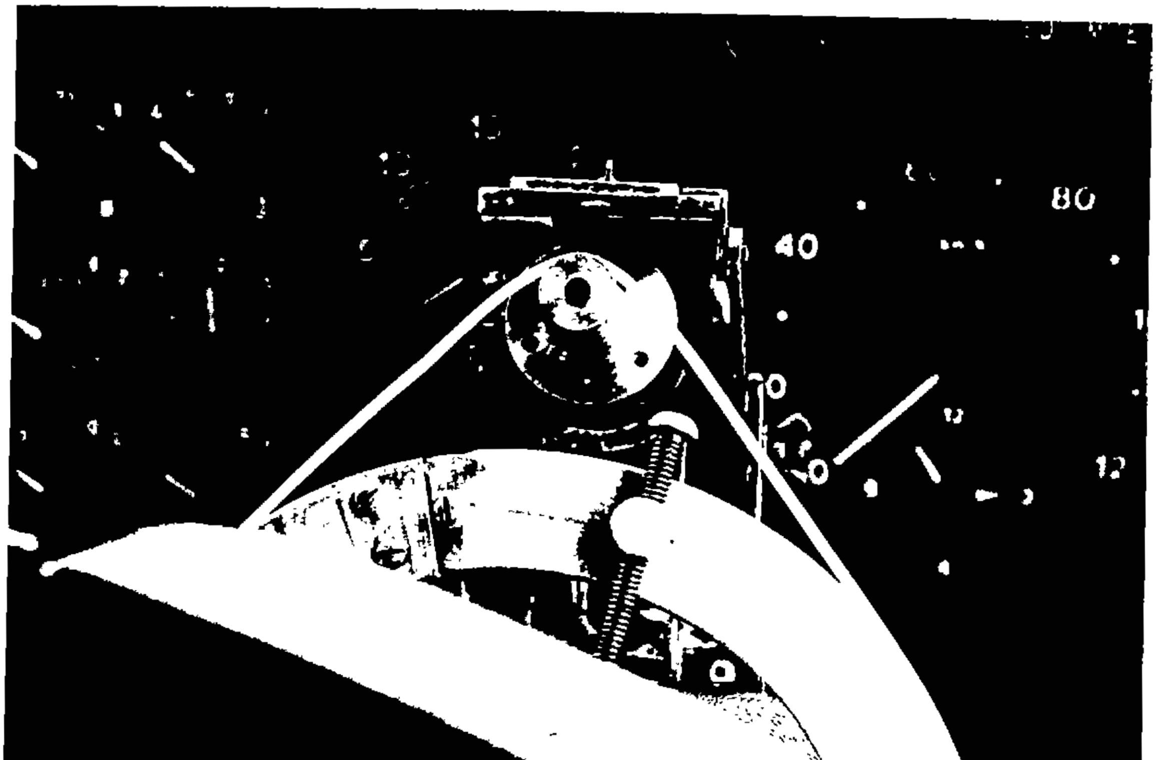
The input to this channel is an analogue input from the wheel under the driver via a digital magnetic pick-up transducer (RS 304172). This sensor was fitted to the dust cover over the brake-drum on the inside of the driver's side wheel with a mechanical device which varied for different truck types (see Figure 5). The sensor picks up the signal from a magnet attached to the wheel rim each time it passes. Wheel revolution rate was sampled 2 times per second as time in 100 microsecond units between wheel revolutions, averaged over two revolutions. This information is calibrated for wheel circumference before the data are up-loaded to PC for analysis. Effective resolution for this measure was approximately 0.2 km/h

(iii) Heart rate

The input to this channel was a digital pulse input from a commercially available heart rate monitor (Polar PE 4000) to detect heart electrical EKG

Figure 4: Apparatus for steering wheel deviation measurement

Side view



Driver's view

signal with chest electrodes (see Figure 6). The unit consists of a chest strap with electrodes built into the strap, as well as a transmitter. The signal from the chest electrodes is transmitted to a watch which has a receiver built into it. The watch was pinned to the driver's shirt to receive the signal. The QRS event discriminator in the watch provided the digital impulse for the logger input. The interval between beats was sampled for each beat pair, in units of 100 microseconds. These data can subsequently be converted to heart rate in beats per minute as well as being analysed as interbeat interval information. Effective resolution for this measure was high, for example, at a heart rate of 60 beats per minute resolution was 1/10000 of a beat.

(iv) Cognitive functioning

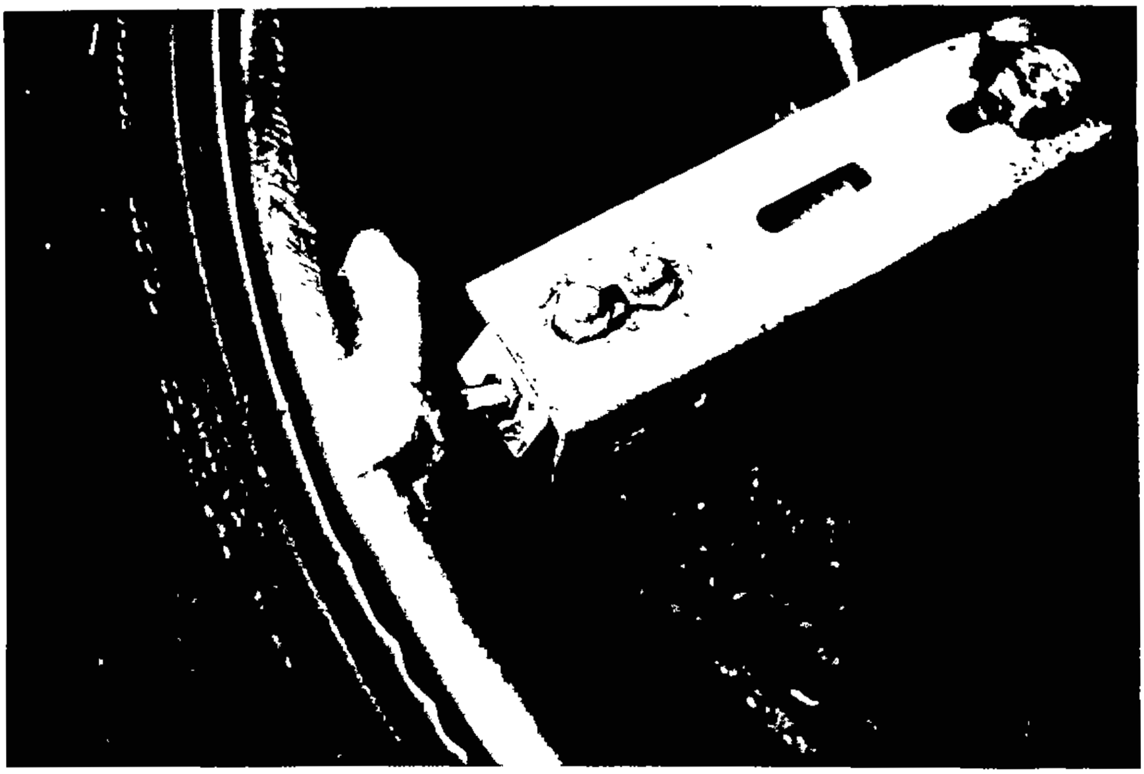
A measure of cognitive functioning was also included as part of the on-board data collection. An episodic secondary task, consisting of an auditory stimulus and an oral response was designed. Using inbuilt amplifiers in the data logger, a 200 millisecond beep tone was delivered, with the driver's task being to say 'yep' as quickly as possible. The driver's response was sensed by a mini tie clip condensor microphone attached to the his shirt, with microphone level input triggering the threshold detection circuitry in the logger (see Figure 6). The interval between the offset of the stimulus and the onset of the response by the driver was recorded in units of 100 microseconds, up to a maximum timeout period of 4 seconds. The interval between the two events, stimulus and response, was corrected to include stimulus duration at the time of analysis.

The task occurred as 30 trials spaced unevenly over a 15 minute period. The inter-trial interval in each block of 30 trials varied randomly between 9 and 24 seconds. Blocks were distributed across the trip such that they occurred 1 hour after departure, and each two hours thereafter. When a break was taken from driving, the timing structure reset to one hour after re-commencing driving, and each two hours thereafter The test yielded two measures, reaction time and number of missed signals (errors).

The task was also completed by drivers immediately before and immediately after the trip. The task was identical in all features, with the exception of the

Figure 5: Speed sensor apparatus

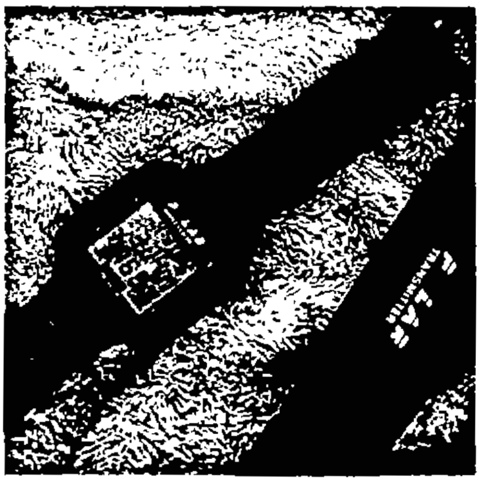
View from front of truck



Side view showing magnet on wheel rim and sensor in place

Figure 6: Apparatus for on-board reaction time and heart rate monitoring

Microphone to capture responses for on-board reaction time test.



Heart rate monitor

timing. The inter-trial interval in these immediate pre- and post-trip blocks varied randomly between 500 and 2000 milliseconds, with a timeout of 2000 milliseconds.

In addition to collecting and storing data from the various sensors, the logger also has an inbuilt timing device which allows time-stamping of all data. Because the logger automatically takes its power from the battery pack if truck power is removed, the clock continues to function during breaks from driving. In this way, the exact topography of the trip is available for analysis, all data can be related to milestones in the trip, and different measures can be compared at identical times in the trip.

2. Cognitive functioning off-road

A selection of tests from the Information Processing and Performance Test System (IPPTS) developed by the senior authors was used in this study (See Figure 7). The system, a computer assisted portable test battery for use in occupational settings, provides tests of basic cognitive functioning based on a generic model of information processing. Tests are designed hierarchically, such that complex tests are composites of the more fundamental ones. The tests selected for this study were ones which were thought to be most relevant to fatigue-related decrements in alertness and performance. Due to operational constraints, the drivers were not available for extensive practice on these tests prior to experimental runs. The tests chosen are all ones which are known to elicit stable responding over relatively few trials. Accordingly, practice trials were included as part of the each testing session, and the data obtained were closely scrutinised for evidence of practice effects during analysis. Where appropriate, comparisons were made of first and second halves of test session performance. The following describes the tests which were included.

(i) Critical flicker fusion

This test provides a measure of basic visual processing. The subject's task is to watch an LED display at the end of a viewing hood (see Figure 7) and press a response button on the hood to indicate the point at which a flickering light no longer appears to flicker (ascending version), and the point at which a solid light begins to flicker (descending version). The frequency at which the subject can detect the change in the stimulus characteristics provides a measure of their sensitivity to subtle changes in their visual environment.

The rate of increase/decrease in the flickering rate is 2 Hz/second within the range of 70-21 Hz for descending and 15-60 Hz for ascending trials, with the start point for each trial being based on the level at which change is detected on the previous trial. There is a fixed 6 sec interval between the subject's response and the onset of the next trial.

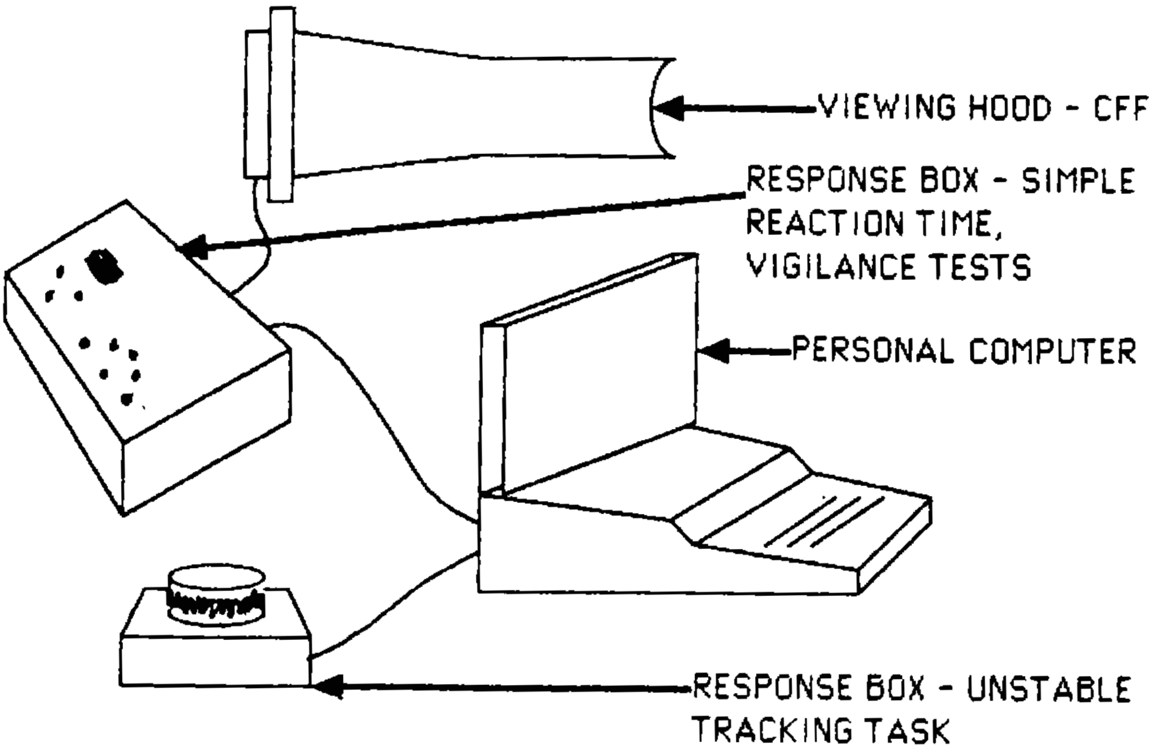
Each eye is tested separately, with both sets of ascending or descending trials being administered before moving to the other type of task. For half of the subjects in the study, ascending trials were presented first, while for the remainder, descending trials were presented first. During each experimental session, 5 trials were administered to each eye of each type of task, yielding 20 trials per subject in total. At the beginning of each testing session subjects were given 2 practise trials before each condition.

(ii) Simple manual reaction time

This test provides the most basic estimate of stimulus response capabilities. A visual stimulus is presented, in this case a circle, on an LED display (see Figure 7). The subject rests the index finger of the preferred hand on a home button located below the display, and his task is to respond as quickly as possible by moving from the home button to the response button immediately above it. In this way, a measure is provided of not only total time to respond to the stimulus (reaction time), but also separate measures of the time for the decision to respond (decision time), and, once having made the decision, the time to execute the response (movement time).

The stimulus duration is 2000 msec maximum or until the response button is pushed. The inter-trial interval varies randomly between 500 and 2000 msec.

Figure 7: Cognitive test apparatus



Subjects in the study were administered one block of 30 trials in each testing session, with only the last 15 being used for analysis. At the beginning of the each testing session, a block of 10 practice trials was given.

(iii) Vigilance

This test provides a measure of the subject's ability to retain high levels of performance in the face of a tedious unchanging stimulus environment. The subject is presented with a semicircular display of 5 lights, each with a button immediately beneath it in the same semicircular display. An additional light and button are located equidistant from each end point and the top of the semicircle (see Figure 7). The lights are illuminated in a quasi-random order, and the subject's task is to hover above the display and press the adjacent button to switch the light off. Occasionally, with a predetermined frequency, two lights are illuminated simultaneously, in which case the subject's task is to press the central bottom button.

The rate at which the lights were illuminated was machine paced, with approximately one trial per second being given. The rate at which double illuminations occurred, was set to be relatively rare, at 20% of trials.

Subjects in the study performed the test for 10 minutes during testing sessions at the beginning and end of trips. At the beginning of each session a 30 second practice (30 trial) sequence was given.

The test yields several measures, including reaction time for all responses, for correct responses, for incorrect responses, the rate of incorrect responses and the rate of missed signals. For analysis, reaction time for correct responses was used, and the number of errors was counted.

(iv) Unstable tracking

The unstable tracking task is considered a highly accurate and reliable test of complex psychomotor control. This task is based on the Critical Tracking Task designed by Jex and colleagues (Smith and Jex, 1986). The subject's task is to control a pointer on a computer screen with movements of an external control dial (see Figure 7). The pointer moves horizontally across the screen and the subject must attempt to keep it within a target zone in the centre of the screen. The pointer changes direction unexpectedly and becomes increasingly difficult to control with the dial, until the subject eventually loses control of it. Two measures are yielded at the end of each trial, the level of difficulty as reflected by the level of instability at the point at which the subject lost control of the pointer, and also the length of time that the subject was able to maintain performance. Together these measures reflect perceptual motor capabilities in terms of hand/eye co-ordination.

During each testing session 10 trials were administered to each driver, with the first 5 and the last 5 being analysed separately. At the beginning of the first session, 5 practice trials were given.

The full battery of tests was performed at the beginning and end of the trip. For those trips were there was a known midpoint, a shortened form of the test battery was performed at the beginning of the break. This session included all tests except the vigilance task, in order to prevent overly compromising the driver's break time. Test order was always as follows: critical flicker fusion, vigilance (for those test occasions where it was included), simple reaction time, and the unstable tracking task.

3. Subjective evaluation of fatigue

At the beginning of the trip, at the beginning of each break and at the end of each trip, drivers were asked to complete a set of ratings of fatigue (see Appendix 1). Two forms of brief evaluation were used, the Stanford Sleepiness Scale (SSS) (Hoddes et al, 1973), and a series of Visual Analogue Scales (VAS) designed by the authors. The two forms of evaluation were used in order to assess different possible dimensions of fatigue. The SSS is very specifically focused on increasing feelings of sleepiness, while the VAS dimensions were focussed on various aspects of the experience of fatigue.

4. Trip diaries

All drivers were asked to keep a diary of activities during and immediately before each experimental trip (see Appendix 2). Prior to each trip, information was obtained about activities in the 12 hours immediately before the trip, as well as information about the proposed trip route and planned stops. During the trip, drivers were asked to keep a log of the trip, including information about the timing of breaks, activities during breaks, and about food and drink intake during driving. The diary also contained self-report forms for drivers to report their level of fatigue at the beginning of each break.

5. Work history

This questionnaire obtained details of the driver's work/rest schedule in the week prior to participation in the study (see Appendix 3). Drivers were asked to describe the week in terms of when they worked and when they rested. This questionnaire provided information about possible work-related influences on fatigue during the experimental trips emanating from factors other than characteristics of the individual trips.

6. Health history

This questionnaire obtained details of the general health and lifestyle status of the drivers in order to provide information about possible health-related influences on fatigue during the experimental trips (see Appendix 3). Drivers were asked to report some basic demographic information, as well as information about health-related lifestyle factors such as regular exercise, the use of cigarettes and alcohol. In addition, information was obtained about any current medical conditions and any current prescribed medications. The questionnaire also obtained information about sleep patterns and sleepiness using the Epworth Sleepiness Scale (Johns, 1991; 1992). These were included because of the well-documented finding that sleep is disturbed among shiftworkers, which may in turn influence fatigue on the job (Koller, 1983; Frese and Harwich, 1984). Further, there has been considerable debate recently regarding the prevalence of obstructive sleep apnea among the commercial driver population (Bearpark et al, 1990). Accordingly questions about a set of phenomena which have been argued to have some potential to predict risk of sleep apnea related problems (Haraldsson, Carenfelt and Tingvall, 1992; Kapuniai, Andrew, Crowell and Pearce, 1988) were included in the questionnaire.

Procedure

Volunteers were obtained through the companies. Drivers at participating companies were provided with information about the study through personal visits by the chief investigators, and an information leaflet circulated to the drivers. Volunteers were sought from drivers involved in carrying freight between Sydney and Melbourne in staged operations. This route was chosen because it appears to be typical of populous zone trips, and it allowed at least one endpoint to be the homebase of the investigators.

Consultation with authorities

One of the major issues addressed by the present project is the possibility that taking rest on needs basis may provide drivers with better fatigue management than taking rest breaks according to current regulations. By allowing drivers to schedule rest themselves for the purposes of the study, it was possible that drivers might contravene current work hours regulations in N.S.W. in their flexible trip. Extensive liaison was undertaken with regulatory authorities in both states in order to obtain exemptions from current regulations for drivers on the individual trial flexible trips. Such exemptions were not able to be obtained from VicRoads, however, the Roads and Traffic Authority of N.S.W. did provide the necessary undertakings (see Appendix 5). Consequently, all flexible trips were run from Melbourne to Sydney in order to ensure that drivers were in N.S.W. when flexibility may have compromised their compliance with current working hours regulations.

Scheduling of experimental trips

Once volunteers for the study were obtained, meetings were held with schedulers at each company. to determine trips for which volunteers were already rostered for staged trips turning around in Tarcutta N.S.W., the changeover point for staged operations delivering freight between Sydney and Melbourne. For both companies participating in the study, drivers were regularly rostered for several staged trips turning around in Tarcutta in the same week, before rotating to other destinations. Weeks in which drivers were already scheduled to drive three staged trips turning around in Tarcutta were chosen for each driver's participation in the study. For the purposes of the study, two of these scheduled staged trips for each driver were rescheduled to go straight through to the capital city destination. Thus in the week in which he participated in the study, each driver undertook one trip as a staged operation turning around in Tarcutta, one trip as a single operation from Melbourne to Sydney, and one trip as a single operation from Sydney to Melbourne.

These drivers, although experienced in single driving, were not regularly scheduled for single trips between Sydney and Melbourne.

The single trips were differentiated by the regime available to the driver to organise work and rest on the trip. On trips originating in Sydney, drivers were required to take rest in accordance with the work hours regulations, designated as control trips. On trips originating from Melbourne, drivers were asked to drive according to a preferred flexible schedule, taking rest as they felt they needed it, designated as flexible trips.

The order in which drivers undertook the three trip types was entirely limited by operational constraints. Overall, the schedules did not permit randomised or counterbalanced order of trip types for each driver (See Table 1). Because single trips resulted in the driver being away from homebase overnight, the two single trips were always scheduled as adjacent trips to allow the driver to return to home as quickly as possible. The pattern of the existing schedules led to most drivers being scheduled to drive adjacent staged trips to Tarcutta later in the week, and isolated staged trips earlier in the week, resulting in the staged trip mostly being the first experimental trip undertaken by most subjects. However, as flexible trips always took place on the Melbourne to Sydney route, and control trips on the Sydney to Melbourne route, the order of single trips was naturally counterbalanced due to the different points of origin of the drivers.

TABLE 1: Order of Trips.

	ORDER OF TRIP		
TRIP TYPE	**1**	**2**	**3**
Staged	92%	0%	8%
Control	11%	44%	44%
Flexible	4%	56%	41%

NOTE: Two drivers did not complete staged trips.

Volunteer drivers from each capital city were scheduled as teams, that is, they were scheduled for the identical trips on the same days from each endpoint. This procedure allowed standardisation of conditions such as weather, road and traffic conditions for subjects participating from each capital city. It also allowed maximal efficiency of data collection. Participation of the drivers in the study as teams was also operationally important in the case of staged trips because the standard practice in staged operations for both participating companies was to exchange vehicles, rather than to exchange loads at Tarcutta. Scheduling drivers as teams, meant that, on any given trip, identical vehicles, both instrumented for the study, departed from each capital city at the same time. The standard practice for drivers of exchanging vehicles at Tarcutta, therefore was able to be maintained within the study.

Data collection

A member of the research team met each driver one hour before each trip. This allowed the driver to read and sign the informed consent form (see Appendix 5), complete work and health histories, and to undertake the pre-trip cognitive performance test. His plans for the trip, such as estimated times of arrival in Tarcutta were also discussed. Once the driver had departed, the member of the research team stationed in Tarcutta was informed of the driver's schedule, in preparation for meeting each driver as he arrived in Tarcutta for the mid-trip data collection. Finally, a member of the research team met the driver of his destination, to administer the post-trip cognitive performance tests, collect the driver's trip diary and remove the equipment from the truck.

As the schematic representation of data collection for each trip type in Figure 8 shows, data were collected according to an almost identical protocol for each trip type. The major difference between trip types related to mid trip meetings with the driver. For control and staged trips, there was a known midpoint, Tarcutta. For flexible trips, where drivers were asked to take rest on a needs basis, there was, by definition, no way of knowing in advance where drivers would chose to break the trip.

Selection of the route for the evaluation reflected that the major focus of the study was related to driving practices in populous zones in general, and working in staged operations in particular. The route therefore was based on a typical trip for staged drivers, namely a 10-12 hour inter-capital city route on the East coast.

FIGURE 8: Summary of measures for each trip type

STAGED	FLEXIBLE	CONTROL
Pre-trip	**Pre-trip**	**Pre-trip**
Health history Work history Cognitive tests Subjective	Health history Work history Cognitive tests Subjective	Health history Work history Cognitive tests Subjective
On-road	**On-road**	**On-road**
Steering Heart rate Speed Reaction time Subjective	Steering Heart rate Speed Reaction time Subjective	Steering Heart rate Speed Reaction time Subjective
Mid-trip		**Mid-trip**
Cognitive tests Subjective		Cognitive tests Subjective
On-road	**On-road**	**On-road**
Steering Heart rate Speed Reaction time Subjective	Steering Heart rate Speed Reaction time Subjective	Steering Heart rate Speed Reaction time Subjective
Post-trip	**Post-trip**	**Post-trip**
Cognitive tests Subjective	Cognitive tests Subjective	Cognitive tests Subjective

Analysis

A major issue in the study concerned the use of an independent groups versus a repeated measures design. A repeated measures design was selected based on the potential power of such designs to provide strong evidence of the impact of the effect under consideration. In such designs, each subject participates in each condition, essentially acting as his own control. In this way, individual variation, for example, predisposition to experiencing fatigue, motivational factors, physiological responsiveness factors and the like do not contribute any noise to the data.

On the other hand, repeated measures analysis techniques are severely handicapped when data are based on small numbers and/ or include missing data. Both of these were problems in the present study.

In general, ANOVA and MANOVA techniques for analysis of repeated measures data were used. These analyses were then extended with post-hoc univariate comparisons, where appropriate. Where applicable, correlations and T-tests were also used. The techniques are described in detail in the sections in which they are used.

Significance levels (alpha) were maintained at 0.05 for each measure. Where appropriate, adjustments were made for multiple tests, and these are discussed as they occur.

RESULTS

Characteristics of the sample

Table 2 displays the characteristics of the drivers participating in this study. The results show that the drivers in this study were experienced drivers of heavy vehicles, most having well over 10 years experience (68.5%). There were few young drivers in the sample, the mean age being 38.4 years. Only one driver was under 25 years of age. Most drivers were married or living in a defacto relationship. Less than one-quarter were single. These results are consistent with the findings of the large survey of long distance truck drivers (Williamson, Feyer, Coumarelos and Jenkins, 1992), showing that the sample of drivers in this study is fairly characteristic of employee drivers of medium and large companies and with those for staged drivers.

TABLE 2: Characteristics of Drivers.

Mean Age	38.4
Marital Status	
% Married	60.9
% Defacto	13.0
%Single	21.7
Driving Experience	
Mean Years	15.9
% <= 10 years	31.5
% <= 20 years	31.6

Health status of the drivers

The drivers in this study were a healthy group who lead a fairly healthy lifestyle (See Table 3). Only two drivers had chronic medical conditions for which they were taking medication. Only about one-quarter of the drivers smoked and almost half reported exercising on a regular basis. Well over half of the exercisers did so at least two to three times per week. Most drivers reported that they drank alcohol, but on a relatively infrequent basis. Almost three-quarters of the drivers reported consuming alcohol no more than once per week. When they do drink, however, almost half of the drivers reported usually consuming more than three regular drinks at one time. These results suggest that drivers regulate their alcohol consumption very well so that the overall amount they consume is low and is unlikely to interfere with their work demands. While the amount of alcohol that drivers report consuming when they do drink could be regarded as high for a single session, the total amount consumed is within the accepted range of social drinking and is unlikely to affect their health in the long run.

TABLE 3: Health and lifestyle characteristics of drivers participating in the study.

CHARACTERISTIC	% DRIVERS
Diagnosed medical condition in past 12 months	8.7
% Smoking	26.1
% Using alcohol	82.6
Frequency of use:	
every day	15.8
2-3 times / week	10.5
once /week	47.4
1-2 times / week	15.8
rarely	10.5
% Consuming >3 drinks at one time	47.4
% Exercising at least 2-3 times / week	63.7
% Using pills to stay awake while driving	0

As staged drivers do a great deal of their work at night, issues relating to sleep are particularly important to consider in this group (See Table 4). The results show that this group of drivers have few sleep problems. Very few drivers reported difficulty getting to sleep or staying asleep and only about one-quarter reported sometimes having difficulty preventing themselves falling asleep during the day. When administered the Epworth Sleepiness Scale which asks about problems of sleepiness during a range of activities, the only activities where more than one driver reported at least a moderate chance of falling into a doze were sitting reading or watching TV and while resting in the afternoon (See Table 5). The overall results for the Epworth Sleepiness Scale items reveal that this group of drivers should be classified as having relatively little problem with daytime sleepiness.

