Federal Office of Road Safety

Strategies to Combat Fatigue in the Long Distance Road Transport Industry

Stage 2: Evaluation of Two-up Operations

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Australian Government Publishing Service
Canberra

ISSN 0810-770X
ISBN 0 642 51333 3

Produced by the Australian Government Publishing Service

DEPARTMENT OF TRANSPORT

FEDERAL OFFICE OF ROAD SAFETY

DOCUMENT RETRIEVAL INFORMATION

Report No.	Date	Pages	ISBN	ISSN
CR 158	December 1995	220	0 642 51333 3	0810-770X

Title and Subtitle

Strategies to Combat Fatigue in the Long Distance Road Transport Industry:
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Abstract

This study investigates the impact of two-up driving on driver fatigue by comparing it to single driving. Performance, physiological and subjective measures of fatigue were taken on 15 single drivers and 22 two-up drivers over a route covering approximately 4,500 km and taking around 100 hours to complete. This study highlights the importance of pre-trip fatigue, night rest, and the loss of effectiveness of short rest breaks after extended periods. Results indicate that for shorter trips, and longer trips incorporating an extended mid-trip break, two-up driving can be an effective way of managing fatigue.

Keywords

driver fatigue, truck, two-up driving, staged driving.

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ACKNOWLEDGMENTS

We would like to thank Chris Watson and Helen Harris for their untiring help with the administration of this study. Many thanks must also go to Samantha Brown for her assistance during the study and for her role in the preparation of the final report. The equipment used on the trucks was custom designed by Bruce Costin (Worksafe), Bob Short (Bob Short Modelmakers), and Anthony Rose (AR Technology) and we are extremely grateful for their ingenuity, skill, and ongoing technical advice. We would also like to thank David Leslie for his role in the planning and data collection phases of the study. Most importantly, we would like to thank the drivers and companies who participated. Without their cooperation, patience, and good will this study would not have been possible.

EXECUTIVE SUMMARY

The aim of the present study was to investigate the impact of two-up driving on driver fatigue by comparing it to the major operational alternative, single driving. A between-subjects design was used, in which 15 single drivers and 22 two-up drivers drove a regular type of trip over a selected route. The route selected was Perth to Broome and return which covered approximately 4,500 km and took in the vicinity of 100 hours to complete. This route is typical of driving in remote zones and was one familiar to most of the participants. The range of fatigue measures used for the evaluation were identical to those used for a previous evaluation of staged driving. In brief, these included subjective measures, measures of physiological state, measures of cognitive performance off road and on-road measures of driving performance.

The results showed that irrespective of operation, fatigue increased for drivers on a long trip typical of remote zone driving. Performance, physiological arousal and subjective fatigue measures tended to converge - self-reported fatigue was associated with poorer performance and reduced arousal.

While, overall, the two-up group showed greater fatigue compared to single drivers, some ways of doing two-up were less fatiguing than single driving. Important differences in the organisation of the trips for two-up drivers were found in terms of trip length and the distribution of rest obtained across the trip. Striking differences were seen in recovery and maintenance of alertness associated with these operational distinctions among two-up drivers. Overnight stationary rest for two-up drivers at the time of peak fatigue, at mid trip, was associated with a dramatic reduction in fatigue levels after the break, and allowed these drivers to finish the trip with the lowest levels of fatigue of any group, including single drivers. Two-up drivers who had no significant stationary rest, but had the shortest trip duration of any group showed minimal recovery at mid trip but showed an overall increase in alertness over the homeward journey, finishing the trip at pre-trip levels of fatigue. These drivers also fared better than single drivers. Among single drivers, substantial recovery of alertness was seen after the stationary rest at mid point, but this recovery was not maintained with decreases in alertness evident at the end of the trip. In contrast, two-up drivers who did much longer trips, and did these trips without the benefit of stationary rest, showed no recovery at mid trip and continued to deteriorate, ending the trip more tired than any other group.

The present results also highlighted the importance of chronic fatigue as a hazard for long distance drivers. Chronic fatigue accumulated before the start of the trip had a clear impact on the development of fatigue during the trip. For two-up drivers, fatigue at the beginning of the trip was clearly influenced by the amount of work they did in the ten or so hours before starting to drive, such that they started the trip more tired than single drivers. Moreover, this disadvantage remained for most of the trip, irrespective of two-up trip type, but was particularly evident over the first leg of the trip where fatigue for two-up drivers continued to worsen at a greater rate than for single drivers. In other words, where fatigue had accumulated before the start of the trip (from activities other than driving) clearly added to the build-up of fatigue due to driving once the trip had started.