TABLE 4:Sleep problems of drivers.

PROBLEM	%
Getting to sleep	8.7
Staying asleep	4.3
Falling asleep during day	Never: 43.5 Rarely: 30.4 Sometimes: 26.1

Compared to a study of the reliability of the scale in which medical students and patients with obstructive sleep apnea syndrome were found to have mean sleepiness scale scores of 7.4 and 14.3 respectively (Johns, 1992), the drivers in this sample showed much lower scores on sleepiness. Considering that all drivers in this study work at night and must, consequently, sleep in the daytime, these results suggest a work group who are dealing well with the demands of this type of lifestyle. Consistent with these results of general low level of sleep and sleepiness problems, no drivers reported needing to consume pills at any time to stay awake while driving.

TABLE 5: Drivers response to the Epworth Sleepiness Scale.

Sleepiness when:	% never doze	% slight chance	% moderate chance	% high chance
Sitting reading	40.9	36.4	13.6	9.1
Watching TV	22.7	36.4	31.8	9.1
Sitting inactive	69.9	26.1	0.0	0.0
As a passenger in a car	73.9	17.4	0.0	4.3
Resting in the afternoon	9.7	40.9	27.3	22.7
Sitting talking	91.3	4.3	0.0	0.0
Sitting after lunch	60.9	30.4	4.30	0.0
In a car stopped in traffic	77.3	18.2	0.0	4.5
TOTAL EPWORTH SCORE (mean)	4.91	(S.D.= 3.13)		

Considerable attention has been drawn to the assertion that truck drivers, as a group, have a high in incidence of sleep apnea. Three questions were included in the health questions for this study which have been used to discriminate sleep apnaeics from the normal population in other studies. The results of these questions are shown in Table 6. The results of individual questions show that no drivers reported any problems due to snoring loudly, stopping breathing or moving around a lot when sleeping. These results were analysed using two different criteria for discriminating individuals at high risk for sleep apnea. The first criterion was based on that used by Kapuniai et al. (1988) which uses the responses to the snoring and stopping breathing questions. On this criterion no drivers in this study could be classified as having high risk for sleep apnea. The second criterion was broader using all three sleep apnea questions and the responses to the questions about day time sleepiness and difficulty in staying asleep (Haraldsson et al., 1992). By this criterion as well, no drivers in this study could be classified as a high risk sleep apneic individual.

TABLE 6: Apnea related questions.

SLEEPING PROBLEM	% Never	% Rarely	% More common
Snore loudly	40.9	59.1	0.0
Stop breathing	100.0	0.0	0.0
Move around a lot	26.1	69.9	0.0

Recent work history

Drivers were asked about their work history over the past seven days. The overall results are displayed in Table 7. The average time worked in the past week was 55.6 hours, however the range was very high, from 24 to 96 hours. The upper limit of the work hours range could be regarded as unusual as it consisted of one driver who reported doing seven shifts in the past week, totalling 96 hour. The next highest group of drivers worked between 60 and 70 hours over the past week. Overall, these hours were worked usually in five shifts in total (range 2 to 7) with on average four shifts worked consecutively (range 2 to 7) The work hours were constructed mainly from night work (39.7 hours), with an average of 4.1 night shifts worked each week. On average, 3.2 nights were worked consecutively. Most drivers had only one rest day although 10.5% had no rest days in the past week and 5.3% (one driver) had three rest days.

Most drivers had comparatively low amounts of sleep compared to community norms. Hyppa, Kronholm and Mattlar (1991) found that the self-reported nightly sleep of a random sample of people was 7.5 hours. For drivers in this study the average weekly hours slept was 44.0 hours but the amount of sleep in the past week ranged from 23 hours (equating to around 6.3 hours per sleep period) to as much as 72 hours. Only about half of the sleep was taken at night (22.8 hours), but two drivers had no night sleep at all in the last week, while seven drivers had at least three-quarters of their sleep during night hours. These results suggest that, as a group, the drivers in this study would be expected to be considerably more tired than workers in the rest of the population based on their overall hours worked, especially at night, and on the amount of sleep they receive, again especially during the night time hours.

TABLE 7: Recent Work History.

	MEAN	S.D.	RANGE
Hours worked	55.55	14.66	24-96 (hrs)
Night hours worked	39.68	15.95	17-69
Total hours slept	44.03	12.94	23-72
Total night hours slept	22.82	15.36	0-54
Number of rest days	1.32	.75	0-3
Number of shifts worked	5.21	1.18	2-7
Number of consecutive shifts	4.26	1.19	2-7
Number of night shifts	4.05	1.84	0-6
Number of consecutive nights worked	3.21	1.84	0-6

Comparing these results with those found for staged drivers in the long distance truck driving survey, the hours worked in the last week for staged drivers doing two-way trips (49.8 hours) was similar to the time worked by drivers in this study, but considerably more than for staged drivers reporting one-way trips (39.1 hours). In the current study only one driver reported doing less than 38 hours in the past week and only one reported doing more than 72 hours. In the current study most drivers worked around four nights shifts (mean 4.05 shifts) in the past week whereas staged drivers in the survey reported an average of around three nights in the past week (2.8 and 2.4 nights for one-way and two-way staged drivers respectively). Overall, it appears that the workload for staged drivers participating in this study was higher than the average for staged drivers based on those surveyed in the previous study.

Examination of the relationships between work and rest in the past week for the drivers in this study (See Table 8) showed that sleep length tended to increase with the amount of work done by drivers. Regardless of the measure of workload used, there was a significant correlation between workload and amount of sleep. Sleep length was significantly correlated with total hours worked, with the total number of shifts worked and with the number of consecutive shifts worked. The same relationship was not found, however, between the amount of work done at night and the amount of sleep obtained. These results confirm that higher workloads are, not surprisingly, associated with greater fatigue in these drivers. They also suggest, however, that these drivers respond appropriately to the higher fatigue by increasing the amount of sleep they obtain. This interpretation is supported by the additional finding that there was a significant negative relationship between the number of rest days and amount of sleep obtained. The more rest days drivers had, the less they slept. This finding again indicates that the drivers adjusted their sleep according to the amount of work they had to do.

TABLE 8: Relationship between work and rest in the past week for all drivers showing correlations between variables.

WORK CHARACTERISTIC	SLEEP LENGTH
Total hours worked	0.63 ($p<0.002$)
Total number shifts worked	0.67 ($p<0.001$)
Number of consecutive shifts worked	0.58 ($p<0.004$)
Number of nightshifts	-0.02 (N.S.)
Number of restdays	-0.45 ($p<0.03$)

COMPARISON OF TYPES OF DRIVING

Chronology of each trip type

For all three types of driving, staged, flexible or control, most trips started in the late afternoon and early evening (See Table 9). A small percentage of flexible and control trips were started in the early morning hours, between midnight and 0400 hours. No staged trips were started later than midnight. This finding is not in accord with the results of the long distance truck driving survey in which around one-third of staged drivers began their trips between midnight and 0600 hours. There was little variation in average trip length between the trip types (See Table 10), all trips taking around 12 hours to complete. For all trip types most trips were completed between 0400 and 1200 hours (see Table 11), however more flexible and control trips were completed early, between 0400 and 0600 hours, than were staged trips (22.2%, 18.1% and 4 2% respectively). Consequently, fewer drivers doing flexible and control trips had the 0400-0600 hours period which is recognised to be a vulnerable period in the circadian rhythm, incorporated into their shift.

TABLE 9: Start time across trips.

TRIP TYPE	START TIME		
	16.00 - 19.59	20.00 - 23.59	24.00 - 03.59
Staged	45.8%	54.2%	0.0%
Control	44.4%	44.4%	11.1%
Flexible	37.0%	48.1%	14.8%

Table 12 shows the details of breaks taken during each trip type. All drivers had at least one break on all trips, but the trip types differed in the number of drivers taking more than one break. Flexible trips were characterised by relatively few breaks. Just over half of the drivers took two breaks on flexible trips and only 16 percent took three breaks. In contrast, the majority of drivers took two breaks during staged trips and almost half took three breaks. These results were also reflected in the total time spent in breaks during each trip type. Flexible trips involved the least time in breaks and staged trips the most.

TABLE 10: Average trip length between trip type.

Trip Type	Mean Trip Length (hrs)	S.D.
Staged	12hrs 36mins	0.92
Control	12hrs 10 mins	1.2
Flexible	11hrs 59 mins	0.67

TABLE 11: Percentage of drivers finishing trips according to time of day. (This information was missing for a number of drivers so row percents do not total 100)

	Finish Time		
Type of Trip	04.00 - 07.59	08.00 - 11.59	12.00 - 15.59
Staged	36.0	48.0	0.0
Control	48.1	25.9	11.1
Flexible	37.0	40.7	11.1

TABLE 12: Percentage of drivers doing each trip type taking one, two, three or four breaks in the trip.

TRIP TYPE	NUMBER OF BREAKS			
	1	2	3	4
Staged	100	66.7 (16)	50.0 (12)	4.2 (1)
Control	100	68.0 (17)	24.0 (6)	0
Flexible	100	60.0 (15)	16.0 (4)	0

The trip types also differed in the relative time spent in each break (see Table 13). Drivers doing staged trips divided their break time fairly equally between breaks. On control trips, however the first two breaks were relatively long, but for drivers taking the third break, it was much shorter. In contrast, when on flexible trips, the second break was much shorter than the first and, for the relatively few drivers who took a third break during flexible trips, it was relatively long. The trip types did not however differ in the relative placement of breaks in the trip. For all types of trips, the first driving stint was longest, being between four and five hours, the second stint the shortest followed by a slightly longer stint for those drivers who took a third break. It would seem that the need for breaks occurred roughly in the same position in the trip no matter what type it was, suggesting that the absolute length of the trip plays a role in determining when breaks occur. In contrast the length of time spent in the break and whether the break was taken at all did differ between trip types suggesting that the different demands of each trip type played a role for these factors.

TABLE 13: Time spent driving and time spent in breaks.

TRIP TYPE	Drive time 1	Time in break 1	Drive time 2	Time in break 2	Drive time 3	Time in break 3
Staged	4hrs 23mins	38mins	2hrs 29mins	40mins	3hrs 20mins	37mins
Control	4hrs 32mins	44mins	2hrs 48mins	50mins	3hrs 45mins	17mins
Flexible	4hrs 30mins	33mins	2hrs 52mins	22mins	3hrs 2mins	40mins

Driver preparation for each trip type

Table 14 displays the details of the drivers activities in the 12 hours before each trip type. The results showed that all drivers consumed a meal and the majority consumed two meals in the 12 hours before starting work on staged trips. For control and flexible trips almost all drivers consumed only one meal before the trip with a small percentage (7.4% on each group) not consuming a meal at all during this time prior to the trip. Most drivers did not consume alcohol at all before any trips. A small percentage of drivers reported taking some medication in the 12 hours before starting a each type of trip. The type of medication taken included, drugs for chronic medical conditions such as diabetes and asthma (four drivers), antibiotics, antacids and analgesics (one driver in each case). No drivers reported taking drugs to stay awake before any type of trip.

Drivers obtained roughly equivalent amounts of sleep before each trip type and compared to the amount os sleep obtained before each trip in the last week. There was, however, a slight difference in the recency of sleep before each type of trip. Drivers slept relatively more recently before doing flexible trips than before staged or control trips.

TABLE 14: Driver's preparation for the trip showing activities undertaken in the 12 hours before each trip type.

	TRIP TYPE		
In the past 12 hours:	**Staged**	**Control**	**Flexible**
% consuming at least one meal	100.0	92.0	92.6
% consuming alcohol	13.0	4.0	14.8
% taking medication	20.8	12.5	11.1
Amount of sleep taken (mean hrs, sd)	6.3 (2.68)	6.79 (2.36)	6.05 (1.37)
Time since sleep was taken (mean hrs, sd)	3.86 (2.28)	3.25 (1.47)	2.83 (1.58)

The effect of driver experiences on each trip type

Table 15 shows the consumption of food and beverages during each trip type. Consumption of food and drinks was similar for all trip types. During all trips, only about half of the drivers reported eating at all during each type trip, but considerably more drank non-alcoholic beverages. Only one driver reported taking stay-awake drugs, and only for a control trip. No other drivers reported using drugs on any other trip.

The results of the two methods of assessing drivers' feelings about their current state of fatigue and alertness at points in the trip while stopped are displayed in Tables 16 and 17. For the seven-point Stanford Sleepiness scale, repeated measures analysis of variance revealed a significant main effect for type of trip ($F_{(2,42)}=5.33, p<0.009$), a significant effect of time of rating ($F_{(1,21)}=62.14, p<0.0001$) but no significant interaction effect ($F_{(2,42)}=2.08$, n.s.). This analysis showed reductions in alertness across the trip for all trip types. Drivers on control trips showed significantly higher alertness at the beginning and end of the trip compared to both staged and flexible trips.

TABLE 15: Consumption of food and beverages during the trip for each trip type.

	TRIP TYPE		
	Staged	**Control**	**Flexible**
% consuming food	71.4	54.5	51.9
% consuming nonalcoholic beverages	81.0	68.2	70.4
% using "stayawake" drugs	0	4.0	0

This analysis showed that more drivers reported reduced alertness before their staged trip than before any other trip. Although the ratings of alertness were overall towards the good performance end of the scale at the beginning of all trips, one in five drivers reported marked depression in alertness before the staged trip. For all trips more drivers reported reduced alertness at the end of the trip than at the beginning, although again, the staged trips produced lower alertness ratings from most drivers. About one-third of drivers reported being at least foggy and not at their peak at the end of the staged trip. During the trip more drivers reported lower alertness at the end of the first driving period (just before the first break) than at any other time. This result occurred for all trip types.

For the analysis of the breaks taken after the first one, interpretation of the results must take into account the fact that fewer drivers took more than one break, and a likely reason for taking these breaks would be reduced alertness and increased fatigue. Ratings of alertness for the beginning of breaks 2 and 3 suggested, if anything, higher alertness levels than at the beginning of the first break for both staged and control trips. For flexible trips, however, there was a considerable increase in the number of drivers reporting reduced alertness at the beginning of the second break. Only about two-thirds of drivers took a second break on all types of trips. On flexible trips, however, drivers were instructed to take a break if they were feeling fatigue so that fatigue is likely to be the main reason for taking the break, whereas for the other types of trip, breaks may have been taken for reasons other than fatigue.

TABLE 16: Reported alertness of drivers at different stages across trips.

TRIP TYPE	FATIGUE RATING	PRE TRIP %	BREAK 1 %	BREAK 2 %	BREAK 3 %	POST TRIP %
Staged	1	50	26.1	28.6	10.0	4.2
	2	29.2	34.8	42.9	20.0	25.0
	3	0	21.7	14.3	50.0	37.5
	4	16.7	8.7	7.1	0	25.0
	5	4.2	4.3	7.1	20.0	4.2
	6	0	4.3	0	0	4.2
Control	1	58.3	41.7	14.3	20.0	32.0
	2	33.3	33.3	35.7	60.0	20.0
	3	8.3	8.3	35.7	20.0	40.0
	4	0	8.3	14.3	0	8.0
	5	0	4.2	0	0	0
	6	0	4.2	0	0	0
Flexible	1	42.3	34.8	15.4	0	3.7
	2	42.3	26.1	46.2	33.3	37.0
	3	15.4	13.0	7.7	66.7	40.7
	4	0	0	7.7	0	11.1
	5	0	13.0	23.1	0	7.4
	6	0	4.3	0	0	0

FATIGUE RATING CATEGORIES

1- Feeling active and vital; Alert and wide awake.
2- Functioning at a high level, but not at peak; Able to concentrate.
3- Relaxed and awake but not at full alertness; Responsive.
4- A little foggy, not at peak; Let down.
5- More foggy; Beginning to lose interest in staying awake; Slowed down.
6- Very sleepy, fighting sleep, woozy; Prefer to be lying down.
7- Almost asleep; Lost struggle to remain awake.

Very similar results were found for the other subjective measure of fatigue, the visual analogue scales (See Table 17). For this analysis the results of the three scales were averaged for the pre-trip and post-trip ratings and then were compared for each trip type using multivariate analysis of variance. The results revealed a significant main effect of time of rating ($F_{(1,21)}=94.34, p<0.0001$), a significant effect due to the type of trip ($F_{(2,20)}=6.22, p<0.008$), but no interaction effect between these two factors ($F_{(2,20)}=0.59$, n.s.). These results indicate that when asked to rate their current state at the beginning and end of the trip and just before they took each break, drivers rated their levels of fatigue as higher at the beginning of their staged trips compared to the other trips. Drivers also tended to rate their fatigue higher at the end of staged trips compared to control and flexible trips.

TABLE 17: Drivers ratings for the Visual Analogue Scale taken at intervals in the trip for each trip type.

TRIP TYPE		PRE TRIP	BREAK 1	BREAK 2	BREAK 3	POST TRIP
STAGED	**Tired**	21.9 (23.65)	38.1 (27.1)	30.4 (23.9)	48.9 (31.1)	51.7 (25.5)
	Muzzy	20.18 (22.1)	31 9 (24.3)	23.0 (15.5)	37.6 (21 8)	43.4 (20.4)
	Drowsy	19.09 (19.6)	32.6 (23.9)	25.9 (16.1)	49.2 (26.2)	46.7 (17.5)
CONTROL	**Tired**	11.6 (9.6)	28.3 (23.7)	34.4 (19.6)	19.6 (10.2)	38.96 (20.1)
	Muzzy	10.75 (7.8)	23.9 (21.2)	31.6 (21.6)	17.2 (6.5)	29.4 (15.7)
	Drowsy	13.2 (12.3)	27.4 (21.1)	32.7 (21.2)	17.2 (13.1)	34.8 (18.5)
FLEXIBLE	**Tired**	15.4 (16.0)	31.1 (25.8)	42.9 (32.1)	35 3 (4.5)	48.7 (20.9)
	Muzzy	12.5 (9.9)	28.6 (23.0)	38.6 (29.1)	26.0 (6.6)	35.9 (17.0)
	Drowsy	14.2 (13.1)	27 7 (23.7)	38.6 (29.7)	32.3 (2 9)	37.2 (16.3)

Analysis of fatigue experiences within the trip using the visual analogue scales was performed using t-tests. Ratings of fatigue at the end of the first driving stint showed that mean fatigue ratings were not different for staged and control trips ($t_{(45)}=1.16$,n.s.) nor for flexible and control trips ($t_{(44)}=0.39$,n.s.). Since not all drivers took more than one break in each trip, the results for breaks 2 and 3 should be interpreted differently from break 1 which all drivers took on all trips. The results of t-test comparisons of mean visual analogue ratings before the second and third breaks for each trip type showed that drivers who took break 2 on flexible trips showed considerably more signs of fatigue than did the drivers before the second break on both staged and control trips. In contrast, drivers doing staged trips reported higher levels of tiredness and associated symptoms of fatigue just before the next, third break than did the drivers on the other trips who took three breaks.

Performance test battery results

1. Critical flicker fusion test:

The results of this test were analysed separately for the ascending and descending parts of the test and for the left and right eye using repeated measures multivariate analyses of variance. Table 18 shows the results for this test. For the ascending threshold test comparison of performance before and after each of the three trip types, revealed a trend towards a significant main effect for type of trip ($F_{(2,10)}=3.47, p<0.07$) which univariate tests showed was due to CFF thresholds being lower on staged trips than on control trips (($F_{(1,11)}=6.32, p<0.03$). There were no differences between thresholds on flexible and control trips. In addition there was a significant interaction effect ($F_{(2,10)}=4.71, p<0.036$) which was due to a larger difference in the opposite direction between pre and post CFF performance for staged trips compared to control trips (($F_{(1,11)}=8.32, p<0.015$). On staged trips thresholds improved over the trip, whereas on control trips there was a small deterioration in performance. There was no significant main effect for time in the trip ($F_{(1,11)}=0.25$,n.s.). For the descending threshold measures there were no significant main effects or interaction effects (time effect, $F_{(1,11)}=1.24$,n.s., type of trip effect, $F_{(2,10)}=1.47$,n.s., interaction effect, $F_{(2,10)}=0.69$,n.s.) indicating that CFF thresholds did not differ between types of trips nor between time of test.

Similarly when the midtrip measurement was included in the analysis of staged and control trips (See Table 19), analysis of ascending CFF results showed significant differences for the type of trip effect ($F_{(1,10)}$=4.16,p<0.07) with staged trips having lower thresholds overall than control trips. The time main effect was not statistically significant

TABLE 18: Results for the Critical Flicker Fusion test (CFF) for pre and post trip measure for staged, control and flexible trips.

		FLICKER FUSION THRESHOLD	
		Ascending measures	**Descending measures**
STAGED	**Pre-trip**	39.6 (5.6)	41.2 (13.2)
	Post-trip	41.0 (5.7)	44.5 (2.7)
CONTROL	**Pre-trip**	42.4 (4.8)	44.4 (2.6)
	Post-trip	41.3 (4.8)	45.2 (2.8)
FLEXIBLE	**Pre-trip**	42 7 (4.5)	44.0 (3.3)
	Post-trip	41.3 (4.9)	43.7 (3.4)

($F_{(2,9)}$=2.05,n.s.) but there was a significant interaction effect ($F_{(2,9)}$=4.12,p<0.05) which univariate tests showed was due to a difference between the change in CFF threshold across staged trips compared to the change in thresholds across control trips ($F_{(1,10)}$=5.65,p<0.04). While thresholds for staged trips increased in a linear fashion over the trip, for control trips the CFF thresholds were lower at midtrip than either the beginning or end of the trip. For the descending threshold measure there were no significant main effects or interaction effect (time effect $F_{(2,9)}$=1.1,n.s., type of trip effect, $F_{(1,10)}$=0.26,n.s., interaction effect, $F_{(2,9)}$=1.65,n.s.). Thresholds did not differ between trip types.

Critical flicker fusion performance therefore did not appear to be a particularly sensitive measure of driver fatigue in this study since it only discriminated differences in alertness using the ascending threshold method. It must be recognised, however, that the sample size was relatively small due to incomplete data. Examination of the data shows that CFF thresholds were lower before staged trips compared to the other trips and higher at the end of the staged trips. As lowered CFF thresholds indicate lower alertness, this result shows that staged drivers were more fatigued and less alert at the commencement of their trip and that their alertness actually improved over the duration of the trip. The other trips types exhibited the effects of reduced alertness over the trip with CFF thresholds decreasing although not significantly.

TABLE 19: CFF results for staged and control trips for before, middle and after trip measures (Hz, mean, s.d.).

		FLICKER FUSION THRESHOLD	
TRIP TYPE	**TIME OF TEST**	**Ascending (n=11)**	**Descending (n=11)**
STAGED	**Pre-trip**	38.5 (5.7)	40.8 (13.8)
	Mid-trip	39.6 (5.2)	44.5 (1.6)
	Post-trip	40.1 (5.7)	44.3 (2.7)
CONTROL	**Pre-trip**	41.3 (5.0)	43.9 (2.9)
	Mid-trip	39.7 (3.9)	43.1 (4.1)
	Post-trip	40.7 (4.9)	44.9 (3.1)

2. Simple reaction time test:

Tables 20 and 21 display the results of the simple reaction time tests before and after the trip for each trip type and before, in the middle and after the trip for staged and control trips. For each trip, comparisons were made between the last 15 trials of this test at the beginning and end of each trip and for the middle of the trip for staged and control trips. The sample sizes used in these two analyses differed since statistical repeated measures were used and complete data was not available for all measures of this test. The results for the last 15 trials were used in this analysis. Repeated measures multivariate analysis of variance showed no significant differences between each of the three trip types for simple reaction time performance between trips or between times in the trip. This result was found for both measures of simple reaction time performance, decision time and movement time (for decision time, time effect, $F_{(1,10)}$=0.03,n.s., trip type effect, $F_{(2,9)}$=0.74,n.s. and interaction effect, $F_{(2,9)}$=2.29,n.s.; for movement time, time effect $F_{(1,10)}$=1.32,n.s. trip type effect, $F_{(2,9)}$=0.64,n.s. interaction effect, $F_{(2,9)}$=1.48,n.s.). The comparison of simple reaction time performance before, during and after trips for staged and control trips also showed no significant differences (for decision time, time effect, $F_{(2,10)}$=0.21,n.s., trip type effect, $F_{(1,11)}$=0.02,n.s. and interaction effect, $F_{(2,10)}$=0.38,n.s.; for movement time, time effect $F_{(2,10)}$=1.28,n.s. trip type effect, $F_{(1,11)}$=1.91,n.s. interaction effect, $F_{(2,10)}$=0.21,n.s.). The results suggest that if there is variation in the amount of fatigue experienced on different trips, it has no effect on the driver's reaction time. Again, however, incomplete data has led to a relatively small sample of drivers for analysis which will reduce the power of the analysis to detect small differences between the groups.

TABLE 20: *Simple reaction time test results for the three trip types both before and after each trip, showing mean decision time and mean response times separately (means, msecs and s.d's).*

TYPE OF TRIP	DECISION TIME (n=11)	MOVEMENT TIME (n=11)
	Pre-trip	
Staged	256.8 (33.7)	145.5 (60.9)
Control	265.5 (43.7)	131.0 (37.0)
Flexible	268.6 (58.0)	120.2 (20.0)
	Post-trip	
Staged	265 0 (38.8)	131.5 (25.4)
Control	273.4 (32 1)	121.2 (29.2)
Flexible	270.6 (56.8)	117.4 (14.7)

TABLE 21: Simple reaction time results for staged and control trips showing mean decision time and mean movement time before the trip, at the mid-trip break and after the trip (mean, msecs, s.d's).

TYPE OF TRIP	DECISION TIME (n=12)	MOVEMENT TIME (n=12)
	Pre-trip	
Staged	260.0 (34.6)	145.0 (58.1)
Control	265.9 (41.6)	133.4 (36.3)
	Mid-trip	
Staged	272.2 (46.2)	127.6 (33.6)
Control	267.5 (56.7)	133.4 (22.6)
	Post-trip	
Staged	273.8 (30.6)	121.4 (27.9)
Control	268.8 (54.6)	118.4 (14.4)

3. Unstable tracking task:

For this test the results of the second five trials were analysed comparing before and after the trip for each trip type and before, during and after the trip for staged and control trips (See Tables 22 and 23). Two measures were analysed, time on target and the level of difficulty or critical instability reached in the test. For the time on target measure, comparison of the pre and post trip results for all trips showed no statistically significant main effect for time of test ($F_{(1,16)}$=0.00,n.s.), nor for trip type ($F_{(2,15)}$=0.88,n.s.). There was a marginally significant interaction between time of test and trip (F(2,15)=3.08, p<0.07). Subsequent univariate analysis showed that for staged and control trips the difference in time on target performance on the CTT test was significantly larger and in the opposite direction for the post trip test than for the before trip test (F(1,16)=5.97,p<0.026). This result indicates that for control trips, drivers' performance improved significantly between pre and post measurements, whereas staged drivers did not show such improvement. The results for flexible and control trips did not differ.

TABLE 22: The results of the Critical Tracking task for staged, control and flexible trips before and after each trip showing mean time on target (and s.d.) and the mean level of difficulty achieved (and s.d.) (Lambda).

TYPE OF TRIP	TIME ON TRIP	TIME ON TARGET (mean, sd)		LEVEL OF DIFFICULTY ACHIEVED	
		1st 5 Trials n=17	2nd 5 Trials n=17	1st 5 Trials n=17	2nd 5 Trials n=17
STAGED	Pre-trip	7.8 (2.1)	9.6 (2.9)	4.3 (0.88)	5.0 (1.1)
	Post-trip	9.9 (1.2)	9.4 (2.4)	4.9 (0.97)	5.0 (0.9)
CONTROL	Pre-trip	9.2 (2.1)	10.0 (1.7)	5.1 (0.76)	5.3 (0.7)
	Post-trip	9.2 (1.2)	10.9 (1.8)	5.2 (0.8)	5.5 (0.9)
FLEXIBLE	Pre-trip	9.8 (2.0)	10.6 (2.1)	5.1 (1.0)	5.4 (0.9)
	Post-trip	9.4 (2.1)	10.0 (2.4)	5.0 (0.9)	5.1 (1.1)

When the mid-trip comparison for time on target was included in the analysis for staged and control trips, a significant main effect was found for time of test such that for both types of trip, the mid-trip measurement was significantly poorer than either pre or post-trip measures ($F(2,13)=4.38, p<0.035$). There was also a marginally significant main effect for trip type revealing that time on target in the CTT was poorer overall for staged trips compared to control trips ($F(1,14)=3.98, p<0.066$). The interaction effect between time of test and trip type was not statistically significant ($F_{(2,13)}=2.49$,n.s.), however univariate analysis revealed the same results as when all three trip types were included in the analysis of only pre and post time on target measures ($F(1,14)=5.03, p<0.04$), that is the difference between control and staged trips was greater at the end of the trip than at the beginning of the trip. This indicates again, that CTT results improved over test times for control trips but not for staged trips.

TABLE 23: Results for staged and control trips for the Critical Tracking task showing results for tests before, in the middle and after the trip. Time on target and the level of difficulty achieved are shown.

TYPE OF TRIP	TIME IN TRIP	TIME ON TARGET 2nd 5 Trials (mean, sd, n=15)	LEVEL OF DIFFICULTY ACHIEVED 2nd 5 Trials (mean, sd, n=15)
	Pre	9.98 (2.6)	5.1 (1.0)
STAGED	Mid	8.6 (2.1)	4.2 (0.9)
	Post	9.91 (2.8)	5.2 (1.0)
	Pre	10.53 (2.0)	5.5 (0.75)
CONTROL	Mid	9.97 (1.4)	4.8 (0.6)
	Post	11.5 (3.3)	5.7 (1.3)
		n=15	n=15

For the critical instability measure of the CTT (lambda), the analysis of pre and post performance for all three trip types showed no significant main effects or interaction effect (time effect, $F_{(1,16)}=0.11$,n.s., trip type effect, $F_{(2,15)}=1.57$,n.s., and interaction effect, $F_{(2,15)}=1.69$,n.s.). Analysis of pre, mid and post-trip performance for staged and control trips, however revealed a significant main effect for time of test ($F(2,14)=12.38, p<0.001$) which subsequent univariate analysis showed was due to mid-trip performance reaching significantly lower levels of difficulty than performance either before or after the trip ($F_{(1,14)}=28.59, p<0.001$). Trip type was also found to produce a significant main effect

$F_{(1,14)}$=5.6.1,p<0.03). On control trips, the drivers' were able to achieve significantly higher levels of critical instability for all measurement occasions than they were on staged trips. Results for flexible trips were not significantly different from those for control trips. There was no significant interaction effect for this analysis ($F_{(2,13)}$=0.35,n.s.).

4. Vigilance test:

The results for this test are shown in Table 24. The speed of response measure for correct responses was analysed by repeated measures multivariate analysis of variance. The results showed that there was a multivariate effect due to type of trip ($F_{(2,10)}$=5.08,p<0.03), which subsequent univariate tests showed was due to the vigilance test performance of drivers doing staged trips being significantly slower overall than when they did either control or flexible trips ($F_{(2,10)}$=8 1,p<0.016). Overall performance on flexible and control trips did not differ ($F_{(2,10)}$=0.16,n s.). In addition, there was a significant effect on vigilance performance of the time in the trip, with the mean reaction time in this task being significantly faster at the end of the trip than before the trip ($F_{(1,11)}$=16.97,p<0.002). There was no effect of test block or position in the test session ($F_{(1,11)}$=0.10,n.s.) and there were no significant interaction effects for this measure ($F_{(2,10)}$=2.46,n.s.).

TABLE 24: Results of the vigilance test for each trip type showing mean reaction time for first and second half of the test before and after each trip type.

	Part of Test	STAGED	CONTROL	FLEXIBLE n=12
BEFORE TRIP	**1st Half**	583.1 (42 5)	521.2 (62.5)	528.8 (76.6)
	2nd Half	568.5 (55.5)	518.3 (47 9)	527.6 (84.9)
AFTER TRIP	**1st Half**	544.9 (50.3)	509.8 (68.3)	508.5 (52.1)
	2nd Half	543.8 (47.5)	512.3 (69.0)	515.9 (54.5)

Analysis of the number of errors made in this test (see Table 25), also by multivariate repeated analysis of variance, demonstrated no significant main effect of time of test ($F_{(1,11)}$=1.72,n.s.) showing that the number of errors did not change across the trip. There was a significant effect of trip type ($F_{(2,22)}$=3.88,p<0.04). On staged trips drivers made significantly more errors than on control trips, with least errors occurring on flexible trips. The number of errors did not change between the first and second half of each test session ($F_{(1,11)}$=0.00,n.s.) and there were no significant interaction effects between any of the factors.

TABLE 25: Errors made during the Vigilance test for each trip type both before and after the trip. Mean number of incorrect responses are shown for each half of the test session.

		TYPE OF TRIP		
		Staged	**Control**	**Flexible**
BEFORE TRIP	**1st half**	8.17 (6.4)	5.6 (3.8)	3.7 (4.2)
	2nd half	7.5 (4.4)	5.1 (3.7)	3.3 (2.8)
AFTER TRIP	**1st half**	5.4 (5.7)	3.7 (3.0)	4.2 (3.7)
	2nd half	6.7 (7.7)	4.0 (6.1)	4.2 (3.7)

These results indicate that vigilance performance was poorer both in terms of reaction time and the number of errors before and after staged driving compared to both alternative types of trips. Vigilance performance speed did not differ between flexible and control trips. For all types of driving, reaction speed improved between the beginning and end of the trip but the number of errors did not change. While this result is suggestive of a practice effect, there was no significant improvement in performance across each block of trials within a test for either speed or errors. If practice effects occurred they would most likely be seen within a test session as well as between sessions. As this did not occur, the improvement in performance within each trip is more likely to be due to factors other than simple practice. It is possible that drivers experienced a degree of rearousal once they actually completed their trips, which could be seen in their ability to perform tests requiring vigilance. It is likely that this rearousal effect would not persist for very long.

On-road measures

1. Onboard reaction time test:

For this measure repeated measures multivariate analysis of variance was performed on speed of reaction and the number of errors in performance but as the data was not complete for all trips, the sample size included in the analysis varied depending on the analysis used. The analysis compared performance at specific times in the trip, the first, middle and last blocks of trials. The middle block of trials was determined individually for each subject as the third last block. Due to incomplete data for staged driving, the multivariate repeated measures analysis only compared control and flexible trip performance (see Table 26). The results for staged trips were compared with performance on the control trips using matched t-tests (see Table 27). The repeated measures analysis showed no difference between flexible and control trips in speed of performance on this test (main effect for trip type $F_{(1,14)}$=3.39,n.s.), nor was there an effect of test time or an interaction between the two factors ($F_{(2,13)}$=0.48,n.s. and $F_{(2,13)}$=0.48,n.s.) respectively). For the staged trips, on-board reaction time showed no significant differences in reaction speed compared to control trips (first block, $t_{(14)}$=-0.66,n.s.; middle block, $t_{(8)}$=0.65,n.s.; final block $t_{(10)}$=0.24,n.s.). Trip type and trip duration did not affect drivers' reaction time speed on this test.

TABLE 26: On-board reaction time test results for control and flexible trips showing performance (msecs) at the beginning, middle and end of each trip.

	TYPE OF TRIP	
	Control (n=15)	**Flexible (n=15)**
Beginning of Trip	1083.3 (504.3)	1188.3 (582.3)
Middle of Trip	1021.5 (481.0)	1101.3 (569.6)
End of Trip	1014.3 (465.4)	1310.5 (610.7)

For the error results for this test, the analysis again compared the first, middle (third from last block) and last blocks of trials for flexible and control trips only (See Table 28). Staged trip analysis was again compared with control trips using matched t-tests (See Table 29). For the comparison between flexible and control trips, there was no significant main effect for trip type ($F_{(1,14)}$=1.62,n.s.) nor for time in the trip ($F_{(2,13)}$=0.61,n.s.). In addition there was no significant interaction between trip type and block $F_{(2,13)}$=0.57,n.s.). Drivers doing flexible and control trips made about the same number of errors through the trip. Similarly, drivers did not differ in the number of errors across the trip when doing staged trips and control trips (first block, $t_{(14)}$=1.53,n.s.; middle block, $t_{(8)}$=0.33,n.s.; final block $t_{(10)}$=-0.35,n.s.). This analysis shows that the number of errors made in the on-board reaction time task were not affected by either the type of trip nor the length of the trip.

Analysis of on-board reaction time by real time of day showed that overall there was a weak, but statistically significant relationship between mean reaction time and time of day (r(288)=-0.12,p<0.04) and the standard deviation of the reaction time and time of day (r(286)=-0.12,p<0.04). This indicates that reaction time tended to be longer and more variable in the late afternoon and up to midnight than at other times.

TABLE 27: Staged and control trip results for the on-board reaction time task showing mean reaction time (and s.d.) for the beginning, middle and end of each trip type.

	TYPE OF TRIP	
	Staged	**Control**
Beginning of trip (n=15)	1212.4 (688.5)	1077.6 (555.9)
Middle of trip (n=12)	1201.4 (656.5)	1320.4 (676.1)
End of trip (n=11)	1140.0 (565.8)	1187.0 (544.5)

TABLE 28: Error results for the on-board reaction time task showing mean number of responses for the beginning, middle and end of flexible and control trips.

	TYPE OF TRIP	
	Control n=15	Flexible n=15
Beginning of trip	5.3 (6.1)	5.9 (6.2)
Middle of trip	5.0 (5.6)	8.0 (8.9)
End of trip	7.2 (8.2)	8.4 (9.1)

TABLE 29: On-board reaction time task error results for staged and control trips. The mean number of missed signals are shown for the beginning, middle and end of each trip type.

	TYPE OF TRIP	
	Staged	Control
Beginning of trip	10.33 (10 7)	5.6 (6.9)
Middle of trip	7.6 (9.3)	6.3 (5.7)
End of trip	8.8 (9.2)	10.0 (9.3)

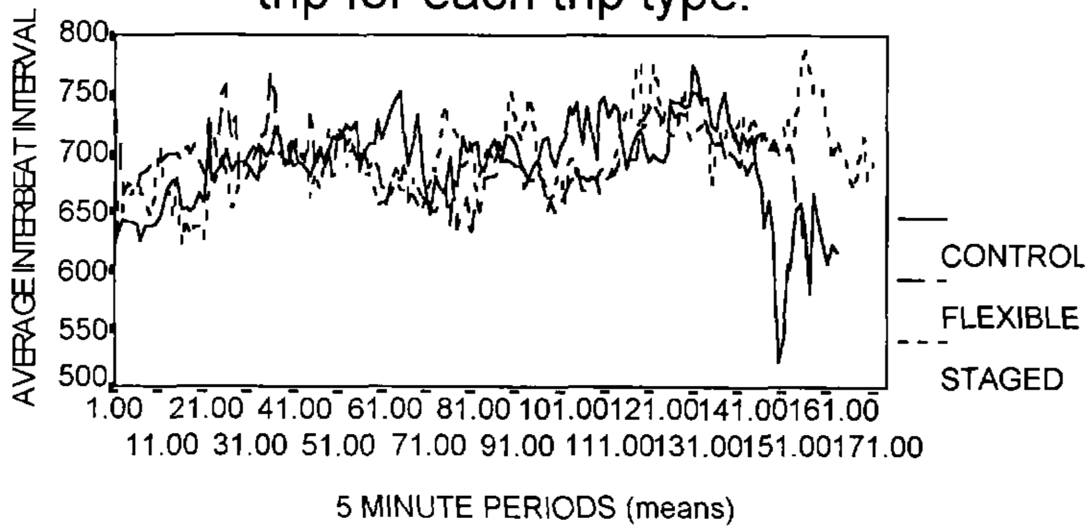
For each trip type correlation analysis revealed that the relationship between on-road reaction time and time of day was significant only for staged trips (for staged trips, $r_{(72)}=-0.23, p<0.05$; for flexible trips, $r_{(104)}=-0.16$, n.s., and for control trips, $r_{(112)}=0.004$, *n.s.*). Drivers doing staged trips had longer reaction times in the afternoon and early evening, at the beginning of the trip than the end of the trip. This is consistent with the level of reported fatigue for staged drivers which was much higher at the beginning of the trip than for other trip types. Analysis of the standard deviation of these reaction time measures by trip type showed that only flexible trips showed a significant relationship with time of day (for flexible trips, $r_{(103)}=-0.24, p<0.2$; for staged trips, $r_{(71)}=-0.1$,n.s., and for control trips, $r_{(113)}=-0.04$,n.s.). Drivers doing flexible trips tended to have more variable reaction times in the late afternoon and early evening that is when they began their trips, compared to the early morning when their trips finished.

There was no such relationship between reaction time performance and the relative time in the trip that the test was taken (mean reaction time $r(288)=-0.02$, n.s.; standard deviation of reaction time $r(286)=-0.03$, n.s.). The same analysis for each trip type also showed no significant effect of the relative time in the trip for either mean reaction time or reaction time variability ($r_{(71)}=-0.05$,n.s. for staged trips; $r_{(103)}=-04$,n.s. for flexible trips and $r_{(112)}=0.01$,n.s. for control trips).

2. Heart rate and associated measures

Changes in the driver's heart rate, measured as the interbeat interval and interbeat variability were plotted as means for 5 minute blocks for the duration of each type of trip. (See Figure 9). This measure is related to fatigue such that higher arousal levels are correlated with shorter interbeat interval (faster heart rate) and lower variability in heart rate.

Figure 9: Plot of interbeat interval across trip for each trip type.



2.1 Comparison of beginning and end of the trip

Change in the interbeat length and variability were analysed by plotting the lines of best fit for the second and third hours of the trip and the second and third last hours of the trip. The first and last hours were not included in this analysis because they were judged to be unrepresentative of the rest of the trip. Drivers spent a large proportion of this time negotiating city traffic since depots were in the city. As this factor was also likely to produce variability in heart rate it would confound estimates of the drivers' current state of arousal.

Figures 10and 11 show plots of the lines of best fit for interbeat interval at the beginning and end of each trip type and Appendix 5 displays the slopes and intercepts of each of these lines. Analysis of differences between trip types and over the beginning and end of the trip for the two measures, slopes and intercepts, was by multiple, independent t-tests using a Bonferroni correction for alpha rate. Seven comparisons were made for each measure using corrected critical values of Bonferroni for alpha of 0 05, so permitted actual statistical significance to be judged at $p<0.007$. The seven comparisons included, comparing measures taken at the beginning and end of each type of trip, a comparison of staged and control trips for the beginning of the trip and for the end of the trip and the same comparison between flexible and control trips.

Analysis of the lines of best fit describing the change in interbeat interval (see Figures 10 and 11)across the trip showed that staged and control trips were not significantly different for interbeat interval at either the beginning or end of the trip (beginning of trip, slope, $F_{(1,46)}=1.4$,n.s.; intercept, $F_{(1,46)}=1.39$,n.s.; end of trip, slope, $F_{(1,46)}=1.2$,n.s.; intercept, $F_{(1,46)}=1.86$,n.s.) For both staged and control trips interbeat interval was shorter but lengthening at the beginning of the trip compared to the end of the trip (slopes, for staged $t(46)=4.42,p<0.01$ and control, $t_{(46)}=4.41,p<0.01$, and the intercepts, for staged, $t_{(46)}=11.77,p<0.01$ and control $t_{(46)}=8.03,p<0.01$). In contrast the flexible trips, showed significant increase across the trip in slopes of the lines of best fit ($t_{(46)}=5.88,p<0.01$) and a significant decrease in the size of intercepts ($t_{(46)}=6.98,p<0.01$). Flexible trips differed significantly from control trips in interbeat interval at both the beginning and end of the trip. At the beginning of the trip, the slopes of the lines of best fit did not differ significantly between the two trip types ($t_{(46)}=1.07$,n.s.), but the intercept for the flexible trip indicated significantly longer interbeat intervals than for the control trip ($t_{(46)}=4.3,p<0.01$). At the end of the trip, for flexible trips, both the

Figure 10: Interbeat interval before 2nd & 3rd hour of trip for each trip type.

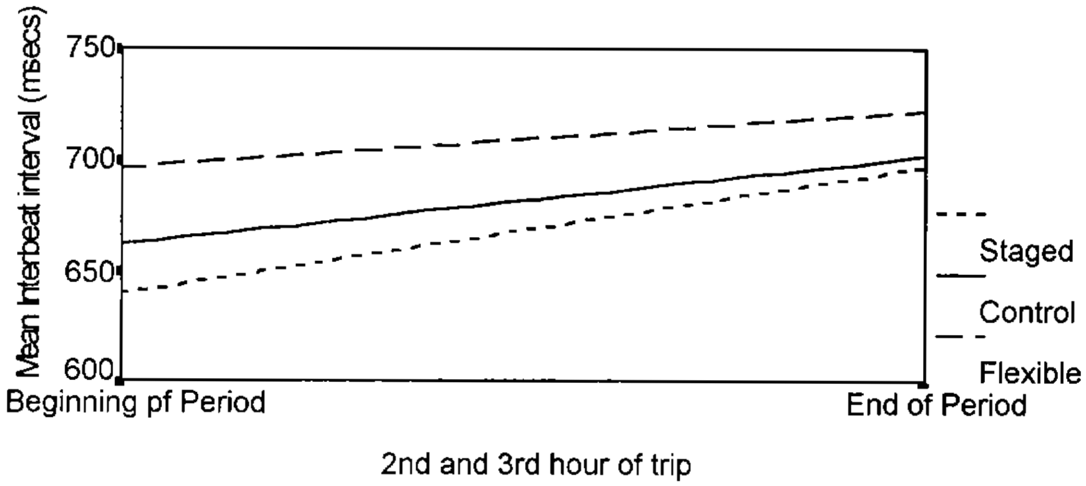
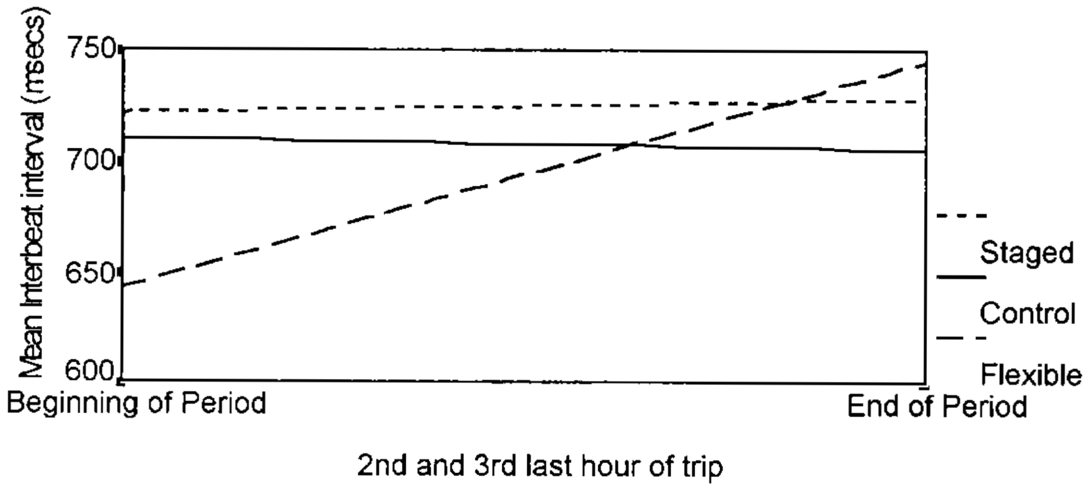


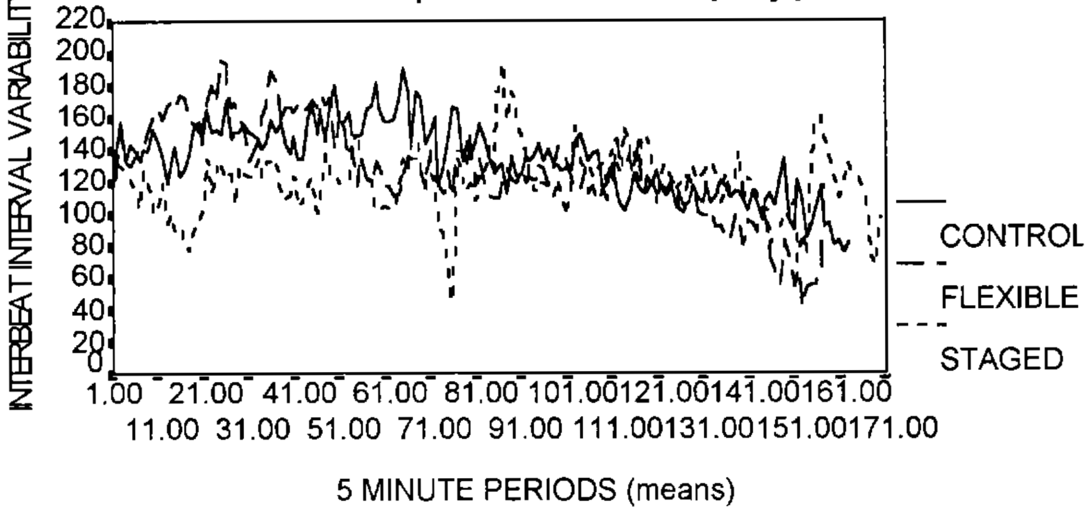
Figure 11: Interbeat interval after the 2nd & 3rd last hour of trip for each trip type.



slopes and intercepts of the interbeat interval lines were significantly different The line for flexible trips showed a significantly larger slope ($t_{(46)}$=11.0,$p<0.01$) but a significantly smaller intercept ($t_{(46)}$=11.85,$p<0.01$) compared to the line for control trips. These results indicate that for staged and control trips, interbeat interval lengthened over the duration of the trip (decreased arousal) but the rate of change in interbeat interval decreased markedly so that by the end of the trip alertness was lower for both types of trip although it was not decreasing very much. Flexible trips, however displayed the opposite pattern with interbeat interval showing similar patterns at the end of the trip to that shown at the beginning of staged and control trips. Interbeat intervals became shorter over flexible trips and the slope increased markedly suggesting that they were considerably more alert at the end of the trip than the beginning of the trip and compared to the other trip types at the same time, but they were fairly rapidly becoming less so.

Analysis was also performed of the variability of interbeat interval across the trip using the same multiple t-test method with a Bonferroni correction (See Figures 12, 13 and 14). Staged drivers showed significantly increased slope and lower intercept at the beginning compared to the end of the trip (slope, $t_{(46)}$=6.54,$p<0.01$; intercept ($t_{(46)}$=9.00,$p<0.01$), indicating lower interbeat variability at the beginning of the trip, although it was rapidly increasing. In contrast, at the end of the trip interbeat variability was higher but decreasing slightly. Drivers doing control trips also showed significantly decreasing rates of variability across the trips (slopes, $t_{(46)}$=3.42,$p<0$ 01) but overall variability did not change (intercepts, $t_{(46)}$=1.83,n.s.) When doing staged trips, the slopes for were significantly higher at the beginning of the trip than for drivers doing control trips ($t_{(46)}$=3.76,$p<0.01$), but the intercepts of the lines were not significantly different ($t_{(46)}$=0 61,n.s.). By the end of the trip, however, the rate of change in variability was not different between staged and control trips (slopes, $st_{(46)}$=1.61,n.s.), but the overall variability was higher for staged trips than control trips (intercepts, $t_{(46)}$=3.81,$p<0$ 01).

Figure 12: Plot of interbeat variability across trip for each trip type.



On flexible trips, drivers showed no significant difference in the rate of change of interbeat variability across the trip (slopes, $t_{(46)}$=0.92,n.s.), but overall variability decreased between the beginning and end of the trip (intercepts, $t_{(46)}$=3.79,$p<0.01$). In addition, drivers doing flexible trips started their trips with higher overall variability compared to drivers doing control trips, but the rate of change in heart rate variability was not significantly different between the trip types (slopes, $t_{(46)}$=2.88,n.s., intercepts, $t_{(46)}$=4.39,$p<0.01$). The lines of best fit for flexible and control trips did not differ, however, at the end of the trip (slopes, $t_{(46)}$=1.52,n.s., intercepts, $t_{(46)}$=1.99,n.s.).These results for interbeat interval and interbeat variability together show that drivers doing staged trips, showed higher levels of alertness at the beginning of the trip as shown by short interbeat interval (fast heart rate) and low variability. By the end of the trip, however staged drivers were showing signs of decreased alertness with longer interbeat interval (slow heart rate) and higher variability although variability was tending to decrease. Control trips, like staged trips, could be characterised as showing higher alertness at the beginning of the trip by the short interbeat interval and relatively lower variability. At the end of control trips, however, interbeat interval had increased but overall variability had not changed significantly. These results suggest that drivers doing both staged and control trips were comparatively fresh at the beginning of the trip, but alertness was decreasing quite rapidly. Staged drivers, however showed larger decreases in alertness by the end of the trip. In contrast, for flexible trips, drivers started less alert than the other two trip types

Figure 13: Interbeat variability before 2nd & 3rd hour of trip for each trip type.

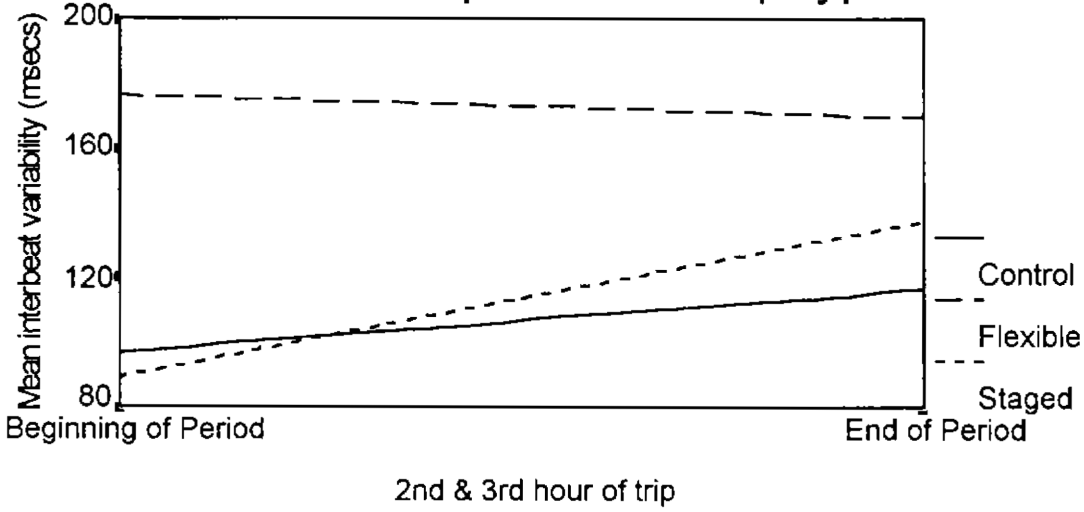
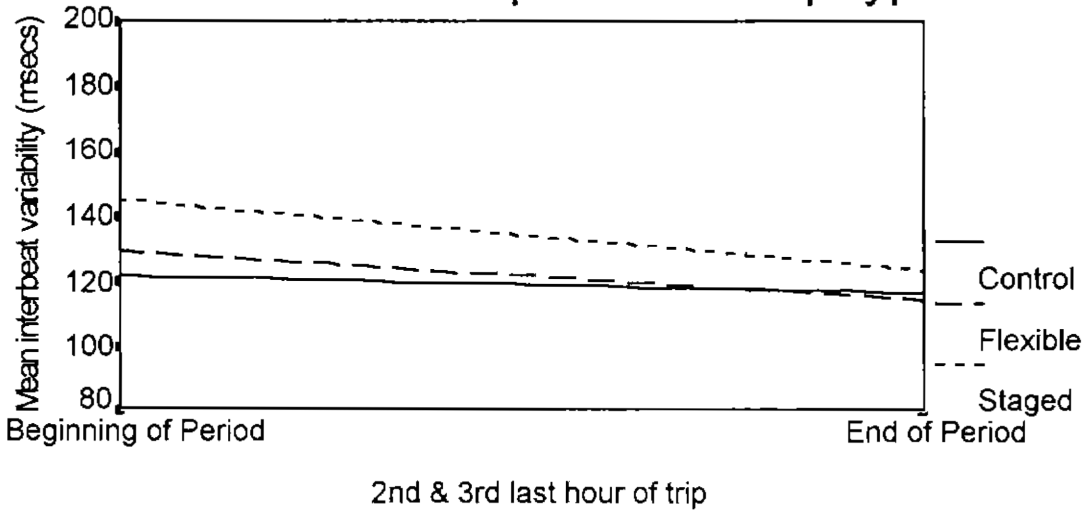


Figure 14: Interbeat variability after the 2nd & 3rd last hour of trip for each trip type.



as shown by much longer interbeat intervals and higher variability, but this improved early in the trip. At the end of flexible trips, however drivers were more alert than they were at the end of control trips. It is possible that differences in the nature of the terrain at the beginning of control and flexible trips may be at least partly responsible for the differences in heart rate pattern for these two trip types. The road conditions when leaving Melbourne are straighter and overall easier to negotiate than the road leading out of Sydney. As control trips were begun in Sydney, the apparent higher alertness of drivers at this time compared to the beginning of flexible trips, which began in Melbourne may have been contributed to by the different demands of the road conditions. The results for staged trips would not be affected by road conditions since drivers began their staged trips from both cities.