Compelling evidence for the impact of chronic fatigue was also provided by analysis of changes in the effectiveness of breaks taken by drivers as the trip progressed. As a whole, two-up drivers appeared to gain less from breaks than did single drivers but the influence of work practices among two-up drivers critically influenced the utility of breaks. As two-up trips became longer, breaks became increasingly ineffective in the latter part of the trip, and totally lost their effectiveness towards the end of the trip. It seems that these drivers simply became too tired for breaks to be of any use. Breaks were most useful for the two-up group which had a long overnight stop in Broome. This group showed better response to breaks than single drivers and also better than two-up drivers who only went as far as Broome but had no overnight rest. Thus, where the work practices kept fatigue under control, such as on shorter two-up trips and two-up trips including overnight rest, breaks were more likely to be helpful. In contrast, on trips where fatigue was allowed to build-up, such as on single trips and the two-up trips going beyond Broome, breaks did not provide relief once fatigue had accumulated.

Taken together the findings of this study suggest that judicious use of effective rest (that is, night rest) in combination with two-up driving may be the best strategy to manage fatigue on very long trips such as these. The results also underscore that the most effective improvements in managing fatigue must take account of overall work practices, including activities in the past week, activities before driving begins as well as the way the trip is structured.

BACKGROUND

Driver fatigue is a major problem for drivers in the long distance transport industry in Australia due to the very long distances between centres and the relatively few opportunities or inducements to stop. Working hours regulations are intended to ensure that drivers manage their fatigue in a trip, but there is concern that the specifics of the regulation may not be ideal, and whether this approach to fatigue management is the most effective. The aim of this project is to investigate which strategies would be most effective for reducing fatigue in the long distance road transport industry. The impetus for the study came from a request by the Federal Office of Road Safety to Worksafe Australia to research this question.

The project was designed to proceed in two stages. The first stage attempted to establish the dimensions of the problem of fatigue for both drivers and the industry and to attempt to determine what strategies were being used by drivers to reduce their fatigue on a trip and what work practices were being used to attempt to address the problem. Two surveys were conducted, one of drivers in the freight sector (truck drivers; Williamson, Feyer, Coumarelos and Jenkins, 1992) and one of drivers in the passenger sector (bus and coach drivers; Feyer, Williamson, Jenkin and Higgins, 1993) using largely the same questionnaire method. For each survey, roughly two-thirds of the sample was surveyed by self-administered questionnaire, and the remainder by interview using the same questionnaire.

The major findings revealed that fatigue was a problem for most drivers on at least some trips and that drivers were clear that their driving performance was adversely affected when they were tired. The findings were similar for each industry sector. Differences in the experience of fatigue were evident in different work practices within the industry. In particular, the results suggested that drivers who had flexibility in the scheduling of work and rest within a trip appeared to experience less fatigue. They also suggested that two methods of organising work, staged or relay driving and two-up or team driving may not be achieving their alleged purpose of fatigue reduction.

Staged driving is generally believed to reduce fatigue for long distance drivers as drivers only do short return legs, swapping loads with another driver who works the same way but from the other end of the route. This allows the drivers to work from home and sleep at home rather than at the midpoint of the trip. Nevertheless, the survey showed that staged drivers reported fatigue much earlier in the trip in spite of the fact that they did much shorter trips than other types of work organisation. Two-up driving is thought to assist in fatigue management by allowing two drivers travelling together to share the burden of driving. The survey found that two-up trips were vastly longer in distance and duration than any other type of driving. Two-up drivers did not get tired as early as other drivers, but they were more tired overall.