2.2 Changes in heart rate within the trip

Changes in interbeat interval were also examined just before and after the first and second breaks from driving in order to examine the extent to which drivers benefited from them. In order to analyse change in interbeat interval while driving before and after the break and any differences between trip types, break time was defined to also include the fifteen minutes just before and just after each break as interbeat interval measures at these times were likely to be confounded by activity related to town driving and were therefore not included in the analysis. Consequently interbeat interval data were plotted as lines of best fit for the hour before and the hour after each break.

First break from driving

Figures 15 to 16 show the lines of best fit describing interbeat interval before and after the first break. Both staged and flexible trips showed larger interbeat interval before break than after the break as seen by the significantly different intercepts for each trip type (for staged, $t_{(22)}=3.82, p<0.01$ and for flexible $t_{(22)}=4.93, p<0.01$). Control trips showed no significant difference in intercept between beginning and end of the break $t_{(22)}=0.01$,n.s.). The rate of change in interbeat interval did not vary across the trip for any trip type (slopes for staged trips, $t_{(22)}=2.14$,n s., for control trips, $t_{(22)}=0.08$,n.s., and for flexible trips, $t_{(22)}=1.29$,n.s.). Compared to control trips, staged trips showed similar slopes and intercepts of the lines of best fit for interbeat interval at the beginning of the break (slope $t_{(22)}=2.69$,n.s. and intercept $t_{(22)}=3.8, p<0.01$), but not at the end of the break. At the end of the first break on staged trips interbeat interval was significantly shorter and decreasing compared to the same point on control trips in which interbeat interval was higher and increasing (for slopes, $t_{(22)}=-3.75, p<0.01$ and intercepts, $t_{(22)}=3.8, p<0.01$). Comparing the interbeat interval of flexible and control trips, flexible drivers had significantly longer interbeat intervals which were decreasing rapidly just before the first break (for slope $t_{(22)}=5\ 82, p<0.01$ and for intercept $t_{(22)}=7.16, p<0.01$), and at the end of the break interbeat interval for flexible drivers was at about the same level as for control trips, but was still decreasing rapidly compared to control drivers at the same time (for slopes, $t_{(22)}=7.09$, $p<0.01$ and for intercepts, $t_{(22)}=1\ 76$,n.s.).

Figure 15: Interbeat interval before the first break showing each trip type.

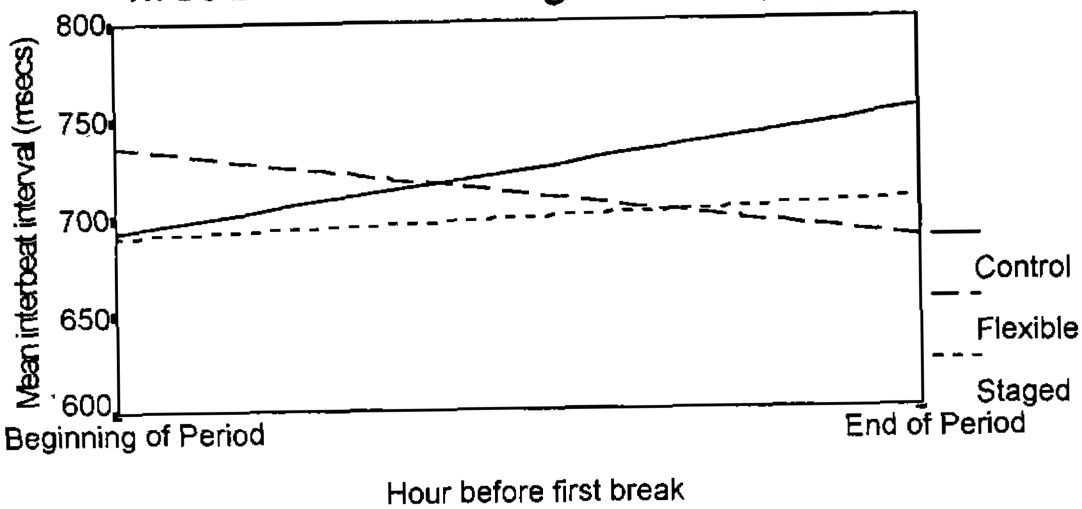
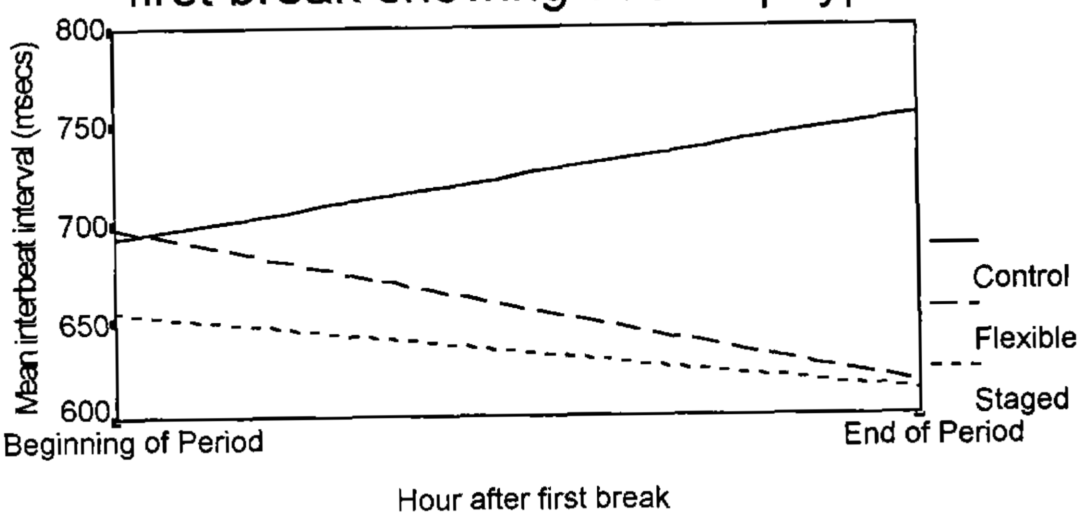


Figure 16: Interbeat interval after the first break showing each trip type.



The lines of best fit showed that before the first break drivers on staged and control appeared to be experiencing about the same level of alertness, but it was increasing. On flexible trips, however, the overall level of alertness was lower, but it was decreasing. After the first break, staged drivers showed an overall shortening of the interbeat interval suggesting increased alertness (increased heart rate) and the direction of change in interbeat interval was towards continued reduction in the size of the interbeat interval, indicating further increases in alertness. For flexible trips, the effect of the first break was to decrease interbeat interval size and to continue the decreasing interbeat interval. These results suggest that the first break improved the state of alertness for staged and flexible trips. Control trips, however, were characterised by no change in interbeat interval following the first break suggesting that arousal levels remained the same on control trips regardless of the break.

Analysis of the change in interbeat variability due to the first break from driving (See Figures 17 and 18) revealed that before the break flexible drivers were most variable but this was decreasing, control drivers had similar levels of interbeat variability (comparing flexible and control trips, slopes, $t_{(22)}=0.77$,n.s.; intercepts, $t_{(22)}=1.83$,n.s.), but it was increasing and staged drivers had lowest overall variability which was increasing most rapidly (comparing staged and control trips, slope $t_{(22)}=2.38$,n.s. and intercept $t_{(22)}=10.41, p<0.01$). After the break it appeared that alertness was lower for staged trips since the amount of variability in heart rate on these trips increased significantly although the direction of change was towards decreasing variability (for slope, $t_{(22)}=4.59, p<0.01$ and for intercepts $t_{(22)}=3.21, p<0.01$) For flexible trips variability decreased significantly following the first break and the trend was to decrease further (for slope, $t_{(22)}=1.81$,n.s. and for intercepts $t_{(22)}=3.05, p<0.01$) which suggests increasing alertness. No change in interbeat variability was found following the first break in control trips (for slope, $t_{(22)}=2.17$,n.s. and for intercepts $t_{(22)}=0\ 77$,n.s.). Comparing trip types after the break, interbeat variability was lower in staged trips than in control trips (slope, $t_{(22)}=0.48$,n.s., intercept $t_{(22)}=3.17, p<0.05$), but flexible and control trips were not different (slope, $t_{(22)}=1.29$,n.s., intercept $t_{(22)}=0.33$,n.s).

The results for interbeat variability lend support to those for interbeat interval. Both measures showed that drivers on flexible trips seemed to gain benefit from the first break whereas drivers on control trips showed no change in interbeat interval or variability after the break. For staged drivers there was a tendency to shortening of interbeat interval after the break suggesting increased alertness and, although interbeat variability increased

Figure 17: Interbeat variability before Break 1 for each trip type.

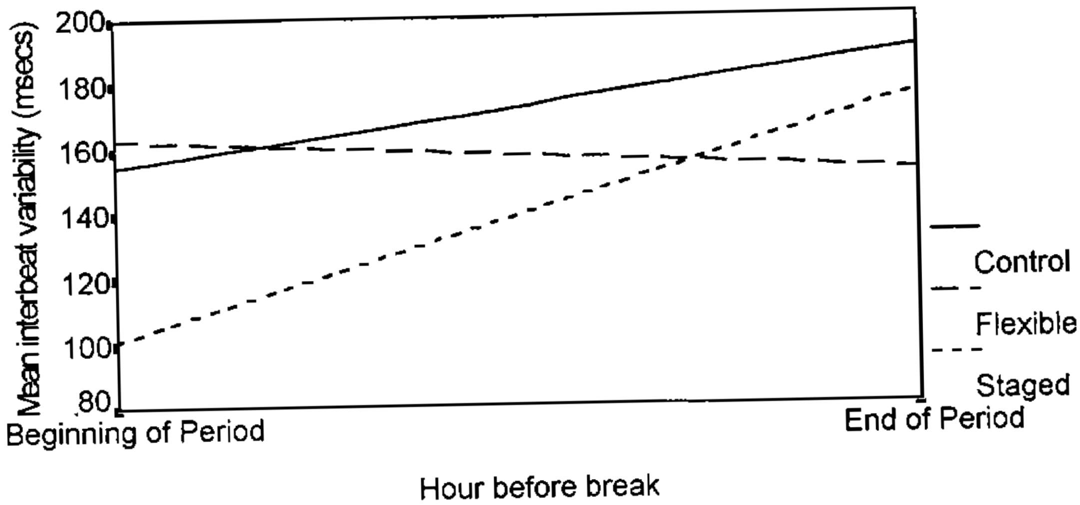
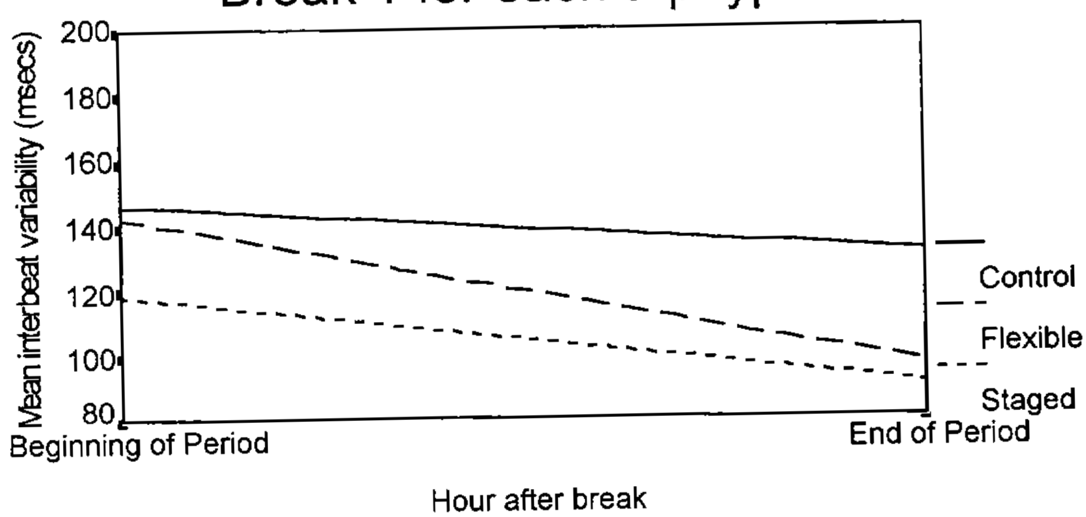


Figure 18: Interbeat variability after Break 1 for each trip type.



suggesting some decrease in alertness, the trend was to lower variability. Furthermore, for both measures staged drivers had lowest interbeat interval and variability before and after the break indicating highest alertness for this trip type at this point in the trip.

Second break from driving

Comparing the three trip types before the second break (See Figures 19 and 20), control trips showed significantly longer interbeat intervals than for either staged or flexible trips (for staged trips, slopes $t_{(22)}=0.86$,n.s., and intercepts $t_{(22)}=-7.05, p<0.01$), and for flexible trips, slopes, $t_{(22)}=0.38$,n.s., and intercepts $t_{(22)}=5.36, p<0.01$).
For the staged trips interbeat interval after the break was increasing markedly compared to interbeat interval before the break (for slope, $t_{(22)}=4.19, p<0.01$ and for intercept, $t_{(22)}=2.63$,n.s.). For flexible trips, the rate of change of interbeat interval remained in the same negative direction across the break (for slope, $t_{(22)}=0.38$,n.s.), and also increased in size (for intercept, $t_{(22)}=2.92, p<0.05$). For control trips, the second break produced no change in the lines of best fit describing interbeat interval, (for slope, $t_{(22)}=0.21$,n.s., and for intercept $t_{(22)}=0.98$,n.s.). These results suggest that the second break provided little benefit to the drivers when on staged trips as interbeat interval was longer after the break (slower heart rate) indicating lower alertness Similarly for flexible trips there was little benefit since interbeat interval was increased after the trip, but direction of change was for it to decrease. As for the first break, control trips showed no significant change across the trip although judging by the longer interbeat intervals for control trips, overall alertness appeared to be lowest for control trips both before and after the break.

Figures 21 and 22 show lines of best fit for interbeat variabilities before and after the second break. For the second break from driving no trip types showed a significant change in heart rate variability (for staged trips, slope $t_{(22)}=0.49$,n.s., and intercept $t_{(22)}=0.56$,n.s.; for control trips, slope $t_{(22)}=1.86$,n.s., and intercept $t_{(22)}=2.52$,n.s.; and for flexible trips, slope $t_{(22)}=0.29$,n.s., intercept $t_{(22)}=1\ 46$,n.s.). These findings indicate that the second break had a no effect on the interbeat variability of drivers on any trip type, so adding little to the findings for interbeat interval change after the second break

Figure 19: Interbeat interval before the second break showing each trip type.

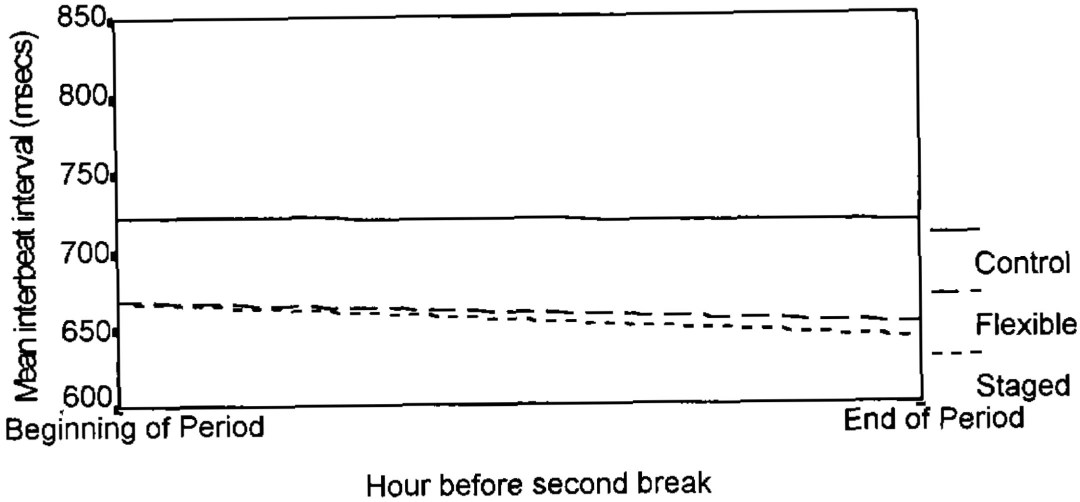


Figure 20: Interbeat interval after the second break showing each trip type.

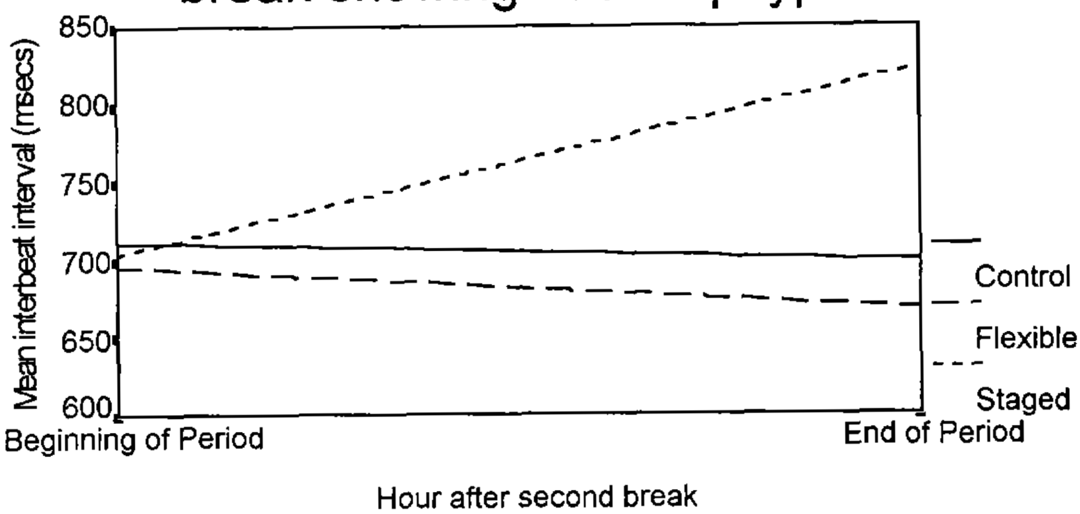
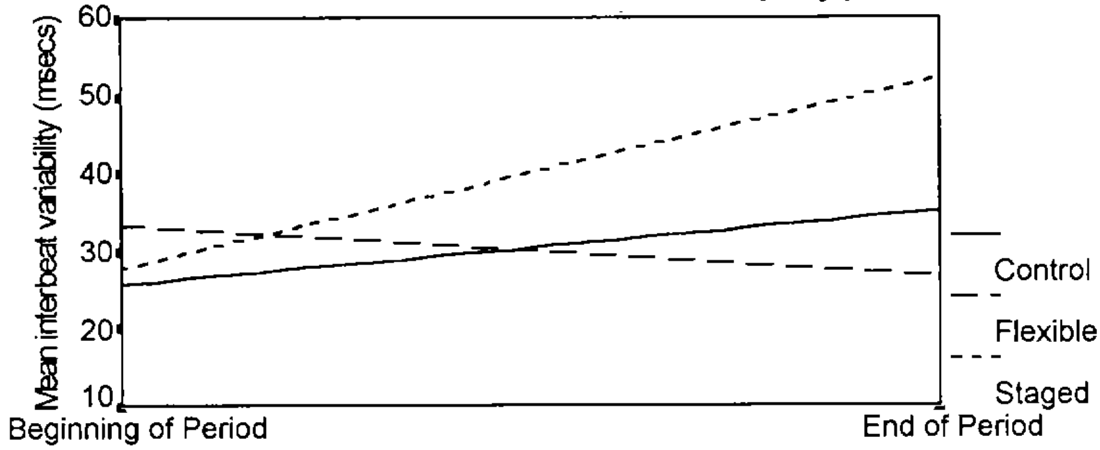
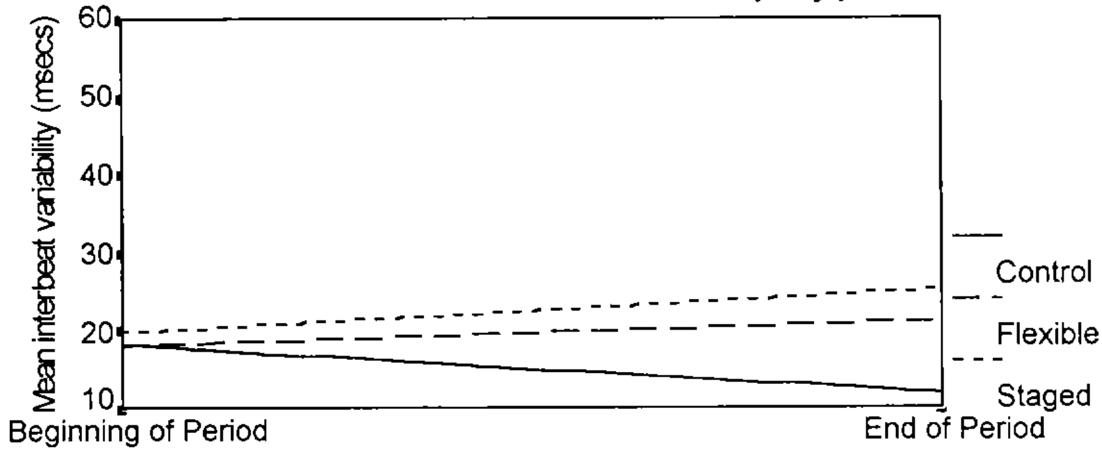


Figure 21: Interbeat variability before the second break for each trip type.



Hour before break

Figure 22: Interbeat variability after the second break for each trip type.



Hour after break

3. Steering

The same form of analysis was carried out for the pattern of steering across trips as for the heart rate measures. For this analysis steering deviation measures were used which had not been corrected for road geometry. Lines of best fit were plotted for the beginning and end of each trip, again taking the second and third hours of the trip and the second and third last hours of the trip. As for the heart rate measures, the break was defined to include the 15 minutes of recording directly before and after it so that the one hour periods for analysis of prebreak performance began 1 hour and 15 minutes before the break and for analysis of post break performance, the 1 hour period started 15 minutes after the break. Again, the slopes and intercepts of these lines of best fit were used to allow comparisons by multiple t test with Bonferroni correction.

3.1 Comparison between the beginning and end of the trip.

Figure 23 shows a plot of average steering deviation in five minute periods across each trip type. For analysis of changes in average size of steering deviation across the trip, Figures 24 to 25 show plots of the lines of best fit for the first and last parts of each trip type (See Appendix 5 for table of slopes and intercepts).

Figure 23: Plot of average steering deviation across trip for each trip type.

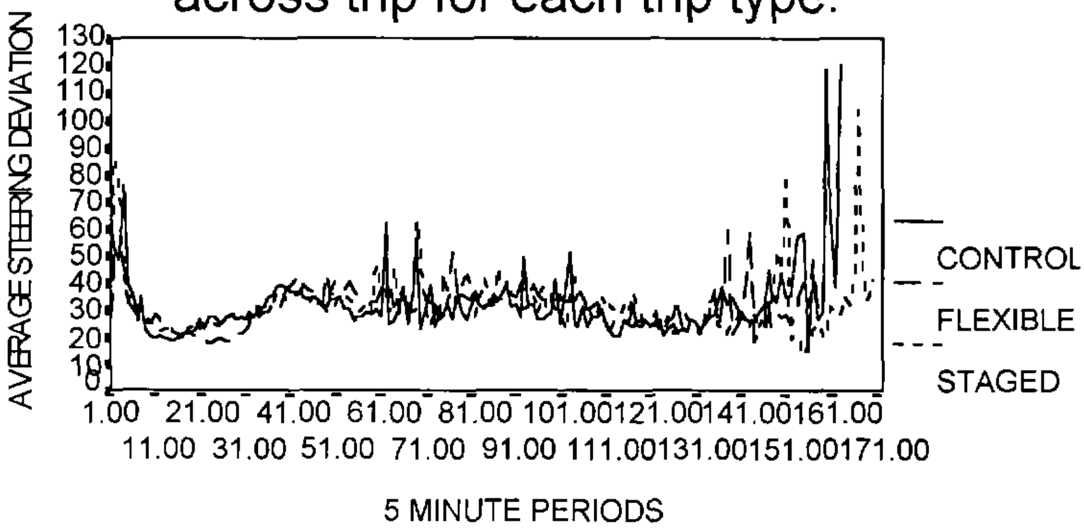


Figure 24: Mean Steering deviations before the 2nd & 3rd hour of trip for each trip type.

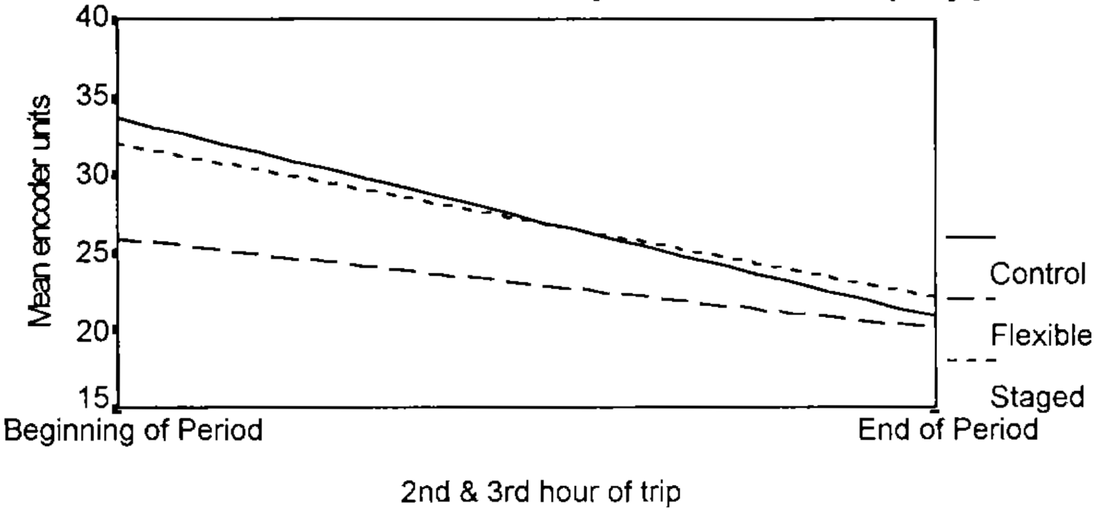
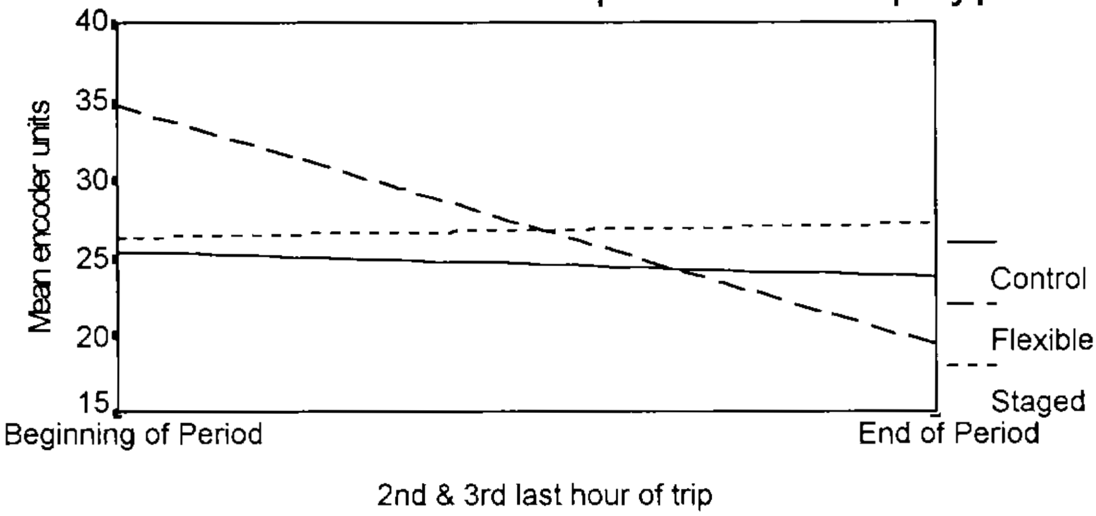
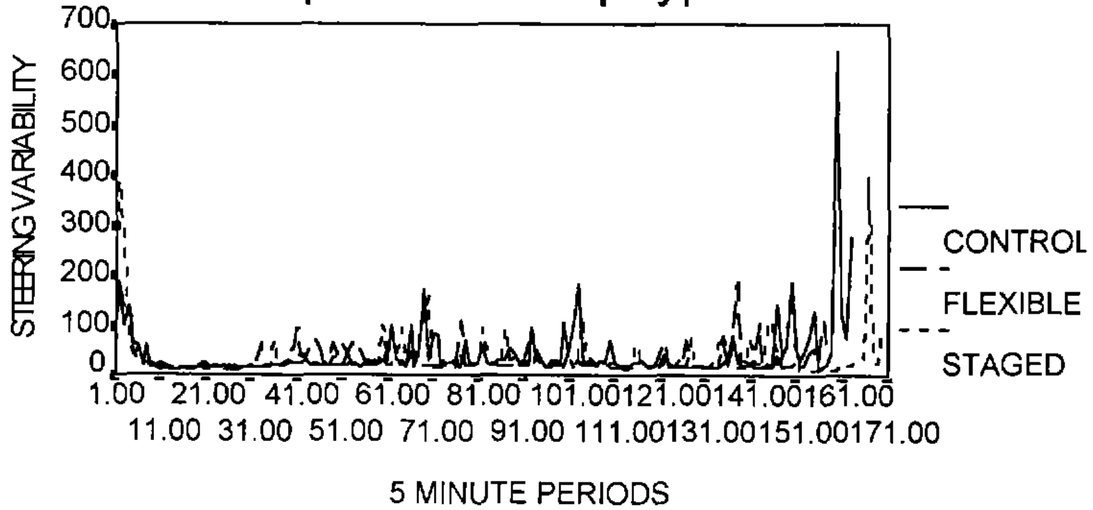


Figure 25: Mean Steering deviation after the 2nd & 3rd last hour of trip for each trip type.



The analysis revealed that steering movements varied significantly between the beginning and end of the trip for all three trip types, but the nature of the variation was different for each trip type. For staged trips, drivers showed more steering wheel deviation at the beginning of the trip compared to the end but the size of the deviation was decreasing more rapidly at the beginning of the trip compared to the end when there was very little change in steering deviation (for slope, $t_{(46)}=5.22, p<0.01$, and intercept $t_{(46)}=4.6, p<0.01$). Control trips showed much the same pattern of a tendency for the size of the steering deviations to decrease across the trip (slope $t_{(46)}=.1.48$,n.s. and intercept $t_{(46)}=6.97, p<0.01$). In contrast, flexible drivers showed change in the opposite direction, as demonstrated by larger and decreasing slopes and larger intercepts at the end of the trip compared to the beginning (for slope, $t_{(46)}=4.2, p<0.001$, and intercepts $t_{(46)}=-6.13, p<0.0001$). When doing flexible trips, drivers showed significantly different patterns of steering wheel movement to when they did control trips (beginning of the trip, slope, $t_{(46)}=0.94$,n.s., and intercepts $t_{(46)}=-5.65, p<0.0001$, and for the end of the trip, slope, $t_{(46)}=-6.0, p<0.0001$, and intercepts $t_{(46)}=7.09, p<0.0001$). At the end of the flexible trip drivers showed a similar pattern of steering wheel deviations to the beginning of the control trips. Staged and control trips, however were not significantly different in the pattern of steering wheel movement (beginning of trip, slope, $t_{(46)}=0.39$,n.s., intercept $t_{(46)}=-2.09$,n.s., and end of trip, slope, $t_{(46)}=0.92$,n.s., intercept $t_{(46)}=0.48$,n.s.).

Figure 26: Plot of steering variability across trip for each trip type.



Analysis of the variability in steering wheel movement across trips revealed similar results for all three trip types (see Figures 26, 27 and 28). Variability did not change significantly across the trip for any trip type (for staged trips, slope, $t_{(46)}$=1.67,n.s., intercept, $t_{(46)}$=-2.44,n.s.; for control trips, slope, $t_{(46)}$=1.55,n.s., intercept, $t_{(46)}$=2.12, n.s., and for flexible trips, slope, $t_{(46)}$=1.52,n.s., intercept, $t_{(46)}$=2.47,n.s.).

The comparison of patterns of steering movement before and after the trip showed that the size of steering deviations decreased across the trip for staged and control trips but for flexible trips they increased significantly and were significantly larger at the end of flexible trips than at the same time on control trips. Differences in road terrain encountered at different times in control and flexible trips may contribute to this difference. The trip types did not, however, differ in the amount of variability in steering movements across the trip. This shows that drivers tended to decrease the size of steering movements across staged and control trips, but their steering did not become more erratic.

3.2 Changes in steering wheel movements within the trip.

The patterns of average steering wheel deviation before and after the two major breaks are shown in Figures 29 to 36.

First break from driving

Analysis of the patterns before and after the first break for each trip type (see Figures 29 and 30) suggests that for staged and flexible trips this break had little effect on driver performance since there was no significant change in either slopes or intercepts across the break for either staged or flexible trips (for staged trips, slope, $t_{(22)}$=0.03,n.s., and intercept $t_{(22)}$=-0.33, n.s. and for flexible trips, slopes, $t_{(22)}$=-0.53,n.s., and intercept, $t_{(22)}$=0.52,n.s.). On control trips, however, the first break saw a significant change in steering deviations. Before the break they were larger but decreasing in size, whereas after the break they had decreased in size but the direction of change was to increase (slope, $t_{(22)}$=3.49,$p<0.01$, intercept, $t_{(22)}$=3.3,$p<0.01$). In addition, drivers on control trips showed a significantly higher rate of decrease in size of the steering deviations before the break compared to the pattern at the same time on staged and flexible trips (staged trips, slopes $t_{(22)}$=4.65,p<0.01 and flexible trips, slope $t_{(22)}$=3.62,p<0.01) and also a higher intercept compared to flexible trips only (intercepts, flexible trips, ($t_{(22)}$=-3.35,p<0.01, staged trips, $t_{(22)}$=-1.98,n.s.).

Figure 27: Steering variability before the 2nd & 3rd hour of trip for each trip type.

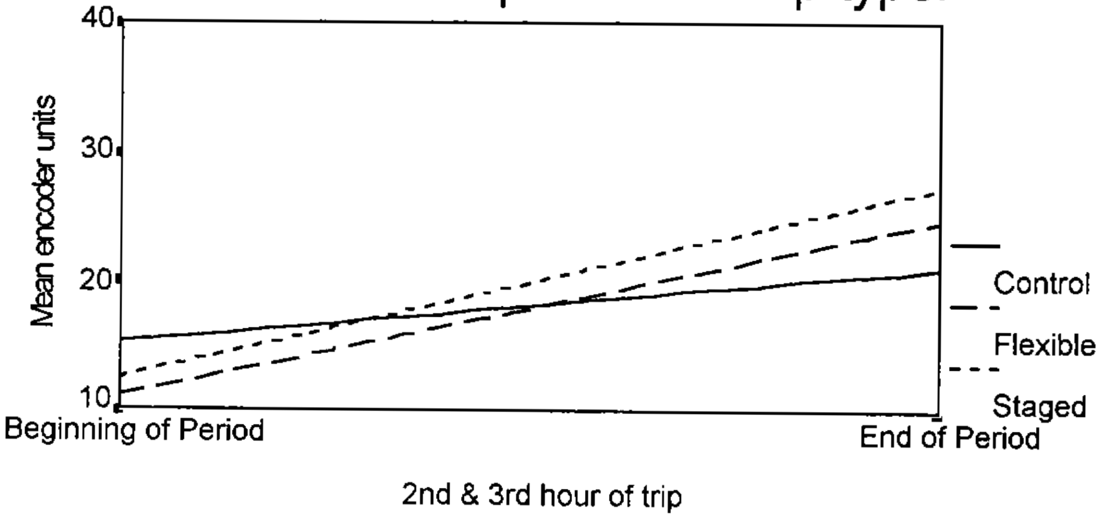


Figure 28: Steering variability after the 2nd & 3rd last hour of trip for each trip type.

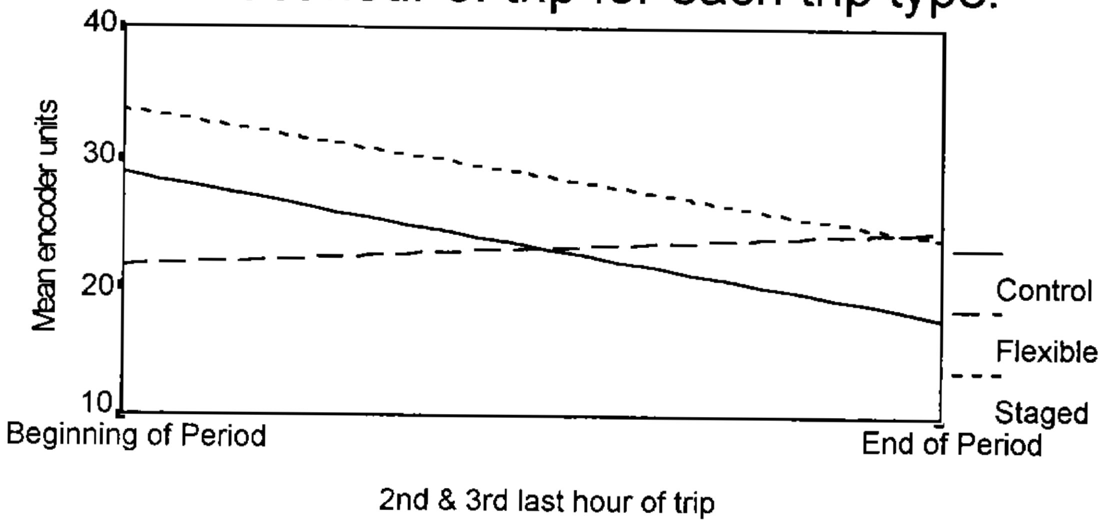


Figure 29: Mean steering deviation before the first break for each trip type.

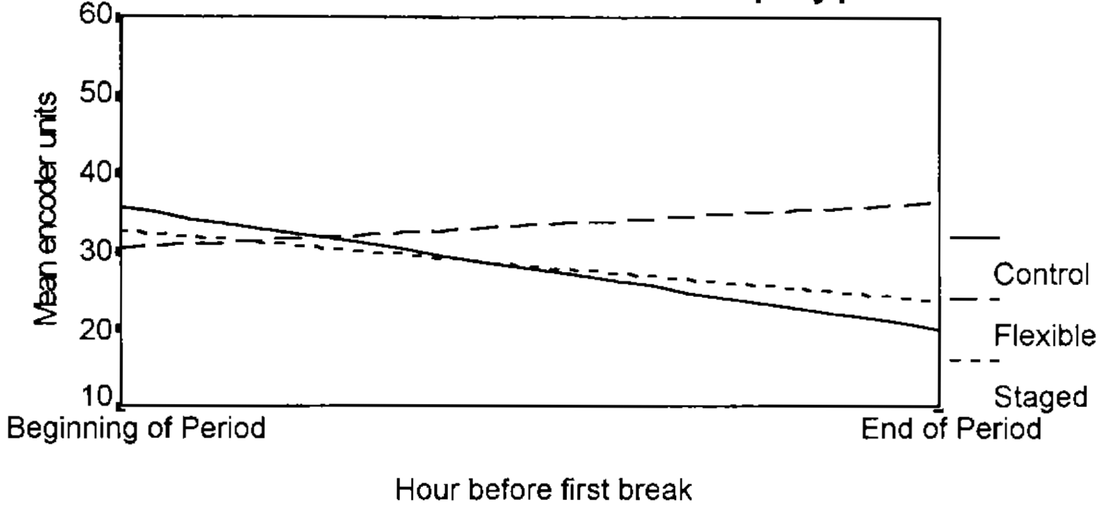
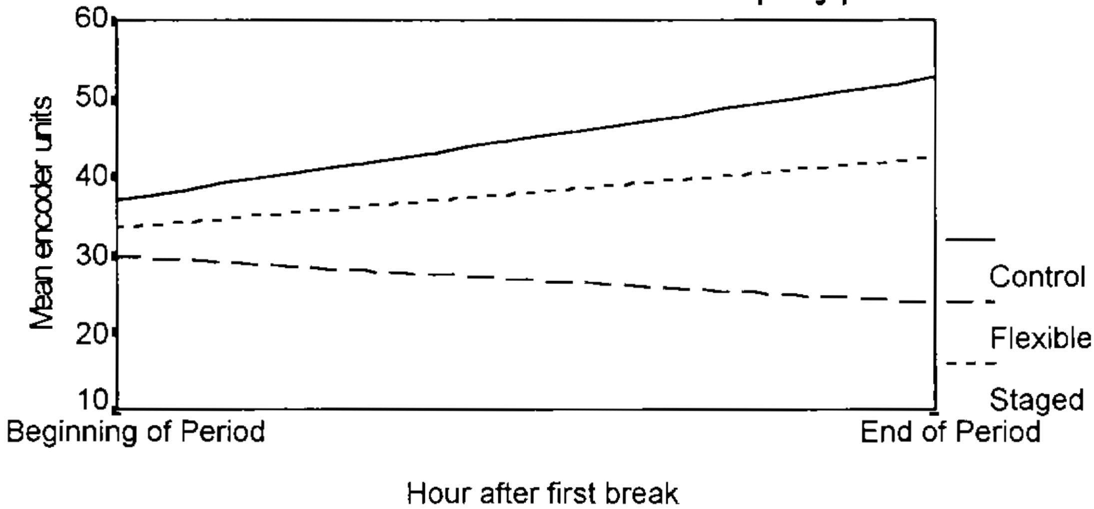


Figure 30: Mean Steering deviations after the first break for each trip type.



Within the trip (see Figures 31 and 32), for the first break there were no significant changes in steering variability following the break for any trip type (for staged trips, slope, $t_{(22)}$=1.61,n.s., intercept, $t_{(22)}$=2.76,n.s., for control trips, slope, $t_{(22)}$=-1.75,n.s., intercept, $t_{(22)}$=1.5,n.s., and flexible trips, slope $t_{(22)}$=1.71,n.s., intercept, $t_{(22)}$=0.19,n.s.). The only difference between trip types was that on flexible trips, drivers showed a trend to increasing variability before the break compared to control trips which were tending to decreasing variability at the same time in the trip. No such difference was evident after the break (for before the break, slope, $t_{(22)}$=3.5,$p<0.01$, intercept, $t_{(22)}$=1.64,n.s.; following the break, slope, $t_{(22)}$=1.83,n.s., intercept, $t_{(22)}$=0.78,n.s.)

The results showed that before the first break the steering deviations of control drivers were tending to decrease compared to both staged and flexible trips even though the overall size of their deviations was significantly higher than for flexible trips. Steering patterns did not change across the break for staged or flexible trips. Control trips showed a decrease in size of steering movements after the break, but the direction of change was to larger steering movements. For flexible trips the size of steering movements also did not change following the break, but they became less variable.

Second break from driving

For the second break, drivers appeared to obtain little benefit when on staged trips as the pattern of steering wheel deviations did not change across the break (see Figures 33 and 34)(slope, $t_{(22)}$=0.28,n.s., intercept, $t_{(22)}$=0.44,n.s.). When on control trips there was a significant reduction in the size of deviations after the break, but the rate of change was not different (slope, $t_{(22)}$=0.93,n.s., intercept, $t_{(22)}$=5.09,$p<0.0001$.). For flexible trips, there was a significant change in the size of steering movements following the second break. Before the second break on flexible trips, steering deviations were significantly larger in size than for control drivers, but the rate of change was not different. (slope $t_{(22)}$=-2.57,n.s. and intercept, $t_{(22)}$=4.6,$p<0.01$) however after the break steering movements were increasing significantly compared to both before the break and compared to deviations for control trips at the same time (compared to before the break, slopes, $t_{(22)}$=4.11,$p<0.01$, intercept, ($t_{(22)}$=6.12,$p<0.01$); compared to control trips after the break, slope ($t_{(22)}$=3.0,$p<0.05$, intercept, $t_{(22)}$=0.03,n.s.).

Figure 31: Steering variability before the first break for each trip type.

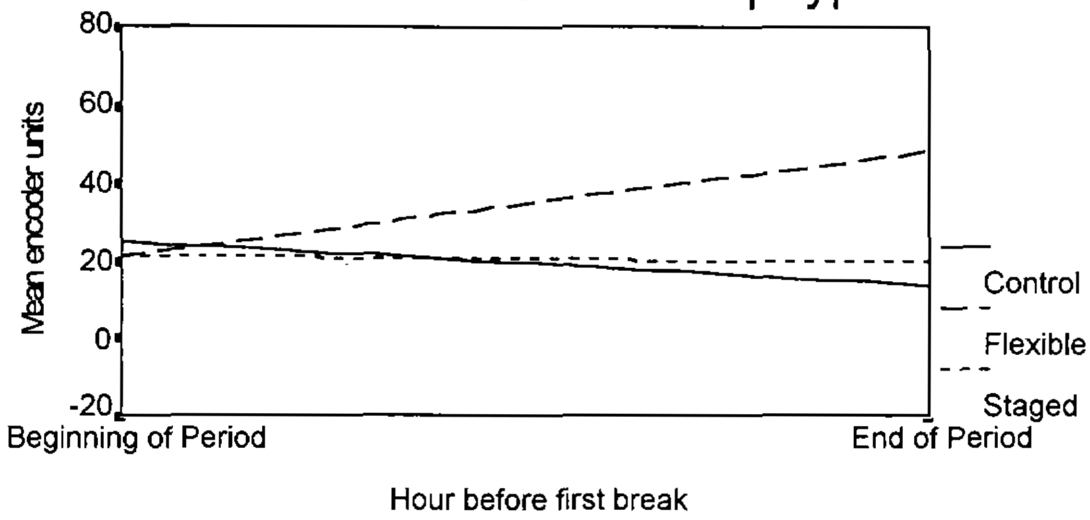


Figure 32: Steering variability after the first break for each trip type.

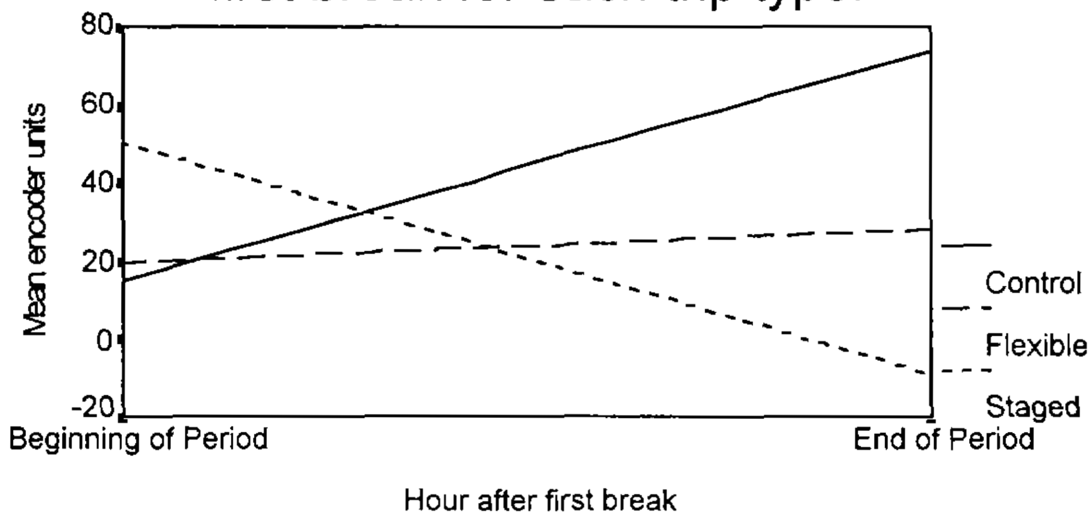


Figure 33: Mean steering deviation before the second break for each trip type.

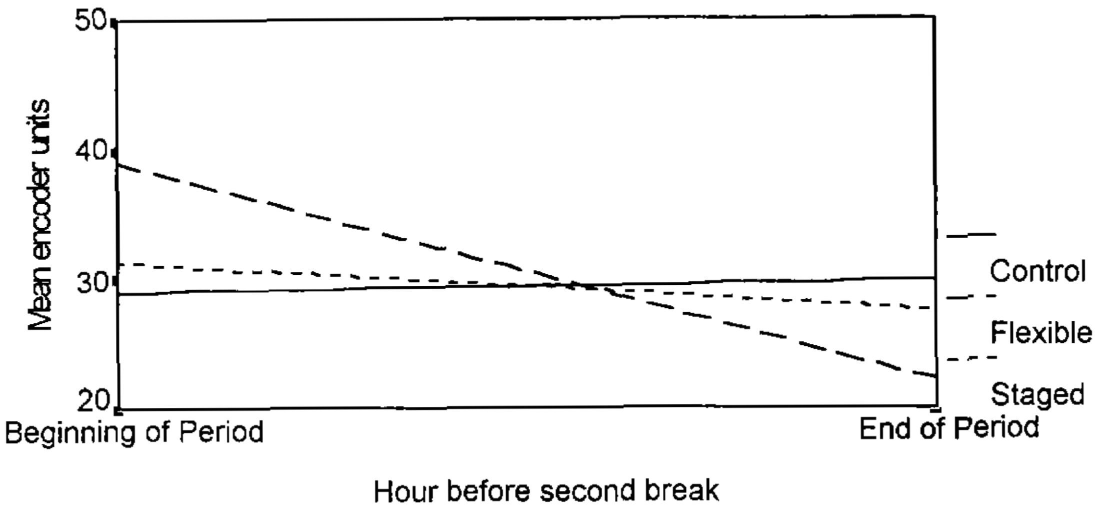
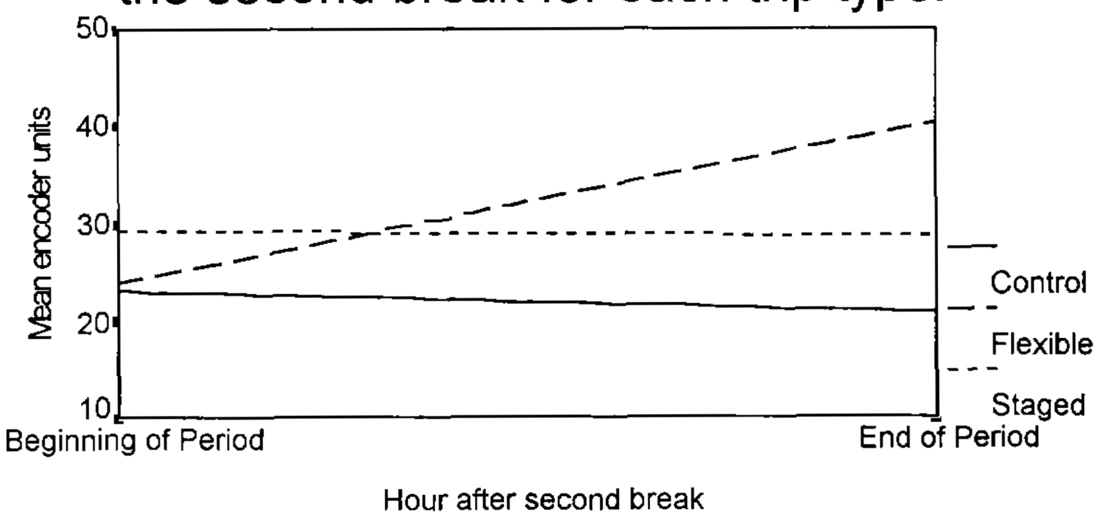


Figure 34: Mean steering deviations after the second break for each trip type.



Following the second break, steering variability did not change significantly for any trip type (see Figures 35 and 36) nor were there any differences between trip types (comparing pre and post break, for staged trips, slopes, $t_{(22)}$=0.49,n s , intercepts $t_{(22)}$=0.57,n.s.; for control trips, slopes, $t_{(22)}$=-0.41,n.s., intercepts $t_{(22)}$=2.47,n.s.; for flexible trips, slopes, $t_{(22)}$=0.29,n.s., intercepts, $t_{(22)}$=1.46,n.s.); comparing staged and control trips, before the break, slopes, $t_{(22)}$=0.87,n.s., intercepts, $t_{(22)}$=0 12,n s., after the break, slopes, $t_{(22)}$=1.59,n.s., intercepts, $t_{(22)}$=0.39,n.s.; comparing flexible and control trips, before the break, slopes, $t_{(22)}$=0.09,n.s., intercepts, $t_{(22)}$=0.78,n.s., after the break, slopes, $t_{(22)}$=1.52,n.s., intercepts, $t_{(22)}$=0.29,n.s.).

The second break made little difference to the patterns of steering movements for staged trips, but they decreased in size for control trips Before the break flexible drivers displayed the largest steering deviations, but these decreased to the same level as for control trips after the break. The direction of change in steering pattern also changed for flexible trips from a negative or decreasing rate of change before the break to an increasing one after the break.

This overall pattern of results for steering wheel movements show that the steering wheel movements on staged and control trips were quite similar showing fairly rapid decrease in size of steering movements at the beginning of the trip, which were significantly reduced at the end of the trip. For staged trips, breaks did not appear to change the size of steering deviations very much at all whereas for control trips the steering wheel movements were increased in size after first break, but after the second one, they were reduced. For flexible trips the size of steering movements were reducing at both the beginning and end of the trip, but at a faster rate at the end. Within the trip, however, flexible trips showed a tendency to increase the size of steering movements, and this occurred most noticeably after the second break from driving.

Figure 35: Steering variability before the second break for each trip type.

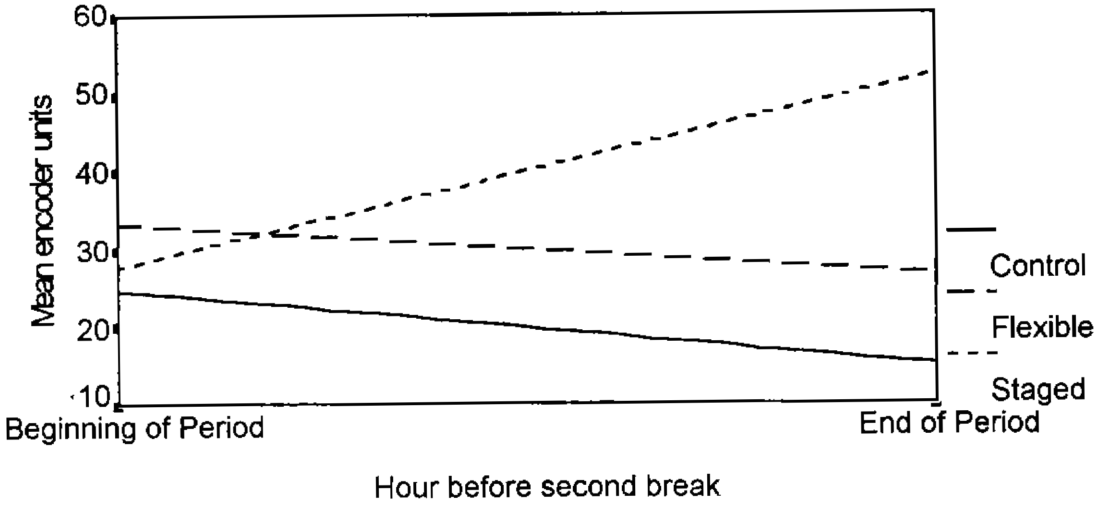
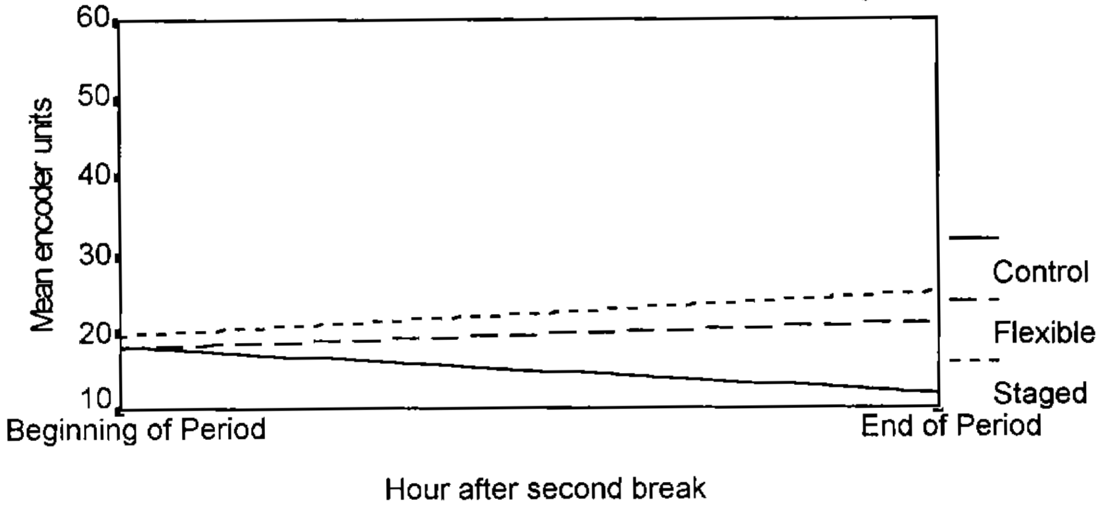


Figure 36: Steering variability after the second break for each trip type.



4. Speed

Table 30 displays the speed of the vehicle for each trip type at the beginning and towards the end of the trip. The results were analysed by multiple t-tests with a Bonferroni correction using the same seven comparisons as for the heart rate and steering measures. Drivers did not vary their speed significantly between each end of the trip for either staged or control trips (staged trip, $t_{(6)}$=-0.62,n.s., control trips, $t_{(11)}$=-1.87,n.s.). In addition speed did not vary between staged and control trips either early or late in the trip ($t_{(9)}$=-.33,n.s., $t_{(6)}$=-0.37,n.s., respectively).

TABLE 30: Changes in speed of the vehicle at the beginning (first 15 mins of hour 2) and end (first 15 mins of hour 11) of the trip for Staged, Control and Flexible trips.