For these reasons, the effectiveness of flexible scheduling, staged driving and two-up driving were evaluated while in operation on the road. This became the second stage of the project. Again this was tackled in two studies. The first evaluated flexible and staged driving and the second evaluated two-up driving. In the first evaluation study, a group of drivers were studied while they did each of three trips using three different work practices (Williamson, Feyer, Friswell and Leslie, 1994). Over the same trip between Sydney and Melbourne, the drivers did one trip using a staged method of operation, one as a single driver completing the entire trip, working to working hours regulation and one as a single driver, but scheduling their work and rest within the trip in response to their level of alertness and fatigue. A range of measures were used to assess fatigue and its physiological correlates and its effects on driving-related performance. The measures included subjective fatigue ratings at intervals in the trip, performance tests at the beginning, middle and end of the trip and on-road measures of heart activity, steering, speed and performance. The results showed that on all types of trip, the roughly 12 hour trip between Sydney and Melbourne caused increased fatigue. No particular way of operating the trip seemed to be better than any other, but also no worse. The results also showed that there was a relationship between the level of fatigue before the trip and fatigue at the end of the trip. Drivers who were more tired at the beginning of the trip were more tired at the end. Chronic fatigue was found to be an important determinant of fatigue on a trip.

The second study in stage two of the project is the subject of the current report. The main object of this study was to evaluate the role of two-up driving in managing fatigue on the road.

INTRODUCTION

One of the most obvious ways of managing fatigue on long trips for professional and nonprofessional drivers is to have two drivers share the driving. When drivers are able to stop driving if they feel tired, without sacrificing trip time, they are likely to be much more motivated to stop when they are tired rather than push on. Furthermore, sharing the driving means that each driver only has to drive half the trip. If driving itself leads to fatigue, this should have considerable effect in reducing it. A review of the issue concluded that "the few studies that allow direct comparison of crash-rates between single and two-up drivers have shown little significant difference between the two operations" (Henderson, 1990, p.79).

Given the perceived advantages of two-up driving, it is surprising that the survey of long distance truck drivers showed relatively mixed findings regarding fatigue. The survey revealed that as many two-up drivers as single drivers reported fatigue occurring on most trips. In addition, the percentage of two-up drivers rating fatigue as a substantial personal problem was not much different to that of single drivers. Yet two-up drivers tended to report starting to feel tired much later in the trip. These results suggest that two-up may not be achieving its theoretical benefit, at least as it is being used in Australia.

Work by Hertz (1988) in the USA also sheds some light on the usefulness of the practice of sharing the driving between two drivers. This study showed that drivers who needed to take sleep on a noncontinuous basis had a three-fold increase in risk of fatal crashes. Two-up or sharing driving did not reduce the risk. These sorts of results lead us to ask the question, why would two-up driving *not* be useful for drivers?

There are a number of characteristics of two-up operations which could aggravate fatigue for long distance drivers. First, the earlier survey of truck drivers (Williamson et al., 1992) found that two-up drivers travelled vastly longer trips than all other types of driving operations. The question was raised in that report that fatigue problems may present for two-up drivers not because of the type of driving operation, but simply because of the distances they needed to travel. Fatigue under these conditions may occur simply because their trips are so long that any benefits of shared driving are lost. It is possible that two-up driving would be useful for shorter trips. Ellingstad and Heimstra (1970) found in a simulated driving task that tracking performance started to decrease in the first nine hours of the task, so providing support for the contention that shorter driving periods may be of benefit to drivers.

Second, the two-up operation involves drivers doing continuous work and taking relatively short breaks on an irregular basis, as often in the day time as the night time, and usually in a moving vehicle. This means that two-up drivers, despite access to a relief driver, tend to live a life similar to a shift worker and consequently experience the same sorts of pressures. In particular, disruption to the body's circadian rhythm through the need to work at night and sleep during the day is recognised to lead to chronic psychological and physical health problems such as gastrointestinal, cardiovascular and psychosocial stress problems and sleep disturbances (Scott and La Dou, 1990). The need to work at night is known to be a problem in itself. Night work, typically is done at a considerably greater cost to the individual in terms of effort to remain alert and performing well and there is a much higher risk of error at this time (Folkard and Monk, 1985). There is considerable evidence that night work is a problem for drivers. A number of studies have shown that the risk of single vehicle accidents increases markedly during night driving, particularly in the early hours of the morning (van Ouwerkerk, 1987; Hamelin, 1987). If the practice of using two drivers to share the job is to be useful in managing fatigue, these factors will all need to be overcome.

The need to work at night is also likely to increase problems with sleeping and in getting enough sleep. A large number of studies have demonstrated that individuals are more fatigued on night shift not just because of the influence of the body clock, but also because of the reduced length of day sleep following night work (Waterhouse, Folkard and Minors, 1992). The demand on two-up drivers to take sleep in short snatches is also likely to increase their fatigue. Akerstedt et al. (1993) showed that irregular sleep patterns strongly affected sleep efficiency both in terms of the quality and quantity of sleep. Hertz (1988) concluded that the increased crash risk in drivers who used a sleeper berth was due to nonconsecutive sleep rather than disturbance from sleeping in a moving vehicle. Any driving operation that emphasises night driving is therefore much more likely to be at risk for increasing fatigue.