	MEAN SPEED	
TRIP TYPE	**Beginning of Trip**	**End of Trip**
Staged	80 6 (29.0)	90.8 (24.0)
Control	87.4 (7 3)	94.7 (11.2)
Flexible	98.4 (5.7)	83.6 (13.8)

For flexible trips, there was a significant decrease in speed between the beginning and end of the trip ($t_{(13)}$=3.37,p<0.01) and drivers were significantly faster at the beginning of flexible trips than control trips ($t_{(16)}$=-5.32,p<0.01) but at the end of the trip, speed was not significantly different between flexible and control trips ($t_{(8)}$=2.26,n.s.). It is possible that the difference in speed between flexible and control trips is influenced by the nature of the road at the beginning of each of these trips. Since flexible trips always started in Melbourne and finished in Sydney and control trips always went in the opposite direction, it is likely that the higher speeds seen at the beginning of flexible trips and the end of control trips is due to the road conditions outside Melbourne which permit faster speeds.

Relationship between subjective fatigue ratings and heart rate measures

In order to investigate the relationship between the drivers' ratings of fatigue and measured changes in heart rate across the trip the results for each trip type were categorised into those reporting low, medium and high subjective fatigue on the Visual Analogue Scale. The categorisation was performed by dividing drivers into tertiles for each trip type at the beginning and end of the trip. Lines of best fit were then plotted to describe changes in interbeat interval for each fatigue group. Figures 37 to 42 show the results of this analysis.

For staged trips at the beginning of the trip there was a clear positive relationship between interbeat interval and fatigue rating such that interbeat interval was shortest for the low fatigue group (see Figures 37 and 38), indicating higher alertness compared to the high fatigue group which had longer interbeat interval which was increasing at a comparatively high rate (for slope, $t_{(46)}=-1.55$,n.s., intercept, $t_{(46)}=-5.25, p<0.01$). By the end of staged trips the difference between high and low fatigue groups was even more pronounced. For the low group interbeat interval was short, but increasing, whereas for the high fatigue group interbeat interval was significantly higher but they were not changing very quickly (slope, $t_{(46)}=4.02, p<0.01$; intercept, $t_{(46)}=9.85, p<0.01$). Comparing interbeat interval at the beginning and end of the trip showed that for the low fatigue group interbeat interval was significantly longer at the end of the trip and increasing, suggesting that alertness was lower at the end of the trip for this group (slope, $t_{(46)}=2.33$,n.s.; intercept $_{(46)}=3.61, p<0.01$). For the high fatigue group interbeat interval was largest (slower heart rate) at the end of the trip but the rate of change was much lower (slope, $t_{(46)}=3.27, p<0.01$; intercept $t_{(46)}=7.16, p<0.01$). These results suggest that changes in interbeat interval varied with the drivers' level of fatigue when on staged trips so that interbeat interval increased (slower heart rate) with higher fatigue ratings both at the beginning of the trip and at the end.

For control trips there was not such a clear relationship (see Figures 39 and 40). At the beginning of the trip the high fatigue group had larger interbeat intervals compared to the low group (for slope $t_{(46)}=1.67$,n.s.; intercept, $t_{(46)}=-4.73, p<0.01$), indicating lower alertness in the high fatigue group. At the end of the trip, in contrast, interbeat interval was shorter for the high fatigue group, but the size of the interval was increasing compared to the low fatigue group (slope, $t_{(46)}=0.80$,n.s.; intercept, $t_{(46)}=4.58, p<0.01$).

Figure 37: Interbeat interval before the 2nd & 3rd hour of staged trip.

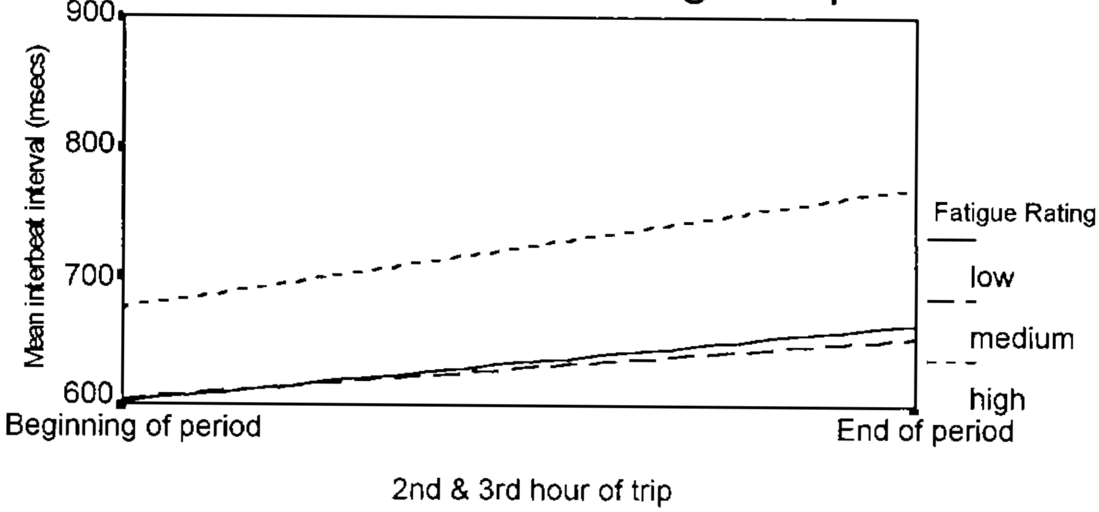


Figure 38: Interbeat interval after the 2nd & 3rd last hour of staged trip.

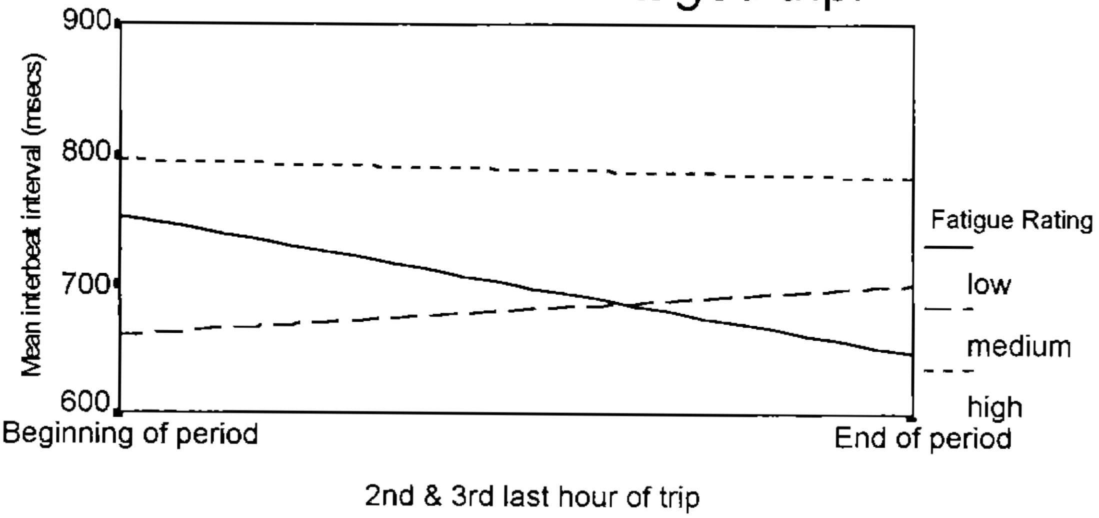


Figure 39: Interbeat interval before the 2nd & 3rd hour of control trip.

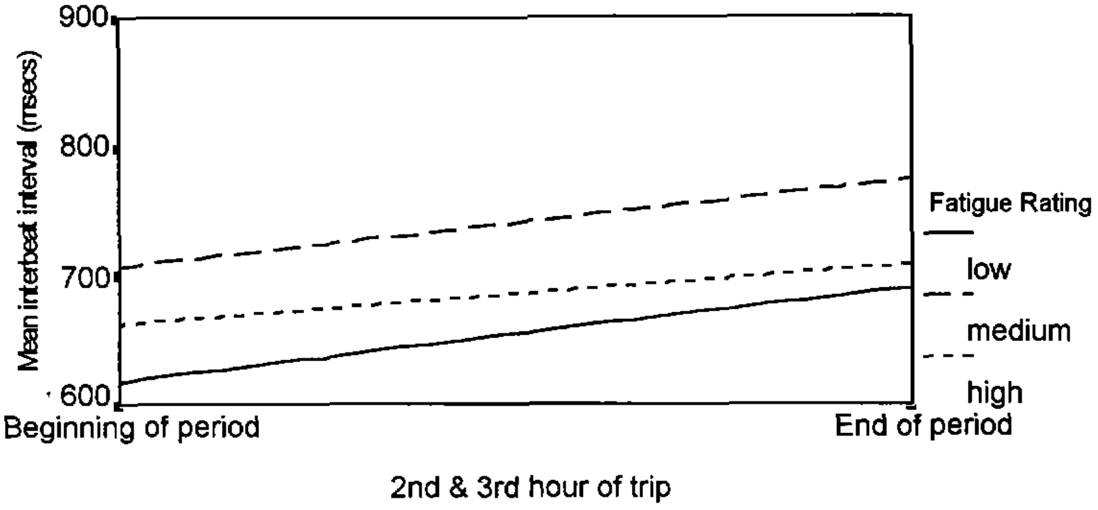
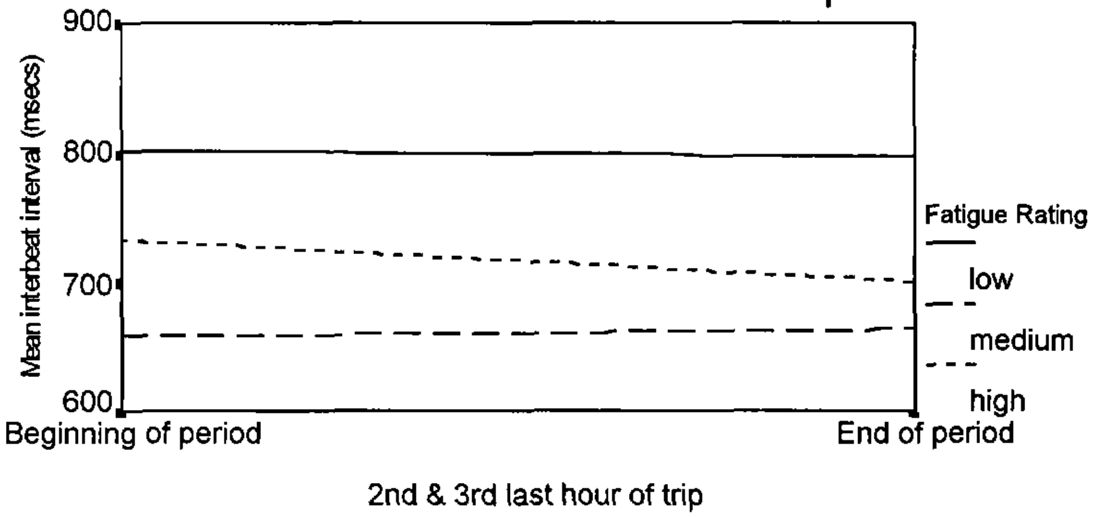


Figure 40: Interbeat interval after the 2nd & 3rd last hour of control trip.



In addition, low fatigue drivers showed an increase in the size of interbeat interval and a significant decrease in rate of change at the end of the trip compared to the beginning (slope, $t_{(46)}=3.95, p<0.01$; intercept, $t_{(46)}=16.98, p<0.01$). High fatigue drivers did not show any significant changes in interbeat interval between the beginning and end of the trip (slope, $t_{(46)}=0.45$,n.s., intercept, $t_{(46)}=1.96$,n.s.). This suggests that high fatigue drivers were less alert at the beginning of control trips, but by the end they showed higher alertness compared to less fatigued drivers. Low fatigue groups manifest different patterns of interbeat interval between the beginning and end of the trip, but high fatigue groups did not.

At the beginning of the trip (see Figures 41 and 42) flexible drivers with low fatigue showed larger interbeat interval than the high fatigue group (intercept, $t_{(46)}=8.95, p<0.01$) but the rate of change for both fatigue groups was to increasing size of interbeat intervals (slope, $t_{(46)}=2.13$,n.s.). At the end of the trip, low and high fatigue groups did not differ in the rate of change of interbeat interval, but the size of the interbeat interval was longer for the high fatigue group (slope, $t_{(46)}=1.25$,n.s., intercept, $t_{(46)}=2.71$,p,0.05). This suggests that drivers with low fatigue at the beginning of flexible trips were less alert than those reporting high fatigue at the same time. At the end of the flexible trip, however the high was significantly less alert than the low fatigue group. Comparing interbeat interval between the beginning and end of the trip for flexible trips showed shorter interbeat interval for the low fatigue group although the direction of change was to increasing interval size at both times (slope, $t_{(46)}=1.21$,n.s., intercept, $t_{(46)}=3.36, p<0.01$). For the high fatigue group interbeat interval increased across the trip and the slope of the line for interbeat interval at the end of the trip for this group was significantly increased (slope, $t_{(46)}=9.12, p<0.01$, intercept, $t_{(46)}=5.24, p<0.01$). These results imply that drivers experiencing low fatigue on flexible trips finished the trip with higher alertness than when they started but high fatigue drivers were significantly less alert at the end of the trip compared to the beginning and low fatigue drivers at the same time.

Overall these results suggest that the relationship between subjective fatigue and heart rate differed between trip types. For staged trips, high fatigue ratings were associated with longer interbeat interval (slow heart rate) at both the beginning and end of the trip. In addition the time on staged trips was influential since interbeat interval was longer for low fatigue drivers at the end of the trip. This suggests that both high fatigue and time on the trip produce decreased alertness in staged trips. For control trips, high fatigue was associated with longer interbeat intervals at the beginning of the trip, but not at the end.

Figure 41: Interbeat interval before the 2nd & 3rd hour of flexible trip.

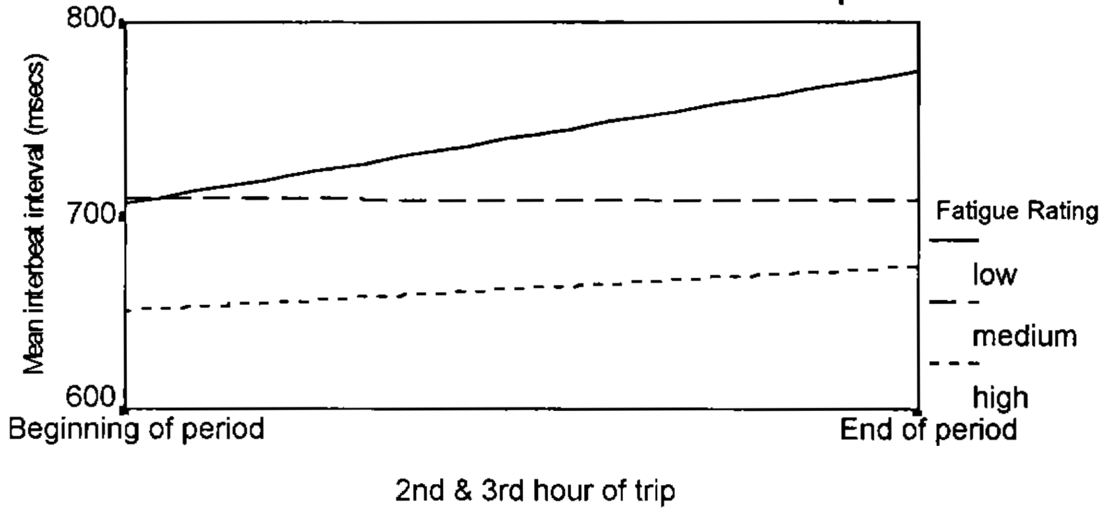
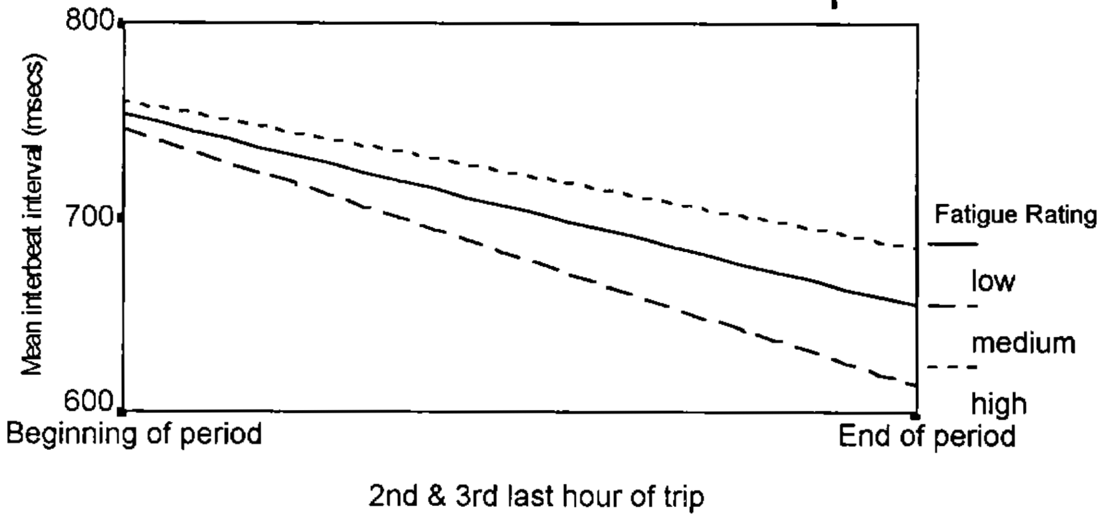


Figure 42: Interbeat interval after the 2nd & 3rd last hour of flexible trip.



While the high fatigue group had slower heart rate (long interbeat interval) compared to the low fatigue group at the beginning, it did not change much over the trip whereas interbeat interval was longer for the low group at the end of the trip compared to the beginning such that by the end their interbeat interval was significantly longer than the high fatigue group. These results indicate that the two factors, high fatigue and time on the trip, interacted for control trips. Low fatigue seemed to be associated with higher alertness at the beginning of the trip, but after the experience of the control trip alertness appeared to decrease to levels even lower than those displayed by the high fatigue group.

The flexible trip, in contrast, showed the opposite relationship. The low fatigue group had longer interbeat intervals suggesting lower alertness than the high fatigue group at the beginning of the trip, which was contrary to the pattern for the beginning of staged and control trips. By the end of the trip, the relationship was the same as that shown for the beginning of staged and control trips, with the high fatigue group showing reduced alertness by their longer interbeat intervals.

DISCUSSION

The results of this study showed, as might be expected, that reduced alertness and increased fatigue occurred across all types of trip. Both subjective measures of fatigue, the Stanford Sleepiness Scale and the three Visual Analogue scales showed the same result. For control and flexible trips drivers started the trip with fairly low fatigue and high levels of alertness but by the end of the trip drivers rated themselves as considerably more tired and less alert than they had been at the beginning of the trip. Drivers did not show the same results, however when on staged trips. A significant number of drivers were more tired at the beginning of staged trips than when on other trips. As for other trips fatigue increased and alertness deteriorated across staged trips, and drivers were more tired at the end of staged trips than on other trips.

The effects of changes in the level of fatigue could be seen in most of the measures of cognitive functioning and driving performance used in this study. For the CFF test the poorest performance was seen at the beginning of staged trips and CFF thresholds for staged trips had actually increased by the end of the trip. For the other trip types there was little change in thresholds across the trip. Similar results were seen for the Unstable tracking test with performance on staged trips being poorer than on control trips for both measures, time on target and the level of difficulty reached in the test. In addition, drivers were not only poorer overall on this test while they were on staged trips, but drivers showed improvements in performance when they were on control trips whereas on staged trips their performance did not change. For the vigilance test drivers performed worst overall when they were on staged trips compared to control trips. When on staged trips vigilance performance was poorer at the beginning and at the end of the trip even though, as for other trip types, speed of response to stimuli increased between the beginning and end of the trip. The simple reaction time test was the only cognitive test where there were no significant effects due to the time spent driving or the type of trip the driver was on.

Examination of the performance of drivers for the on-board reaction time test revealed no significant differences between any trip type for either reaction time or the number of errors made in the test. In addition, there was no apparent change in performance across the trip for any trip type. Performance remained the same at the beginning, middle and end of the trip. On-board reaction time performance was affected to some extent, however, by the time of test such that reaction times were slowest earlier in the trip. This finding was peculiar to staged trips. As for the cognitive performance tests drivers performed worst in the on-board reaction time test at the beginning of their staged trips.

This finding adds weight to the results of the cognitive performance tests. The on-board test was a low-effort, low-load continuous task which was integrated at intervals into the driving task, unlike the cognitive tests which were done outside the vehicle at the beginning and end of the trip and during the middle break. Consequently it might have been expected that the on-board test would be more sensitive to changes in performance due to driver fatigue. The results showed that this test was no more sensitive to changes in driver performance than the cognitive tests. Both types of tests showed similar findings relating to poorer performance on staged trips.

The findings regarding changes in cognitive performance across the trip differed between test types. There did not appear to be any relationship between simple reaction time performance and fatigue or time on the trip whereas all other tests showed some fatigue related changes. The simple reaction time test requires the least amount of effort of any of the tests employed in this study. In fact this test is the closest to an automatic processing task of all the cognitive tests included in this study. It has been recognised that changes in physiological or psychological state have relatively little effect on tasks requiring automatic processing (Aasman, et. al, 1987). In addition, the driving task, particularly for these experienced drivers, is an automatic or routine task which does not, in itself, demand much effort from the driver. Therefore drivers will have sufficient spare capacity to manage the simple reaction time test with ease. Consequently, it could be argued that simple reaction time would be the last test to be affected when cognitive functioning begins to be impaired by fatigue or any other factor likely to change the body's state. The drivers in this study were clearly able to continue functioning adequately throughout all of their trips regardless of any reduced alertness. It is not surprising then the very fundamental simple reaction time test was not affected by changes in alertness in these drivers.

It is clear that cognitive performance was affected most when drivers were on staged trips with drivers consistently performing poorer when on these trips compared to the other types. The most striking finding for staged trips was that performance was so poor at the beginning of the trip compared to the other trip types. As staged trips were typically the first trip the drivers undertook for this study, it is possible that this finding was due to practice effects. This explanation is not supported, however because practice trials were given to all drivers before they did each test for all three trips. Furthermore there is little other evidence of the effects of practice in the performance of these cognitive tests. For the vigilance test, for example, this was tested directly. Reaction speed during the vigilance test did not differ significantly between the first and second halves of each block of tests. Visual inspection of the first and second halves of each session for the simple reaction time and unstable tracking tests led to the same conclusions. In addition, for the unstable tracking test both measures showed the poorest performance for the midtrip test for both staged and control trips. If test performance was improving due to practice, midtrip performance should have been superior to performance at the beginning of the trip.

For both the Unstable tracking and vigilance tests, rather than showing deteriorating test performance due to the fatigue of long periods at the wheel, performance actually improved between the beginning and end of the trip. As discussed above, this phenomenon is not likely to be due to the effects of practice. Rather it is more likely to be due to the rearousing effects of completing the trip and getting out of the truck. It is likely that this level of stimulation was sufficient to raise the driver's level of alertness enough to function well in these tests. Other studies have shown increases in the alertness of drivers due to changes in the level of stimulation while driving. For example, Brookhuis and Ward (1993) demonstrated after 2.5 hours of driving that a car-following test produced immediate reactivation of drivers as shown by changes in EEG measures.

It is likely, however, that such increases in the level of alertness would be a fairly temporary state such that retesting of drivers a short time later, would show deterioration in performance again. It is interesting that this rearousal phenomenon occurred most noticeably for the Unstable tracking and vigilance tests. Both of these tests are prolonged, active tests compared to the other two tests and require the driver to sustain their alertness for longer. These characteristics are very similar to the demands of the driving task so that changes in the performance on these tests will mirror the sorts of changes that are likely to occur during long periods of driving. If this is the case, it suggests that drivers are able to improve their level of alertness at least for a short period by taking a break from driving and taking some activity, however performance after about 5 hours of driving (midtrip in this study) will show marked deterioration.

The results of the heart rate measures are in harmony with this suggestion and add weight to the cognitive performance results. Changes in the speed and patterning of heart rate are known to be reasonably close correlates of fatigue and loss of alertness (Haworth et al, 1989; Brookhuis and de Waard, 1993). Changes in interbeat interval and interbeat variability revealed changes between the beginning and end of the trip however there were marked differences between trip types. For staged trips, drivers were characterised by faster heart rate (short interbeat interval) and lower variability at the beginning of the trip compared to the end of the trip although interbeat interval was increasing. This suggests that when they started the staged trip, drivers had higher, but decreasing levels of alertness and became less alert over the trip such that staged drivers showed lowest alertness at the end of the trip. Similar results were found for control trips with higher alertness at the beginning of the trip which was decreasing early in the trip, to significantly reduced alertness towards the end of the trip. When on flexible trips, in contrast, drivers had longer interbeat interval (slow heart rate) and considerably greater variability at the beginning of the trip, indicating lower alertness, but this decreased so that by the end of the trip interbeat interval was considerably shorter and variability decreased, signifying increased alertness.

Smaller and less variable steering movement is suggested to be characteristic of alert individuals. On this basis, staged and control trips showed some sign of lower alertness at the beginning of the trip as the size of steering deviations were significantly higher at the beginning of the trip compared to the end. Drivers on flexible trips showed the opposite finding indicating decreasing alertness across the trip. These conclusions must be tempered, however, by the finding that the variability in steering deviation did not change across any of the trip types. Only the absolute size of steering deviations showed any change. As this steering measure has not been corrected for road conditions, control and flexible trips might be expected to differ in the size of steering deviations. Control and flexible trips were started at different ends of the route so any effects of road conditions would have had opposite effects on steering for these two trip types. For these reasons, it must be concluded that there is little evidence of fatigue-related changes across any of the trip types..

Changes in heart rate are recognised to be correlates of change in mental state (Coles and Sirevaag, 1987). Investigation of the relationship between subjective ratings of fatigue and alertness and changes in interbeat interval revealed the clearest relationship for staged trips. The results for drivers on staged trips showed that reports of high fatigue at either the beginning or end of the trip were associated with shorter interbeat interval (fast heart rate) which has been demonstrated to indicate higher alertness. This suggests that for during staged trips there was a clear relationship between subjective fatigue and the body's actual state of fatigue. This finding also adds weight to the results of the cognitive function tests for staged trips. More drivers reported high fatigue at the beginning of staged trips than for any other trip type. Furthermore fatigue ratings were higher for drivers on staged trips right across the trip. In addition changes in interbeat interval and variability indicated lower alertness at the end of the staged trips than the beginning. Consequently it can be concluded that the poorer performance seen for staged drivers for many of the cognitive function tests is associated with high fatigue and lower alertness. This conclusion does not, however, take into account the finding that performance by stage drivers was markedly inferior and fatigue ratings were high at the beginning of the trip when heart rate levels suggested higher alertness at the beginning of the trip compared to the end. The reasons for this apparent inconsistently are not clear. It is possible that the increased effort required of staged drivers to overcome their relatively high subjective fatigue at the beginning of the trip prompted increases in heart rate.

For control and flexible trips different patterns were seen for drivers reporting high and low fatigue across the trip. On control trips the high fatigue group were less alert at the beginning of the trip and this did not change across the trip. In contrast, low fatigue drivers were more alert at the beginning of control trips, but alertness was decreasing such that they had lower alertness at the end of the trip than the high fatigue group. There are several possible explanations for this finding. It possibly reflects individual differences among drivers in their estimations of the severity of their subjective experience of fatigue. Some drivers may underestimate their fatigue experience. It is also possible that this finding is an outcome of low fatigue. Where drivers judge that they are not very fatigued, they may consequently put less effort into maintaining performance so resulting in a finding of lower alertness. This variation in alertness and fatigue within control trips may account for the finding of little change over all drivers in cognitive function.

On flexible trips the low fatigue group were more alert at the end of the trip than the beginning, although there was a trend to decreasing alertness when the trip was finishing. The high fatigue group showed the expected relationship of lower alertness at the end of the trip compared to the beginning and to the low fatigue group. Why alertness improved for the low fatigue group on flexible trips is possibly due to their experiences during the trip since flexible drivers did take more breaks during the trip than the other trip types. These may have been sufficient for drivers who were not very fatigued to maintain and even improve their alertness. Cognitive performance showed little change across the trip, again, probably because there was variation in fatigue and alertness within the drivers when doing flexible trips.

There are a number of possible reasons for self-reported fatigue in long distance drivers. Factors like the length of time at the wheel, the sequencing of breaks, the time of day, and driving conditions can produce acute experiences of fatigue while driving. In addition, factors relating to the driver can also be important such as their age, general health status, lifestyle and preparation for the trip. Finally, factors relating to the work-rest scheduling can produce chronic fatigue in drivers, increasing the possibility fatigue will be experienced on the road. The results of this study provide some insights into the contribution of many of these factors in promoting fatigue in drivers in this study.