While there is some evidence that individuals can obtain recovery effects from sleep lasting for only four to six hours (Haslam, 1985; Mullaney et al., 1983), it is recognised that immediately following awakening from the nap individuals function less well for a period of 15 to 30 minutes than they do prior to taking the nap. This problem is likely to be most pronounced when the sleep occurs in the early morning hours when sleep is more likely to be deeper and consequently more difficult to overcome when sleep length is also short.

The nature of two-up driving means that drivers are much less likely to have had long periods of the trip without opportunity for sleep. There is some evidence that sleep or naps taken regularly and early in a period of sustained work, as they may be in two-up, can be most effective, no matter how short the nap is (Hartley, 1974; Dinges et al., 1988). In two-up driving, however, drivers are much more likely to experience a slow build up of sleep loss and disruption over the period of the trip and over consecutive trips. Sleep deprivation for two-up drivers is more likely to be chronic rather than acute.

The aim of the current study is to investigate the effects of two-up operations on fatigue and performance on the road and contrast it with single driving operations over the same trip. The same methods and general procedures will be used as for the earlier study of staged and flexible driving which was the subject of the previous on-road evaluation.

METHOD

Design

A mixed design was used in the study. Each driver was measured repeatedly across a trip to assess changes in alertness and performance over time. However, two separate groups of drivers were measured under the single and two-up regimes. This allowed drivers to work under their regular driving regime and roster (although not necessarily on their regular route). Two-up trips entailed a pair of drivers who manned a single truck and alternated at will between driving and rest. In contrast, single trips involved a solo driver who completed the trip alone.

A standard route was selected for all trips - the round trip between Perth and Broome, in Western Australia. This particular route was chosen as typical of remote long distance trips in this country, in terms of both length (approximately 4500 km) and terrain. It was also routinely run by a number of transport companies, making subject recruitment and scheduling more practical.

Subjects

Thirty seven professional long distance drivers participated in the study. Of these, 8 (2 single drivers and 6 two-up drivers) were drawn from one company, 16 (all two-up drivers) from a second company, and 13 (all single drivers) from a third company. Eight of the two-up drivers were subcontracted by the participating companies. All the drivers were men.

The participating companies varied in size. Two were medium (see Williamson et al., 1992), running approximately 30 prime movers. The other company was somewhat larger, operating more than 50 trucks. Standard operating procedures varied between two-up and single drivers in the different companies. 2 companies encouraged two-up drivers to alternate every 4 to 5 hours or so, whereas the third company typically encouraged single drivers to break between the hours of 24:00 and 05:00.

Measures used in the study

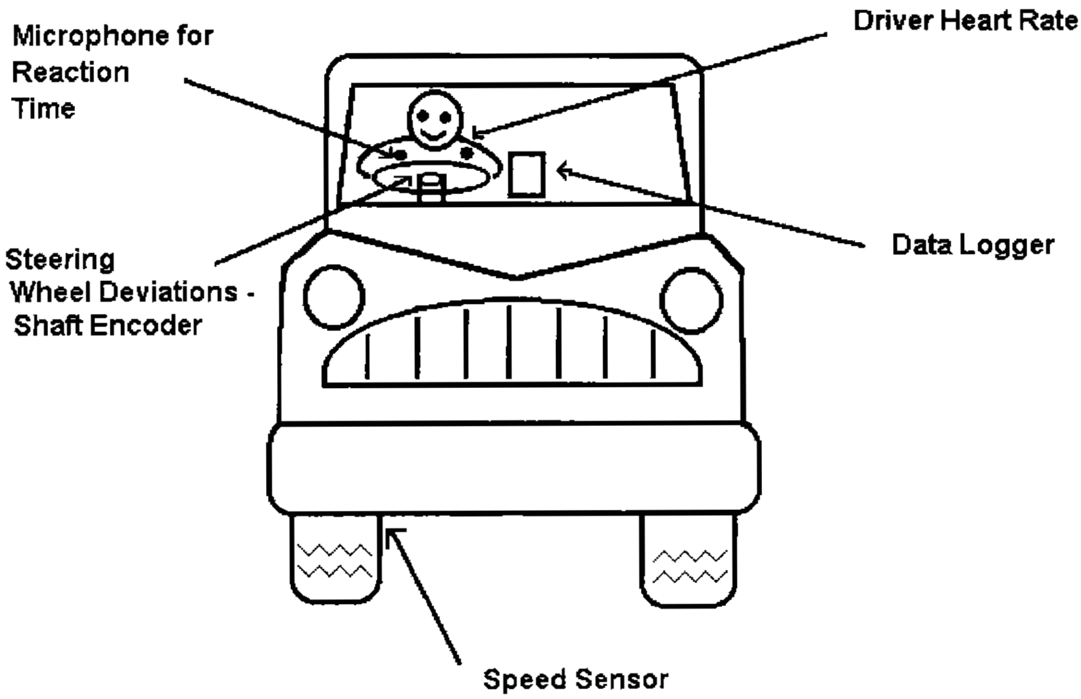
The effects of trip type on driver fatigue were assessed using a variety of measures sensitive to changes in alertness. These included measures of physiological functioning, cognitive functioning, driving performance, and subjective evaluations of fatigue. Detailed information was also obtained about the drivers' health and the pattern of work and rest leading up to the studied trip. Details of each of these measures are provided below.

1. On-board recording apparatus

The study involved monitoring drivers' cognitive and physiological functioning, as well as their driving performance, under operational conditions (see Figure 2.1). The equipment was designed to obtain data in real time without interfering with the driving task, and allowing the driver to use his regular type of vehicle.

The system consisted of a central data logger (A.R.Technology) to which all external devices were attached (see Figure 2.2). The data logger was powered by 12 volt input from the cigarette lighter of the truck. 24-to-12 volt converters were used in trucks with 24 volt systems. An additional 12 volt battery, which received trickle down charge from the truck, was connected to the logger and served as a backup power source. The logger housed the circuitry for collecting data from the various sensors and for storing data in its internal memory. Each logger contained 4 megabytes of Flash Eprom memory, sufficient for approximately 33 hours of continuous recording (within the parameters of the inputs). The memory was non-volatile. That is, it

Figure 2.1: On-road test equipment



retained the stored data even after the power to the unit was turned off. Once stored, the data could be downloaded, in whole or part, to a PC using customised software. In view of the logger's memory limit and the length of the trips involved in the study, data were only recorded continuously on alternate 5 minute periods. In this way, the effective recording span was extended to 66 hours.

The logger contained multiple 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

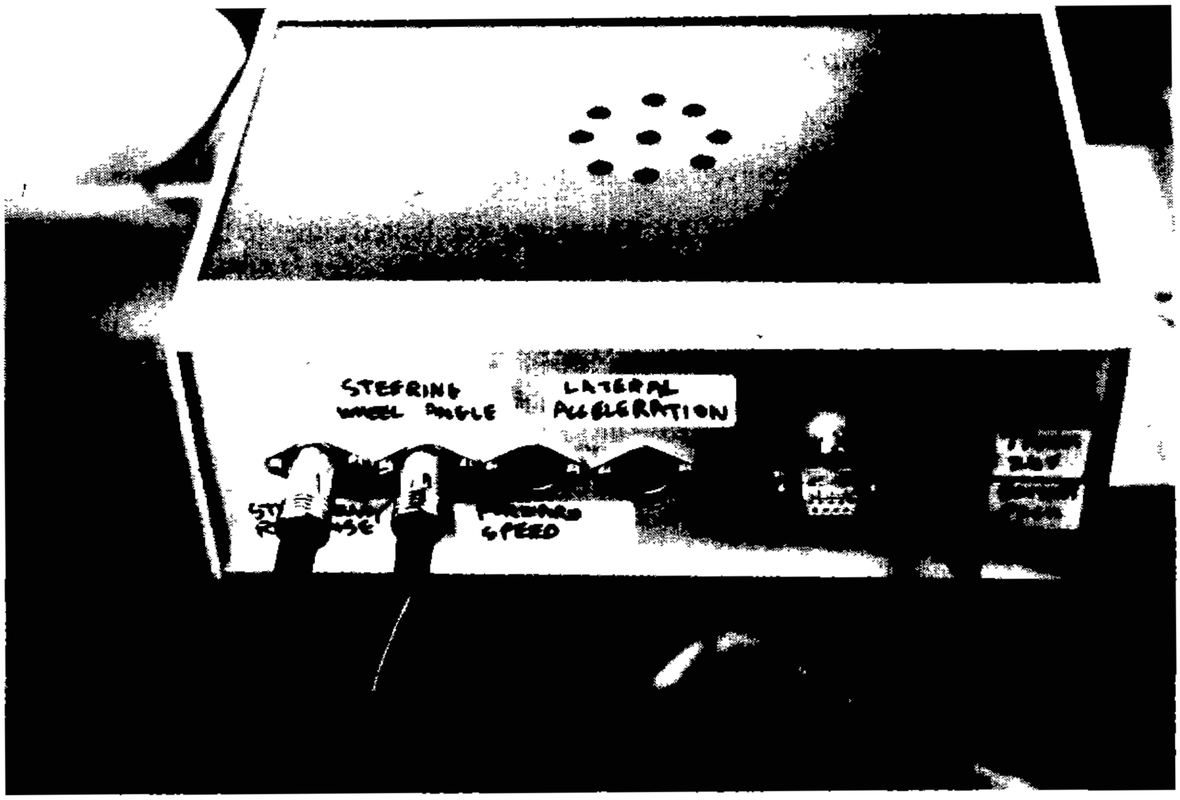
The input to this channel was a quadratic-modulated digital pulse from a rotary shaft encoder (Omron E6B-CW3ZC). This device is a high resolution (360 pulse/revolution) bi-directional multi-turn potentiometer designed to sense absolute shaft angle. It allows the direction of shaft rotation to be measured, and has a zero index to confirm a start reference point. Wheel angle in rotary pulse encoder units was sampled 5 times a second at an accuracy of within 0.5 of one degree. The change in wheel angle between successive samples was calculated, and was converted to degrees as follows:

*Angle (^{o}) = change value * (360/encoder resolution) * (gearing ratio).*

Gearing ratio varied with the size of collars fitted to both the encoder (circumferences: 40 to 44mm) and to the steering wheels (circumferences: 310 to 478mm) of the various trucks used in the study.

The shaft encoder was fixed to an immobile section of the steering column using an adjustable bracket which varied with the make and model of the truck (see Figure 2.3). A small circular collar was fixed to the rotating top of the

Figure 2.2: On-board data logger



shaft encoder and another, larger circular collar was fitted around the rotating undercarriage of the steering wheel. Both encoder and steering wheel collars were machined with a track around their circumferences to hold a length of plastic tubing. The tubing encircled both collars in the manner of a fan belt. In this way, rotations of the steering wheel were translated into corresponding rotations of the shaft encoder.