The drivers who participated in this study were fairly typical staged drivers, as judged by the results of the earlier survey of long distance truck drivers (Williamson, Feyer et al, 1992). They were almost all older and more experienced drivers with fairly stable home lives. The drivers also appeared to be a very healthy group, reporting very low rates of medical problems and to lead a healthy lifestyle. Very few drivers smoked, the majority consumed alcohol on an irregular basis and a large proportion exercised regularly. It is often argued that poor lifestyle will at least aggravate, if not cause problems due to driver fatigue (Telford, 1991; Austroads, 1991), however any problems of fatigue in the drivers in this study would not be due to poor health status or unhealthy lifestyle since drivers were in good health and appeared to lead healthy lifestyles.

Possibly related to their overall healthy status, these drivers reported few sleep problems. This is surprising since all drivers regularly did shiftwork and sleep problems are a common complaint in shiftworking populations (Koller, 1983; Frese and Harwich, 1984). In addition, it appears that none of the drivers in the study would be classified as having sleep apnea on either of two criteria. In fact overall sleepiness scores for these drivers were lower than have been reported for many other groups (Johns, 1992). It is possible that being experienced drivers, this group represents a "survivor" group who can manage the challenges to their sleep/wake cycles which occur on a daily basis due to the scheduling of their work. Other studies have shown higher rates of health and sleeping problems in ex-shiftworkers than in current shiftworkers (Koller, 1983). These results show that on-road fatigue in this study could not be attributed to sleep problems of individual drivers.

From this study it can be argued that poor health and lifestyle habits are not the main causes of driver fatigue. Drivers in this study were healthy and led healthy lifestyles, yet most reported experiencing fatigue over a 12 hour trip. Due to the relatively small size of the study sample, it is not possible to rule out health and lifestyle factors as causes of driver fatigue, however it is clear that they are not necessary causes of driver fatigue.

A similar conclusion can be drawn about the drivers' preparation for the three trips which were monitored in this study. In the 12 hours before each trip almost all drivers had at least one meal and around six hours sleep. Although this is a somewhat lower amount of sleep than the community average (Hyppa, et al, 1991) this would have been day sleep for all trips. Studies of sleep patterns of shiftworkers show that day sleep is typically reduced, largely due to circadian influences (Frese and Harwich, 1984). The amount of sleep obtained by drivers in this study appears to be fairly typical of shift worker populations. Like most shift workers, however, it seems that the drivers in this study normally obtained relatively low amounts sleep and that drivers took the usual amount of sleep in the 12 hour period before they participated in this study.

Fatigue was almost bound to occur for drivers doing any type of trip in this study. All trips spanned the night hours including the early morning hours which are well recognised to increase the likelihood of fatigue (Folkard and Monk, 1979; Krueger, 1989). All drivers on all trips took steps to relieve their fatigue by taking at least one break in the approximately 12 hours that they were on the road. The pattern of break taking, however appeared to be affected by the different pressures of each trip type. Drivers took most breaks and spent most time in breaks when on staged trips, a finding which is consistent with the greater reported fatigue at the beginning of staged trips compared to control trips and suggests that breaks were taken in response to fatigue. On flexible trips, on the other hand, only a few drivers took more than one break.

Changes in the heart rate measures shed some light on the effectiveness of breaks. On staged trips the first break was followed by a limited increase in arousal as seen in an increase in interbeat variability, but a decrease in interbeat interval. The second break, however, was followed by considerable rearousal on staged trips which may have assisted in maintaining overall alertness in staged drivers for the remainder of the trip. For flexible drivers, on the other hand, the first break was followed by a decrease in both interbeat interval and variability, signifying dearousal. The second break on flexible trips was associated with a limited increase in arousal but which was decreasing. For control trips, neither of the breaks produced any change in either of the heart rate measures, suggesting that the break had little effect on alertness.

Considering that drivers were instructed to take breaks on flexible trips whenever they felt tired, regardless of work hours regulations, it is interesting that drivers did not regard it as necessary to have more breaks. It is also interesting that limiting of breaks did not produce significantly greater fatigue for flexible compared to the other trip types. On the other hand, it is also significant that encouraging flexible drivers to manage fatigue better by taking breaks when they needed them provided no additional benefits.

The timing and placement of breaks occurred at about the same time across all trip types. Even when drivers on flexible trips were encouraged to choose if, when and where they took breaks, they still took their break around five hours after the beginning of the trip. This common feature between trip types could mean that drivers really need a break about five hours into any trip. If this is so, it implies that the current working hour regulations are appropriate and in accord with drivers' natural work rhythms. It is also possible, however, that since all drivers in the study are experienced, professional drivers who do the Melbourne-Sydney route regularly, they have a habit of stopping at around five hours which is to do with factors other than fatigue. If this is so, it may be that flexible drivers were responding to habit rather than their body state in judging when to break. This study, therefore, may not have allowed a pure investigation of the effects of designing work-rest schedules around changes in the drivers body state. The results also highlight the reality for Australian long distance drivers that changes in body state and amenable places to stop and take a break from driving may not always be compatible. Consequently, drivers choose to stop at the next available place which may be one to two hours away rather than stopping in remote situations, regardless of their state of fatigue.

This study allows some assessment of the contribution of work-related factors in promoting fatigue. In this study higher levels of fatigue were experienced overall by drivers when doing staged trips than when they did control or flexible trips. This difference could not have been due to differences in the nature of the trip because all trips started at about the same time of the day, travelled over the same time period, including the early morning hours which are recognised to increase fatigue, did the same route and were very similar in the number and timing of breaks. In addition the motivators to complete the trip were very similar between the trip types.

It is possible that recent work history plays a role in determining the amount of fatigue experienced by drivers on any type of trip. Certainly for drivers doing staged trips the work load in the seven days prior to the trip was high relative to that reported in the survey of staged drivers (Williamson, Feyer et al, 1992). In addition, for most drivers a large proportion of their work time occurred at night and as a consequence only about half of their sleep was obtained at night.

There was a reasonably strong positive relationship between a range of work measures and the amount of sleep obtained. This suggests that the heavy workload for drivers increases their requirement for sleep, but also that drivers responded appropriately to the demands of their job by pacing the amount of sleep they obtained according to their workload. This seemed to be a real tendency for drivers to be responsible for their rest requirements since they clearly also balanced sleep and rest. The more rest days drivers had, the less they slept in the past week suggesting that both rest days and sleep served similar purposes and that drivers will use one or the other to alleviate work fatigue, but not both. Again this tendency mitigates against the interpretation of fatigue in long distance driving being due to their poor sleep and lifestyle habits. These results do not, however, reveal anything about the effects of variations in work-rest patterns on fatigue during a trip

It is likely that the higher levels of fatigue reported at the beginning of staged trips in this study was a result of the demands of the previous working week. Since staged trips were mostly the first in the sequence studied, they were most likely to be influenced by the work-rest pattern experienced in the past week. As the workload had been high for many drivers in the past week, this may have led to higher fatigue in drivers even before they started a trip for this study. In contrast, the relatively higher alertness of drivers doing control and flexible trips may have arisen because the experimental regime was not as demanding for drivers as the normal work week. Unfortunately, it is not possible to test these suggestions with the data from this study as although there is a reasonable variation in the drivers workload over the past week, the sample size is too small to allow reliable analysis.

The analysis of the results of this study was hampered to some extent by missing data, particularly in the data collected during the trip. Technical problems with the data logger, especially in the first part of the study meant that for some drivers data was not collected for the entire duration of all trips. This study used a repeated measures design which has a number of significant advantages in that each driver served as his own comparison for all three trips. Missing data creates difficulties for repeated measures designs such that cases can be rejected for analysis when only a section is missing. This can greatly weaken the power of the study to detect differences between groups when differences actually exist, so leading to more conservative conclusions in the study. This point needs to be recognised in interpreting the results of this study. A number of cognitive tests appeared to lack sensitivity to measure driver fatigue, for example the reaction time test. The failure to detect effects of changes in fatigue may have been due at least in part to the smaller sample size that was available for the analysis. Alternatively there may not have been a large enough deterioration in behavioural function over the relatively short 12 hour trip.

The results of this study show that overall there was relatively little difference between the trip types in the effects on the drivers' performance. More drivers reported tiredness at the end of the trip than the beginning no matter how the trip was arranged. This is likely to be the outcome of simply being at the wheel for around 12 hours. Some performance tests did show poorer performance for staged trips compared to control trips. These results suggested that when doing staged trips drivers did not handle tasks requiring prolonged attention as well as when they were doing the other trip types. The conclusion can not be drawn, however that the unique characteristics of staged driving created this inferior performance. The potential demands of making a change of driver at the middle of the trip did not affect test performance since drivers were poorer in the critical tracking and vigilance tasks across the entire trip. This finding has led to the suggestion that factors other than experiences within a single 12 hour trip are considerably more important in determining the level of fatigue and any effects on performance Factors such as prior workload may well be much more important in causing driver fatigue. It is likely that high workload and little time for rest and recuperation will produce higher amounts of chronic fatigue in drivers. It was not possible to investigate this suggestion with this dataset due to small sample size. While trends in this dataset suggest that there is a relationship between prior workload and performance, this suggestion needs to be investigated further in an appropriately designed study.

There is little evidence that allowing drivers the freedom to organise the work-rest schedules of their own trips affected their performance. Drivers on flexible trips showed few differences on any of the cognitive or on-board performance tests compared to control trips. It seems that the requirement to comply with the regulated work-rest arrangement does not enhance the drivers' cognitive functioning or work performance, nor does it reduce the amount of fatigue that drivers report. It should be noted, however that flexible drivers did tend to select work-rest schedules which were quite similar to the regulated working hours. It would be interesting to determine whether this similarity persists when the trip is longer. It is likely that the evaluation of two-up driving, currently being conducted by this project group, will shed some light on this question.

REFERENCES

Aasman, J, Mulder, G. and Mulder, L. (1987) Operator effort and the measurement of heart-rate variability. Human Factors, 29(2), 161-170.

Ackerstedt, T. (1990) Psychological and psychophysiological effects of shiftwork. Scandinavian Journal of Work Environment and Health, 16 (suppl 1):67-73.

Austroads Project Management of Heavy Vehicle Driver Safety. Discussion paper for stakeholder comment on problems, potential countermeasures, stakeholder responsibilities and accountability arrangements, 1991.

Babkoff, H., Caspy, T. and Mikulincer, M. (1991) Subjective sleepiness ratings: The effects of sleep deprivation, circadian rhythmicity and cognitive performance. Sleep, 14 (6), 534-539

Babkoff, H., Mikulincer, M., Caspy, T., Kempinski, D. and Sing, H. (1988) The topology of performance curves during 72 hours of sleep loss: A memory and search task. The Quarterly Journal of Experimental Psychology, 40A (4), 737-756.

Bearpark, H., Fell, D., Grunstein, R., Leeder, S., Berthon-Jones, M. and Sullivan, C. (1990) Road safety and pathological sleepiness: The role of sleep apnea. Report No CR 3/90, Sydney: Roads and Traffic Authority of NSW

Blaauw, G.L. (1982) Driving experience and task demands in simulator and instrumented car: A validation study. Human Factors, 24 (4), 473-486.

Brookhuis, K. and de Waard, D (1993) The use of psychophysiology to assess driver status. Ergonomics, 36 (9), 1099-1110

Brown, I.D., (1967) Measurement of control skills, vigilance, and performance on a subsidiary task during 12 hours of car driving. Ergonomics, 10, 665-673.

Coles, M. and Sirevaag, E. (1987) Heart rate and sinus arrhythmia. In: A. Gale and B. Christie (Eds) Psychophysiology and the electronic workplace. Chichester: John Wiley and Sons.

Davies, D.R., Schackleton, V.J. and Parasuraman, R. (1983) Monotony and boredom. In R. Hockey (Ed.) Stress and Fatigue in Human Performance. Chichester: John Wiley.

De Vries-Griever A.H.G. and Meijman, Th.F. (1987) The impact of abnormal hours of work on various modes of information processing: a process model on human costs of performance. Ergonomics, 30 1287-1299.

Dinges, D. and Graeber, R. (1989) Crew fatigue monitoring. Flight Safety Foundation, Flight Safety Digest, October.

Egelund, N. (1982) Spectral analysis of heart rate variability as an indicator of driver fatigue. Ergonomics, 25, 663-672.

Fagerstrom K.O, and Lisper, H.O. (1977) Effects of listening to car radio, experience, and personality of the driver subsidiary reaction time and heart rate in a long-term driving task. In R.R. Mackie (Ed) Vigilance: Theory, operational performance, and physiological correlates. New York: Plenum Press.

Feyer, A-M., Williamson, A.M., Jenkin, R.A. and Higgins, T (1993) Strategies to combat fatigue in the long distance road transport industry. The bus and coach perspective. Report No CR 122, Canberra: Federal Office of Road Safety.

Folkard, S., and Monk, T.H. (1979) Shiftwork and performance. Human Factors, 21, 483-492.

Frese, M. and Harwich, C. (1984) Shiftwork and the length and quality of sleep. Journal of Medicine, 26 (8), 561-566.

Hamelin, P. (1987) Lorry Drivers' time habits in work and their involvement in traffic accidents. Paper presented at Second CEC workshop on 'Irregular and Abnormal Hours of Work', Brighton, January, 16-18.

Harms, L. (1991) Variations in drivers' cognitive load. Effects of driving through village areas and rural junctions. Ergonomics, 34, 151-160.

Harris, W., and Mackie, R.R. (1987) A study of the relationships among fatigue, hours of service and safety of operations of truck and bus drivers. Report 1727-2, Goleta, California: Human Factors Research Inc.

Haworth, N.L., Heffernan, C.J. and Horne, E.J. (1989) Fatigue in truck crashes. Report No.3, Melbourne: Monash University Crash Research Centre.

Haworth, N.L., Triggs, T.J. and Grey, E.M. (1988) Driver fatigue: Concepts, measurement and accident countermeasures. Report No. CR 72, Canberra: Federal Office of Road Safety.

Hebb, D.O. (1955) Drives and the CNS (conceptual nervous system). Psychological Review, 62, 243-254.

Hoddes, E., Zarcone, V., Smythe, H., Phillips, R. and Dement, W.C. (1973) Quantification of sleepiness: A new approach. Psychophysiology, 10, 431-436.

Hyppa, M.T., Kronholm, E. and Mattlar, C.E. (1991) Mental well being of sleepers in a random population sample. British Journal of Medical Psychology, 64, 25-34

Johns, M. (1991) A new method for measuring daytime sleepiness: The Epworth Sleepiness Scale. Sleep, 14(6), 540-545.

Johns, M. (1992) Reliability and factor analysis of the Epworth Sleepiness Scale. Sleep, 15 (4), 376-381.

Jones, I.S., and Stein, H.S. (1987) Effect of Driver Hours of Service on Tractor-trailer Crash Involvement. Arlington, VA: Insurance Institute for Highway Safety.

Kantowitz, B.H. (1992) Heavy vehicle driver workload assessment: Lessons from aviation. Proceedings of the Human Factors Society 36th Annual Meeting, 1113-1117.

Kecklund, G., and Akerstedt, T. (1993) Sleepiness in long distance truck driving: an ambulatory EEG study of night driving. Ergonomics, 36(9), 1007-1017.

Koller, M. (1983) Health risks related to shift work. International Archive of Occupational and Environmental Health, 53, 59-75.

Krueger,G.P. (1989) Sustained work, fatigue, sleep loss and performance: A review of the issues. Work and Stress, 3(2), 129-141.

Laurell, H. and Lisper, H.O. (1978) A validation of subsidiary reaction time against detection of roadside obstacles during prolonged driving. Ergonomics, 21 (2), 81-88.

Lisper, H.O., Laurell, H. and Stening, G(1976) Effects of experience of the driver on heart-rate, respiration-rate, and subsidiary reaction time in a three hours continuous driving task. Ergonomics, 16 (4), 501-506.

Lisper, H.O., Laurell, H. and Van Loon, J. (1986) Relation between time to falling asleep behind the wheel on a closed track and changes in subsidiary reaction time during prolonged driving on a motorway. Ergonomics, 16, 501-506.

Mackie, R. and Wylie, C. (1991) Countermeasures to loss of alertness in motor vehicle drivers: A taxonomy and evaluation. Proceedings of the Human Factors Society 35th Annual Meeting, 1149-1153.

Mackie, R.R. and Miller, J.C. (1978) Effects of hours of service, regularity of schedules, and cargo loading on truck and bus driver fatigue. Report No DOT-HS-5-01142, Goleta, CA: Human Factors Research Inc.

Mascord, D.J. and Heath, R.A. (1992) Behavioural and physiological indices of fatigue in visual tracking task. Journal of Safety Research, 23, 19-25.

McDonald, N. (1984) Fatigue, safety and the truck driver. London: Taylor and Francis.

Monk, T.H and Folkard, S. (1985) Shiftwork and performance. In: S. Folkard and T.H. Monk (Eds) Hours of work. Chichester: John Wiley and Sons.

Moore-Ede, M., Campbell, S., and Baker, T.(1988) Falling Asleep Behind the Wheel: Research Priorities to Improve Driver Alertness and Highway Safety. In: Proceedings of Federal Highway Administration Symposium on Truck and Bus Driver Fatigue. November 29-30.

Propok, O and Propok, L. (1955) Ermudung und einschlafen am steurer (Fatigue and falling asleep in driving). Deutsche Z. Gerichliche Med., 44, 343-355.

Raggatt, P.T.F. (1991) Work stress among long distance coach drivers: a survey and correlational study Journal of Organisational Behaviour, 12, 565-579.

Ranney, T and Gawron, V.J. (1987) Driving performance as a function of time on the road. Proceedings of the Human Factors Society, 31st Annual Meeting.

Rosa, R. and Colligen, M. (1992) Application of a portable test battery in the assessment of fatigue in laboratory and worksite studies of 12-hour shifts. Scandinavian Journal of Work Environmental Health, 18 (2), 113-115.

Roscoe, A. (1993) Heart rate as a psychophysiological measure for in-flight workload assessment. Ergonomics, 36(9), 1055-1062.

Seko, Y., Kataoka, S. and Senoo, T. (1986) Analysis of driving behaviour under a state of reduced alertness. International Journal of Vehicle Design, Special Issue on Vehicle Safety.

Shiffrin, R. and Schnieder, W. (1977) Controlled and automatic human information processing: II Perceptual learning, automatic attending, and a general theory. Psychological Review, 84, 127-190.

Smith, J. and Jex, H. (1986) Operational manual critical task tester MK 10. Hawthorne, CA: Systems Technology, Inc.

Spencer, M.B. (1987) The influence of irregularity of rest and activity on performance: A model based on time since sleep and time of day. Ergonomics,

Telford, D. (1991) Health and fitness- Some thoughts. In National Road Transport Accreditation Conference, 'Papers and Conclusions'. Melbourne, January 19-20.

Torsvall, L. and Akerstedt, T.,(1993) Sleepiness on the job: continuously measured EEG changes in train drivers, Encephalography and Clinical Neurophysiology, 66, 502-511.

Van Ouwerkerk, F. (1987) Relationships between road transport working conditions, fatigue, health and traffic safety. Report No VK 87-01, Haren, The Netherlands: Traffic Research Centre, University of Groningen.

Vicente, K., Thornton, D. and Moray, N (1987) Spectral analysis of sinus arrhythmia: A measure of mental effort. Human Factors, 29 (2), 171-182.

Warm, J.S.(Ed) (1984) Sustained attention in human performance. New York: John Wiley and Sons.

Wickens, C.D. (1984) Processing resources in attention. In R Parasuraman and D.R.Davies (Eds) Varieties of attention. Orlando: Academic Press.

Williamson, A.M., Feyer, A-M., Coumarelos, C. and Jenkins, A. (1992) Strategies to combat fatigue in the long distance road transport industry. Stage 1: the industry perspective. FORS Report No CR 108, Canberra: Federal Office of Road Safety.

Wilson, J.R. and Corlett, E.N. (1991) Evaluation of human work: a practical ergonomics methodology. London: Taylor an Francis.

APPENDICES

Appendix 1

Subjective scales:

(i) Stanford Sleepiness Scale

(ii) Visual Analogue Scales

A. Here are some descriptions of how alert or sleepy you might be feeling right now.

Please read them carefully and then **CIRCLE** the number that best corresponds to the statement describing how you feel at the moment.

Remember - Only circle **ONE** option.

1 Feeling active and vital.
Alert and wide awake.

2 Functioning at a high level, but not at peak
Able to concentrate.

3 Relaxed and awake but not at full alertness.
Responsive.

4 A little foggy, not at peak.
Let down.

5 More foggy.
Beginning to lose interest in staying awake.
Slowed down.

6 Very sleepy, fighting sleep, woozy.
Prefer to be lying down.

7 Almost asleep.
Lost struggle to remain awake.

B. On each of the following scales, please draw a cross at the point which most closely describes how you are feeling NOW.

e.g. happy —————————————————— sad

This response would indicate that you are feeling more happy than sad

1 fresh —————————————————— tired

2. clear headed —————————————————— muzzy headed

3 very alert —————————————————— very drowsy

Code number: / /

TRUCK DRIVER'S TRIP DIARY

DRIVER FATIGUE STUDY

Worksafe Australia
National Commission of Occupational Health and Safety
Sydney
Australia

1993

Code # / /

Trip Route

Where did you start this trip ? ____________________
____

Where will you finish ? ____________________
____

Departure time:

date: ________ time: ____________am/pm

ETA:

date: ________ time: ____________am/pm

Do you have any stops planned along the way ?

Yes ( )
No ( )

If **YES,**

	Where ?	**What time ?**
Stop 1	____________________	________am/pm
Stop 2	____________________	________am/pm
Stop 3	____________________	________am/pm
Stop 4	____________________	________am/pm

Load:

What freight are you carrying ?

Contents: ______________________________
____

Is this your usual sort of freight ?

Yes	( )
No	( )

If **NO,**

What is your **USUAL** freight ? ____________________
____

Did you load it or help to load it yourself ?

Yes	( )
No	( )

How long did it take ? ________hours

Who will unload it ? ____________________
____

Trip diary

Please answer the following questions about your sleep, food and drink intake in the **12 hours** before your trip.

Where appropriate **CIRCLE** or **TICK** the correct response

1. **How many hours sleep did you have before you started work ?**

   _______ hours

2. **How long before you started work was that sleep ?**

   _______ hours

3. **Did you eat or drink (non-alcoholic drinks) in the 12 hours before starting work?**

   Yes ( )
   No ( )

If YES,

Please list what you ate and drank (excluding alcoholic drinks) over the twelve hours before you started work and the approximate time you did so.

Food/drink	**Time**
______________________	___________am/pm
______________________	___________am/pm
______________________	___________am/pm
______________________	___________am/pm
______________________	___________am/pm

4. **Did you drink alcohol in the 12 hours before starting work ?**

Yes	( )
No	( )

If **YES,**

When did you last drink alcohol ? ________**am/pm**

What alcohol did you drink ?
(please tick, you may tick **more than** one option)

beer	( )
wine	( )
spirits	( )

How much alcohol did you drink ?

______drinks

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

5. **Did you take any medications in the 12 hours before starting work ?**

Yes	( )
No	( )

If YES,

What medications ? ______________________________

____

And at what time ________am/pm

6. **Did you take any pills to help you stay awake in the 12 hours before starting work ?**

Yes	( )
No	( )

If YES,

What did you take ? ______________________________

____

And at what time ________am/pm

Current Trip Diary

In exactly the same way as you filled out a diary for a seven day period, we would like you to fill out this diary for the **CURRENT** trip.

We would like you to indicate on the following page when you start and finish work, when you start and finish driving stints, any breaks you take, either from driving and/or work and how long they are, and whether you eat, drink or sleep during the trip.

All the information will be kept **CONFIDENTIAL** and **ANONYMOUS**. It is not intended to check up on you just to provide us with information about what you were doing during the trip.

Immediately before the current diary sheet for you to fill out there is an example sheet to give you an idea of the sort of information we require.

After the diary page there are some questions about what you do during the trip. In particular we are interested in whether you eat or drink during the trip (ie. while driving) and in what you do during your breaks.

Remember to fill out ONE set of break questions for EVERY break you take on the trip

If you have any problems with any of the questions or with any of the equipment during the trip, please ring David Leslie, Anne-Marie Feyer or Ann Williamson on

008 25 2226

(it is a free call)

THANK YOU FOR YOUR COOPERATION

EXAMPLE OF CURRENT DIARY

Date: 1·07·93
Starting point: SYDNEY
Finishing point: SYDNEY
Route: SYDNEY — Tarcutta - SYDNEY

	WORKING	DRIVING	EATING	SLEEPING
MIDNIGHT				↓
01:00				
02:00				
03:00				↓
04:00			4·30 Breakfast	4·10 Got Up
05:00	Started Work	5·15 Started Driving		
06:00	↓	↓		
07:00			7·30 Snack and Drink	
08:00				
09:00		↓		
10:00		10·20 - Finished Driving	10·30 Meal in Break	
11:00		Started Driving		
12:00		↓		
13:00				
14:00				
15:00		↓		
16:00		16·10 Finished Driving	16·30 Meal in Break	
17:00		Started Driving		
18:00	↓	18·50 Finished Driving		
19:00	19·35 Finished Work			
20:00			Dinner	
21:00				
22:00				Sleep
23:00				↓

Now fill out the sheet following this one with today's activities

CURRENT DIARY

Date: ____________
Starting point: ____________
Finishing point: ____________
Route: ______________________________

	WORKING	DRIVING	EATING	SLEEPING
MIDNIGHT				
01:00				
02:00				
03:00				
04:00				
05:00				
06:00				
07:00				
08:00				
09:00				
10:00				
11:00				
12:00				
13:00				
14:00				
15:00				
16:00				
17:00				
18:00				
19:00				
20:00				
21:00				
22:00				
23:00				

<u>**Details of activities during CURRENT trip**</u>

1. Did you eat **while driving** ?

   Yes ( )
   No ( )

   If YES,

   What did you eat ? ____________________
   ____

2. Did you drink **while driving** ?

   Yes ( )
   No ( )

   If **YES**,

   What did you drink ? ____________________
   ____

3. Did you take any pills **during this trip** to help you stay awake ?

   Yes ( )
   No ( )

   If **YES**,

   What pills did you take ? ____________________
   ____

Break Activities on CURRENT trip

Please answer the following questions about your sleep and food and drink intake **during the breaks** you took on your trip.

Fill out **ONE** set of questions for **EACH** and **EVERY** break

Please fill out the questions asking about how drowsy or alert you are feeling at the **START** of **EACH** break

Where appropriate **CIRCLE** the correct response

Questions for each break are on the same coloured paper.

Fill out all the **GREEN** pages for **BREAK NUMBER ONE**,
the **YELLOW** ones for **BREAK NUMBER TWO**,
the **BLUE** ones for **BREAK NUMBER THREE**
and the **PINK** ones for **BREAK NUMBER FOUR**.

THANK YOU FOR YOUR HELP

BREAK NUMBER ONE

A. Here are some descriptions of how alert or sleepy you might be feeling right now.

Please read them carefully and then **CIRCLE** the number that best corresponds to the statement describing how you feel at the moment.

Remember - Only circle **ONE** option.

1 Feeling active and vital.
Alert and wide awake.

2 Functioning at a high level, but not at peak
Able to concentrate.

3 Relaxed and awake but not at full alertness.
Responsive.

4 A little foggy, not at peak.
Let down.

5 More foggy.
Beginning to lose interest in staying awake.
Slowed down.

6 Very sleepy, fighting sleep, woozy.
Prefer to be lying down.

7 Almost asleep.
Lost struggle to remain awake.

B. On each of the following scales, please draw a cross at the point which most closely describes how you are feeling NOW.

e.g. happy ———————————————— sad

This response would indicate that you are feeling more happy than sad

1. **fresh** ———————————————— **tired**

2. **clear headed** ———————————————— **muzzy headed**

3. **very alert** ———————————————— **very drowsy**

BREAK LOG - BREAK NUMBER ONE

1. What time did you take a break ? ______am/pm

2. Where did you take the break ?

   ____

   ____

3. How long was the break ? ______hours

4. What did you do in the break ?
   (please tick any appropriate answer(s) you may tick more than one option)

   Did you:

   EAT ( ) What did you eat ? ____________________

   ____

   DRINK ( ) What did you drink ? ____________________

   ____

   SLEEP ( ) For how long ? ____hours

   EXERCISE ( ) For how long ? ____hours

   TAKE
   MEDICATIONS ( ) What medications ? ____________________

   ____

   TAKE STAY-AWAKE
   PILLS ? ( ) What pills ? ____________________

   ____

   SHOWER ( )

   LOAD/UNLOAD ( ) How long did it take ? ______hours

BREAK NUMBER TWO

A. Here are some descriptions of how alert or sleepy you might be feeling right now.

Please read them carefully and then **CIRCLE** the number that best corresponds to the statement describing how you feel at the moment.

Remember - Only circle **ONE** option.

1 Feeling active and vital.
Alert and wide awake.

2 Functioning at a high level, but not at peak
Able to concentrate.

3 Relaxed and awake but not at full alertness.
Responsive.

4 A little foggy, not at peak.
Let down

5 More foggy.
Beginning to lose interest in staying awake.
Slowed down.

6 Very sleepy, fighting sleep, woozy.
Prefer to be lying down.

7 Almost asleep.
Lost struggle to remain awake.

B. On each of the following scales, please draw a cross at the point which most closely describes how you are feeling NOW.

e g. happy —————————————————— sad

This response would indicate that you are feeling more happy than sad

1 **fresh** —————————————————— **tired**

2. **clear headed** —————————————————— **muzzy headed**

3. **very alert** —————————————————— **very drowsy**

BREAK LOG - BREAK NUMBER TWO

1. What time did you take a break ? _______am/pm

2. Where did you take the break ?

____

____

3. How long was the break ? _______hours

4. What did you do in the break ?
(please tick any appropriate answer(s) you may tick more than one option)

Did you:

EAT	( )	What did you eat ?	_______________________
			_______________________
DRINK	( )	What did you drink ?	_______________________
			_______________________
SLEEP	( )	For how long ?	_____hours
EXERCISE	( )	For how long ?	_____hours
TAKE MEDICATIONS	( )	What medications ?	_______________________
			_______________________
TAKE STAY-AWAKE PILLS ?	( )	What pills ?	_______________________
			_______________________
SHOWER	( )		
LOAD/UNLOAD	( )	How long did it take ?	______hours

BREAK NUMBER THREE

A. Here are some descriptions of how alert or sleepy you might be feeling right now.

Please read them carefully and then **CIRCLE** the number that best corresponds to the statement describing how you feel at the moment.

Remember - Only circle **ONE** option.

1 Feeling active and vital.
Alert and wide awake.

2 Functioning at a high level, but not at peak
Able to concentrate.

3 Relaxed and awake but not at full alertness.
Responsive.

4 A little foggy, not at peak.
Let down

5 More foggy.
Beginning to lose interest in staying awake.
Slowed down.

6 Very sleepy, fighting sleep, woozy.
Prefer to be lying down

7 Almost asleep.
Lost struggle to remain awake.

B. On each of the following scales. please draw a cross at the point which most closely describes how you are feeling NOW.

e.g. happy ———————————————— sad
This response would indicate that you are feeling more happy than sad

1. **fresh** ———————————————— **tired**

2. **clear headed** ———————————————— **muzzy headed**

3. **very alert** ———————————————— **very drowsy**

BREAK LOG - BREAK NUMBER THREE

1. What time did you take a break ? ______am/pm

2. Where did you take the break ?

   ____

   ____

3. **How long was the break ?** ______hours

4. **What did you do in the break ?**

   (please tick any appropriate answer(s) you may tick more than one option)

   Did you:

EAT	( )	What did you eat ?	____________________ ____________________
DRINK	( )	What did you drink ?	____________________ ____________________
SLEEP	( )	For how long ?	____hours
EXERCISE	( )	For how long ?	____hours
TAKE MEDICATIONS	( )	What medications ?	____________________ ____________________
TAKE STAY-AWAKE PILLS ?	( )	What pills ?	____________________ ____________________
SHOWER	( )		
LOAD/UNLOAD	( )	How long did it take ?	______hours

BREAK NUMBER FOUR

A. Here are some descriptions of how alert or sleepy you might be feeling right now.

Please read them carefully and then **CIRCLE** the number that best corresponds to the statement describing how you feel at the moment.

Remember - Only circle **ONE** option.

1 Feeling active and vital.
Alert and wide awake.

2 Functioning at a high level, but not at peak
Able to concentrate.

3 Relaxed and awake but not at full alertness.
Responsive.

4 A little foggy, not at peak.
Let down.

5 More foggy.
Beginning to lose interest in staying awake.
Slowed down.

6 Very sleepy, fighting sleep, woozy.
Prefer to be lying down.

7 Almost asleep.
Lost struggle to remain awake.

B. On each of the following scales, please draw a cross at the point which most closely describes how you are feeling NOW.

e.g. happy ———————————————— sad
This response would indicate that you are feeling more happy than sad

1. **fresh** ———————————————— **tired**

2. **clear headed** ———————————————— **muzzy headed**

3. **very alert** ———————————————— **very drowsy**

BREAK LOG - BREAK NUMBER FOUR

1. What time did you take a break ? ______am/pm

2. Where did you take the break ? ____________________ ____________________

3. **How long was this break ?** ______hours

4. **What did you do in the break ?**
(please tick any appropriate answer(s) you may tick more than one option)

Did you:

EAT ( ) What did you eat ? ____________________ ____________________

DRINK ( ) What did you drink ? ____________________ ____________________

SLEEP ( ) For how long ? ____hours

EXERCISE ( ) For how long ? ____hours

TAKE MEDICATIONS ( ) What medications ? ____________________ ____________________

TAKE STAY-AWAKE PILLS ? ( ) What pills ? ____________________ ____________________

SHOWER ( )

LOAD/UNLOAD ( ) How long did it take ? ______hours

Appendix 3

Work and health history.

Code number: / /

TRUCK DRIVER'S WORK HISTORY

DRIVER FATIGUE STUDY

Worksafe Australia
National Commission of Occupational Health and Safety
Sydney
Australia

1993

Activities in Last Week

As part of our study of driver fatigue, we are interested in finding out more about your work and rest activities.

We would like to know approximately what work, rest and driving you will do over the next SEVEN DAYS

On the following pages you will find a diary. Please fill in as accurately as possible when you work and drive, when you take breaks from either driving or working, when you sleep and when you eat in the appropriate columns of the diary.

We would like you to do this for **all** seven days even rest days or days off.

The first page is an example diary sheet showing how we would like you to fill in the blank diary sheets.

THANK YOU FOR YOUR CO-OPERATION

EXAMPLE OF DAILY DIARY

Date: 2.7.93
Starting point: SYDNEY
Finishing point: SYDNEY
Route: SYDNEY–Tarcutta–SYDNEY

	WORKING	DRIVING	EATING	SLEEPING
MIDNIGHT				
01:00				
02:00				
03:00				
04:00				4.15 Got Up
05:00	Started Work	5.30 Started Driving	Breakfast	
06:00				
07:00				
08:00				
09:00				
10:00		10.20 Finished Driving		
11:00		Started Driving		
12:00				
13:00				
14:00				
15:00				
16:00		Finished Driving		
17:00		Started Driving		
18:00		18.45 Finished Driving		
19:00	19.30 Finished Work			
20:00				
21:00				
22:00				22.10 Sleep
23:00				

Now fill in the following pages detailing your activities for the last SEVEN days

Code Number / /

DAY ONE DIARY

Date: ____________
Starting point: ____________
Finishing point: ____________
Route: ______________________________

	WORKING	DRIVING	EATING	SLEEPING
MIDNIGHT				
01:00				
02:00				
03:00				
04:00				
05:00				
06:00				
07:00				
08:00				
09:00				
10:00				
11:00				
12:00				
13:00				
14:00				
15:00				
16:00				
17:00				
18:00				
19:00				
20:00				
21:00				
22:00				
23:00				

DAY TWO DIARY

Date: ____________
Starting point: ____________
Finishing point: ____________
Route: ____________________________

	WORKING	DRIVING	EATING	SLEEPING
MIDNIGHT				
01:00				
02:00				
03:00				
04:00				
05:00				
06:00				
07:00				
08:00				
09:00				
10:00				
11:00				
12:00				
13:00				
14:00				
15:00				
16:00				
17:00				
18:00				
19:00				
20:00				
21:00				
22:00				
23:00				

DAY THREE DIARY

Date: __________
Starting point: __________
Finishing point: __________
Route: ____________________

	WORKING	DRIVING	EATING	SLEEPING
MIDNIGHT				
01:00				
02:00				
03:00				
04:00				
05:00				
06:00				
07:00				
08:00				
09:00				
10:00				
11:00				
12:00				
13:00				
14:00				
15:00				
16:00				
17:00				
18:00				
19:00				
20:00				
21:00				
22:00				
23:00				

DAY FOUR DIARY

Date: ______________
Starting point: ______________
Finishing point: ______________
Route: ______________________________

	WORKING	DRIVING	EATING	SLEEPING
MIDNIGHT				
01:00				
02:00				
03:00				
04:00				
05:00				
06:00				
07:00				
08:00				
09:00				
10:00				
11:00				
12:00				
13:00				
14:00				
15:00				
16:00				
17:00				
18:00				
19:00				
20:00				
21:00				
22:00				
23:00				

DAY FIVE DIARY

Date: ______________
Starting point: ______________
Finishing point: ______________
Route: ______________________________

	WORKING	DRIVING	EATING	SLEEPING
MIDNIGHT				
01:00				
02:00				
03:00				
04:00				
05:00				
06:00				
07:00				
08:00				
09:00				
10:00				
11:00				
12:00				
13:00				
14:00				
15:00				
16:00				
17:00				
18:00				
19:00				
20:00				
21:00				
22:00				
23:00				

DAY SIX DIARY

Date: ______________

Starting point: ______________

Finishing point: ______________

Route: ______________________________

	WORKING	DRIVING	EATING	SLEEPING
MIDNIGHT				
01:00				
02:00				
03:00				
04:00				
05:00				
06:00				
07:00				
08:00				
09:00				
10:00				
11:00				
12:00				
13:00				
14:00				
15:00				
16:00				
17:00				
18:00				
19:00				
20:00				
21:00				
22:00				
23:00				

DAY SEVEN DIARY

Date: ____________

Starting point: ____________

Finishing point: ____________

Route: ____________________________

	WORKING	DRIVING	EATING	SLEEPING
MIDNIGHT				
01:00				
02:00				
03:00				
04:00				
05:00				
06:00				
07:00				
08:00				
09:00				
10:00				
11:00				
12:00				
13:00				
14:00				
15:00				
16:00				
17:00				
18:00				
19:00				
20:00				
21:00				
22:00				
23:00				

Code number: / /

TRUCK DRIVER'S HEALTH HISTORY

DRIVER FATIGUE STUDY

Worksafe Australia
National Commission of Occupational Health and Safety
Sydney
Australia

1993

Truck Driver Survey

As part of our research on how to best manage fatigue in the long distance road transport industry, we need to find out a bit more information about the drivers participating in our trial runs. In particular we need to know about who drivers are, whether they are married, how healthy they are, whether they suffer any sleep problems, what sort of trucks they drive and how long they have been working in the industry.

As you have agreed to participate in our study, we need to know more about these sorts of topics in your life.

All the information you give to us will be **CONFIDENTIAL** and you will be assigned a code number so that we do not need to keep your name on file. Once we have finished the study, we will remove all identification so that the information will be **ANONYMOUS**.

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

If you have any problems with the information or the questions please feel free to call David Leslie, Anne-Marie Feyer or Ann Williamson on this number **008 25 2226** (it is a free call)

THANK YOU FOR YOUR HELP

Code number: / /

How old are you ? _____

Please tick

Are you married ? ( )
living in a defacto arrangement ? ( )
single ? ( )

What is your home base postcode ?

____

What is your telephone number ?
(In case we need to contact you for the duration of the study)

work: ______________
home: ______________

Are you an employee driver ? Yes ( )
No ( )

If YES,

How many trucks does the company you drive for operate ?

Please tick

Fewer than 5 trucks ( )
Between 5 and 10 trucks ( )
Between 11 and 50 trucks ( )
More than 50 trucks ( )

Are you an owner-driver ?

	Yes	( )
	No	( )

If YES, how many trucks do you own ? ________trucks

If you are an owner-driver, are you a

	Please tick
Prime contractor	( )
Painted subcontractor	( )
Freelance subcontractor	( )
Freelance owner-driver	( )
Other (please describe)	________________________
	________________________

If you are an owner-driver, do you drive mainly for one company ?

Yes	( )
No	( )

If you are an owner-driver and drive mainly for one company, how many trucks does the company operate ?

	Please tick
Fewer than 5 trucks	( )
Between 5 and 10 trucks	( )
Between 11 and 50 trucks	( )
More than 50 trucks	( )

How long have you been driving a truck for a living ?

________years

Truck description: model ____________________

size: ____________________

In the last twelve months, have you suffered any serious medical conditions (not colds or flu) which have resulted in you having to take time off work ?

Yes	( )
No	( )

If YES,

What medical condition(s) ? ____________________
____

Are you taking any medication for this condition ?

Yes	( )
No	( )

How long did you take off work ?

	Please tick
less than one week	( )
1 - 4 weeks	( )
more than one month	( )

Do you have any of the following medical problems ?

	Please tick	Please tick if you take medications for it ?
Diabetes	( )	( )
Asthma/Hayfever	( )	( )
Stomach or digestive problems	( )	( )
Sleep problems	( )	( )
Heart or circulation problems eg. angina or high blood pressure	( )	( )
Headaches or migraine	( )	( )

Do you smoke cigarettes ?

Yes	( )
No	( )

If YES,

How many cigarettes do you smoke on average per day ?

_______cigarettes

When you are sleeping, how often do you do the following or has someone told you that you do the following ?

Please tick one option

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

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

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 that 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 the traffic	____

Do you have difficulty getting to sleep ?

Yes	( )
No	( )

Do you have difficulty staying asleep once you are asleep ?

Yes	( )
No	( )

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

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

Have you had your adenoids removed ?

Yes	( )
No	( )

Do you drink alcohol ?

Yes	( )
No	( )

If YES,

What sort of alcohol do you usually drink ?
(please tick, you may tick more than one option)

beer	( )
wine	( )
spirits	( )

How much of the alcohol you usually drink, do you drink at one time ? (please tick closest estimation)

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

one drink	( )
2-3 drinks	( )
4-5 drinks	( )
more than 5 drinks	( )

How often do you usually drink alcohol ?

	Please tick
every day	( )
2-3 times a week	( )
once a week	( )
1-2 times a month	( )
rarely	( )

Do you take regular exercise ?

Yes	( )
No	( )

If YES,

How often ?

	please tick
daily	( )
2-3 times/week	( )
weekly	( )
fortnightly	( )
less than once a month	( )

Do you take any pills to help you to stay awake while driving ?

Yes	( )
No	( )

If YES,

What pill/s do you take ? ______________________

____

How often do you take these ?

	Please tick
on every trip	( )
on most trips	( )
on about half of trips	( )
less than half of trips	( )
only occasionally	( )

Appendix 4

Participant information and authorisation.

PARTICIPANT INFORMATION AND CONSENT FORM

STUDY OF STRATEGIES TO COMBAT DRIVER FATIGUE IN THE LONG DISTANCE ROAD TRANSPORT INDUSTRY

Worksafe Australia
National Commission of Occupational
Health and Safety
Sydney
Australia

1993

Background to the study

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 covered. Worksafe Australia is doing a study of ways that might help drivers reduce the amount of fatigue that they experience while driving. The study will compare different ways of organising trips to see how well they reduce driver fatigue. **We would like to invite you to take part in this study.**

What is involved?

You will be asked to drive three trips between Sydney and Melbourne. One trip will be staged. The other two will be one-way trips. On one of these, we would like you to take your breaks according to the regulations, but on the other trip, we would like you to take your breaks when you feel you need them.

We are interested in how alert you are during both trips, and will measure this in a number of ways. At the beginning, middle, and end of each trip, we will ask you to tell us how you feel and to perform some simple reaction time tests to give us an idea of how fresh you are mentally.

During the trip, we will measure your heart rate using a lightweight belt that clips around your chest. We will also measure your natural pattern of blinking by video-taping your face throughout the trip. Additionally, we will measure your spoken reaction time at occasional intervals during the trip. A small microphone will be clipped to your clothes, to record your response. The microphone will only record during the response tests and will not be on continuously.

We also wish to look at changes in your driving style across each trip by measuring your steering patterns and speed. You won't need to do anything for these measures - we will get them straight from the vehicle.

Lastly, we are interested in the trips you have done in the last week or so, and in the stops that you make during the study trips. We will ask you to fill out short questionnaires about these things.

All this measuring will involve about 20-30 minutes of your time at the beginning, at the middle, and again at the end of the trip.

All the information you provide will be kept confidential and anonymous. In fact, once we have collected all the information about the trips, we won't be keeping your name at all. Both your employer and the union have indicated their support for the study. In addition, the N.S.W. R.T.A. will provide a letter of authority to cover your unregulated trip.

If you have any questions about the study, please feel free to contact one of the study team.

Study team:

Ann Williamson (02) 5659 311
David Leslie (02) 5659 392
Anne-Marie Feyer (02) 5659 313
Rena Friswell (02) 5659 562

Consent Form

You are invited to participate in the study of the effect of trip organisation on fatigue in long distance drivers. If you wish to participate, please complete the consent form below.

I, ________________ __________, agree to participate in the Study of Strategies to Combat Driver Fatigue in the Long Distance Road Transport Industry, being undertaken by Worksafe Australia.

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

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

______________________ ________________

(Signature) (Date)

______________________ ________________

(Name of Witness) (Signature of Witness)

WORKSAFE AUSTRALIA
NATIONAL OCCUPATIONAL
HEALTH & SAFETY
COMMISSION

RESEARCH PROJECT ON DRIVER FATIGUE

The Federal Government in the form of the Federal Office of Road Safety and Worksafe Australia are currently undertaking a study of driver fatigue in order to improve safety on Australian roads.

For a short period, this driver is involved in an official project which may find him working outside working hours regulations. The purpose of this trial is to find out the best ways for professional drivers to manage their fatigue from driving. This project has been discussed with the NSW Road and Traffic Authority and the NSW Police. An exemption is attached from the Road and Traffic Authority for the rest break regulation for the trip being studied.

If the logbook for this driver is examined during this trip this information should be taken into consideration.

Driver's name: ______________________________

Trip details: From ___________________________

To ___________________________

Date: ______________________________________

Your cooperation in the success of this project is appreciated. If you want further information about this project please call the Project Coordinators at Worksafe Australia on (02) 565 9555.

Dr Anne-Marie Feyer Dr Ann Williamson

Project Coordinators

92 PARRAMATTA ROAD, CAMPERDOWN NSW 2050
GPO BOX 58, SYDNEY NSW 2001
TELEPHONE (02) 565 9555 FAX (02) 565 9202 TELEX 177243

WORKSAFE AUSTRALIA
NATIONAL OCCUPATIONAL HEALTH & SAFETY COMMISSION

NATIONAL INSTITUTE OF OCCUPATIONAL HEALTH & SAFETY

Study of strategies to combat driver fatigue in the long distance road transport industry.

Driver fatigue is a major safety issue in the long distance road transport industry mainly because of the long distances that have to be covered in Australia. Worksafe Australia is doing a study of how to help drivers reduce the amount of fatigue they experience while driving.

In the first part of the study, we surveyed nearly 1000 truck drivers in order to find out their opinions about the problem of fatigue and what they thought could be done about it. The attached brochure gives some details for your information about what was found in that part of the study.

We are about to start the second part of the study, and **we would like to invite you to take part in this.** This will involve comparing how well different ways of organising trips help to reduce driver fatigue.

What is involved?

You will be asked to drive a staged trip between Sydney and Melbourne, just the way you normally do. You will also be asked to do a trip which is not staged, that is driving straight through between Melbourne and Sydney.

We are interested in finding out how alert you are during both trips. We will measure this in a number of ways. At the beginning, middle, and end of each trip we will ask you tell us how you feel and to perform some reaction time tests to give us an idea of how fresh you are mentally.

During the trip we will measure your heart rate using a small device clipped onto your earlobe at the beginning of the trip. We will also measure your body's natural pattern of blinking by video-taping your face throughout the trip.

Additionally we wish to look at changes in your driving style across each trip by measuring your steering patterns and speed. You wont need to do anything for these measures - we will get them straight from the vehicle.

We are also interested in the trips you have done in the last week or so, including details of stops you make on the trips that we are assessing. We will get you to fill out a questionnaire about this at the end of your trip.

How much time will it take?

All this measuring will involve about 20 minutes at the beginning of the trip, about twenty minutes if you have a break during the trip, and another twenty minutes at the end of the trip.

All information you give us will be kept confidential. In fact, once we have collected all the information about both trips, we wont be keeping your name at all. Your employer has agreed to allow you to take part in the study and the union has indicated its support as well.

Please do not hesitate to contact one of the study team if you have any questions about the study.

Study Team: Ann Williamson (02-565 9311); Anne-Marie Feyer (02-565 9313); David Leslie (02-565 9392); Rena Friswell (02-565 9562).

Mailing address
GPO BOX 58
SYDNEY NSW 2001
AUSTRALIA

Visiting address
92 Parramatta Road
CAMPERDOWN NSW 2050
AUSTRALIA

Telecommunications
Telephone (02) 565 9555
Fax. (02) 565 9202
Telex: 177243

Roads and Traffic
Authority

RTA

Triplet27
LB247
CE93/183

260 Elizabeth Street
Surry Hills
New South Wales 2010
Telephone (02) 218 6888
PO Box K198
Haymarket NSW 2000
DX 13 Sydney

To Whom It May Concern

Mr , Transport Driver, employed by is participating in a special controlled study in strategies to combat fatigue in the long distance transport industry.

This study is being conducted by Worksafe Australia and has the support of the New South Wales Roads and Traffic Authority.

, is exempt from the provisions of NSW Motor Traffic Regulation 126A(1) (which provides for a rest period of at least 30 minutes after 5 hours of driving) while driving vehicle registration number SOU 537 for a single journey departing Melbourne at 6PM on Tuesday 16 November, 1993 and concluding in Sydney on Wednesday 17 November, 1993.

This letter is not valid other than for the specific journey referred to and must be produced in conjunction with a trip authority letter from Worksafe Australia when a logbook is requested by the Police or RTA enforcement officers.

Frank Howarth
General Manager
Vehicle Registration

15 November, 1993

Appendix 5

Slopes and intercepts for lines of best fit.

TABLE 1A: Slopes and intercepts for lines of best fit for interbeat interval and interbeat variability at the beginning and end of each trip type.

	BEGINNING OF TRIP		END OF TRIP	
	Slope	Intercept	Slope	Intercept
<u>Interbeat interval</u>				
Staged	2.5	637.5	0.29	721.9
	(0.57)	(8.1)	(0.43)	(6.1)
Control	1.74	660.5	−0.2	711.0
	(0.48)	(6.9)	(0.39)	(5.9)
Flexible	1.13	695.7	4.42	639.2
	(0.65)	(9.3)	(0.45)	(6.5)
<u>Interbeat variability</u>				
Staged	2.08	87.7	−0.93	146.2
	(0.34)	(4.9)	(0.55)	(7.8)
Control	0.84	96.42	−0.22	122.2
	(0.32)	(19.5)	(0.30)	(4.3)
Flexible	−0.3	176.9	−0.64	130.1
	(0.46)	(17.1)	(0.25)	(3.6)

TABLE 2A: Slopes and intercepts for lines of best fit for interbeat interval and interbeat variability before and after the first break from driving.

	BEFORE THE BREAK		AFTER THE BREAK	
	Slope	Intercept	Slope	Intercept
Interbeat interval				
Staged	0.77	689.6	−1.8	656.7
	(0.79)	(5.8)	(1.5)	(10.7)
Control	2.68	690.3	2.74	689.8
	(0.61)	(4.5)	(0.83)	(6.1)
Flexible	−2.15	739.4	−3.5	701.2
	(1.17)	(8.6)	(0.92)	(6.8)
Interbeat variability				
Staged	3.3	97.7	−1.2	120.0
	(0.68)	(4.9)	(1.2)	(8.5)
Control	1.56	153.1	−0.63	147.4
	(0.77)	(5.7)	(1.2)	(8.8)
Flexible	−0.46	163.7	−1.98	144.9
	(0.81)	(5.9)	(0.87)	(6.4)

TABLE 3A: Slopes and intercepts for lines of best fit for interbeat interval and interbeat variability before and after the second break from driving.

	BEFORE THE BREAK		AFTER THE BREAK	
	Slope	Intercept	Slope	Intercept
Interbeat interval				
Staged	−1.1	669.6	5.22	698.6
	(0.56)	(4.12)	(2.06)	(15.18)
Control	−0.21	723.3	−0.53	712.4
	(1.35)	(9.95)	(1.64)	(12.1)
Flexible	−0.71	669.7	−1.2	697.5
	(1.37)	(10.06)	(1.2)	(8.9)
Interbeat variability				
Staged	1.07	26.7	0.24	19.6
	(2.4)	(17.7)	(0.31)	(2.3)
Control	0.42	25.2	−0.27	18.6
	(0.4)	(12.9)	(0.33)	(2.5)
Flexible	−0.29	33.7	0.14	18.0
	(2.05)	(15.1)	(0.19)	(1.4)

TABLE 4A: Slopes and intercepts for lines of best fit for average steering wheel deviation and steering variability at the beginning (2nd and 3rd hour) and end (2nd and 3rd last hour) of the trip for each trip type.

	BEGINNING OF TRIP		END OF TRIP	
	Slope	Intercept	Slope	Intercept
Average steering deviation				
Staged	−0.43	32.5	0.04	26.29
	(0.05)	(0.91)	(0.12)	(1.7)
Control	−0.56	34.3	−0.07	25.5
	(0.46)	(0.79)	(0.11)	(1.6)
Flexible	−0.25	26.14	−0.67	35.52
	(0.11)	(1.87)	(0.09)	(1.2)
Steering variability				
Staged	0.64	11.98	−0.43	34.21
	(0.31)	(4.4)	(0.85)	(12.1)
Control	0.25	15.07	−0.48	29.3
	(0.07)	(0.97)	(0.66)	(9.5)
Flexible	0.59	10.6	0.12	21.6
	(0.3)	(4.2)	(0.32)	(4.7)

TABLE 5A: Slopes and intercepts for lines of best fit for average steering wheel deviation and steering variability before and after the first break from driving for each trip type.

	BEFORE BREAK 1		BEFORE BREAK 2	
	Slope	Intercept	Slope	Intercept
Average steering deviation				
Staged	−0.39	33.11	−0.40	33.8
	(0.17)	(1.23)	(0.37)	(2.73)
Control	−0.68	36.4	0.54	27.8
	(0.28)	(2.0)	(0.4)	(3.1)
Flexible	0.26	30.16	0.36	29.41
	(0.23)	(1.7)	(0.15)	(1.07)
Steering variability				
Staged	−0.07	21.6	−2.57	53.09
	(0.22)	(1.6)	(2.18)	(16.05)
Control	−0.49	25.72	2.57	12.47
	(0.24)	(1.77)	(1.68)	(12.39)
Flexible	1.19	20.01	0.37	19.34
	(0.63)	(4.6)	(0.26)	(1.9)

TABLE 6A: Slopes and intercepts for lines of best fit for average steering wheel deviation and steering variability before and after the second break from driving for each trip type.

	BEFORE BREAK 2		AFTER BREAK 2	
	Slope	Intercept	Slope	Intercept
Average steering deviation				
Staged	−0.16	31.5	−0.24	29.42
	(0.41)	(3.0)	(0.22)	(1.64)
Control	0.04	29.0	−0.10	23.35
	(0.12)	(0.89)	(0.18)	(1.3)
Flexible	−0.73	39.8	0.71	23.4
	(0.4)	(3.2)	(0.28)	(2.03)
Steering variability				
Staged	1.07	26.7	0.24	19.5
	(2.4)	(17.7)	(0.31)	(2.25)
Control	−0.42	25.2	−0.27	18.57
	(0.4)	(2.9)	(0.33)	(2.46)
Flexible	−0.29	33.7	0.14	18.0
	(2.05)	(15.1)	(0.19)	(1.39)

TABLE 7A: Slopes and intercepts of lines of best fit for interbeat interval at the beginning (2nd and 3rd hour) and end (2nd and 3rd last hour) of the trip for drivers doing each trip type categorised as having low, medium and high fatigue ratings (measured as mean Visual Analogue scale ratings) at each time.

FATIGUE RATING CATEGORY	BEGINNING OF TRIP Slope	BEGINNING OF TRIP Intercept	END OF TRIP Slope	END OF TRIP Intercept
Staged trip				
Low	3.15	615.5	0.20	797.8
	(0.74)	(10.5)	(0.76)	(10.4)
Medium	2.94	704.2	−0.25	665.1
	(1.14)	(16.4)	(1.5)	(21.6)
High	2.03	660.5	1.38	700.8
	(0.59)	(8.4)	(1.9)	(27.88)
Control trip				
Low	2.94	704.2	4.25	651.7
	(1.14)	(16.4)	(1.03)	(14.8)
Medium	−0.049	709.2	5.74	608.7
	(1.3)	(18.7)	(0.66)	(9.4)
High	0.99	650.4	3.28	681.9
	(0.59)	(8.5)	(0.39)	(5.6)
Flexible trip				
Low	2.64	600.6	4.6	643.6
	(0.66)	(9.4)	(0.98)	(14.0)
Medium	2.08	603.4	−1.7	702.6
	(0.78)	(11.10)	(0.62)	(8.9)
High	4.10	671.6	0.57	782.4
	(1.16)	(16.6)	(1.0)	(14.2)