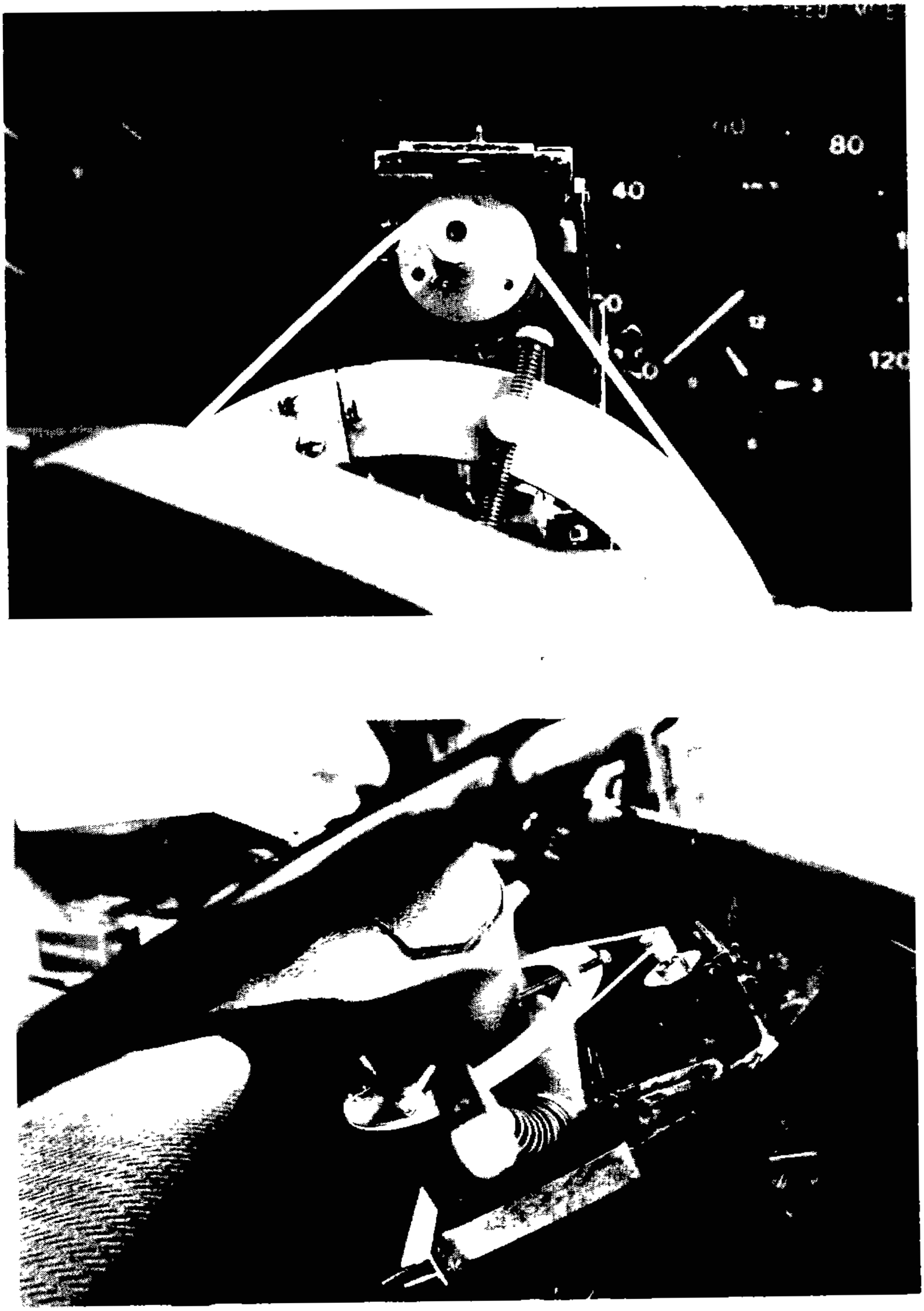
(ii) Forward speed

This channel received an analogue input from a digital magnetic pick-up transducer (RS 304172). The sensor was bolted either to the dust cover or to the metal casting on the inside of the front driver's side wheel, using custom built brackets (see Figure 2.4). The sensor was aligned with a small magnet attached to the inside of the wheel rim, and measured the passing of the magnet with each wheel revolution. Time between wheel revolutions, in 100 microsecond units and averaged over two revolutions, was sampled once per second and was converted at data download to kilometres per hour using the wheel circumference. Effective resolution for this measure was approximately 0.2km/h.

(iii) Heart rate

This channel received a digital pulse input from a commercially available heart rate monitor (Polar PE 4000) designed to detect heart electrical EKG signals via chest electrodes. The unit consisted of a chest strap with built-in electrodes and transmitter (see Figure 2.5). The signal from the chest electrodes was transmitted to a receiver watch which, in turn, plugged into the data logger. 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 were subsequently converted to milliseconds, and were retained in interbeat interval form for analysis (rather than converting them to heart rate in beats per minute).

Figure 2.3: Apparatus for steering wheel deviation measurement



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. Unusually large (>2000ms) or small (<333ms) interbeat intervals were filtered from the data prior to analysis.

All drivers were asked to pin the watch to their shirt when driving to maximise the signal from the transmitter, and to unplug the watch cable from the logger when they stopped driving. Two watch cables with different wiring configurations were constructed, and a different cable was given to each driver in a two-up pair. In this way, the logger registered which of the two drivers, if any, was plugged in at a particular time.

(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 condenser microphone attached to his shirt, with microphone level input triggering the threshold detection circuitry in the logger (see Figure 2.6). 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 these events (stimulus and response) was corrected at the time of analysis, to include stimulus duration and was converted to milliseconds.

The task occurred as 30 trials spaced unevenly over a 15 minute period. The logger was programmed to record continuously for the entire duration of the reaction time task, in contrast to it's usual 5 minute alternations. The inter-trial interval in each block of 30 trials varied randomly between 9 and 24

Figure 2.4: Speed sensor apparatus

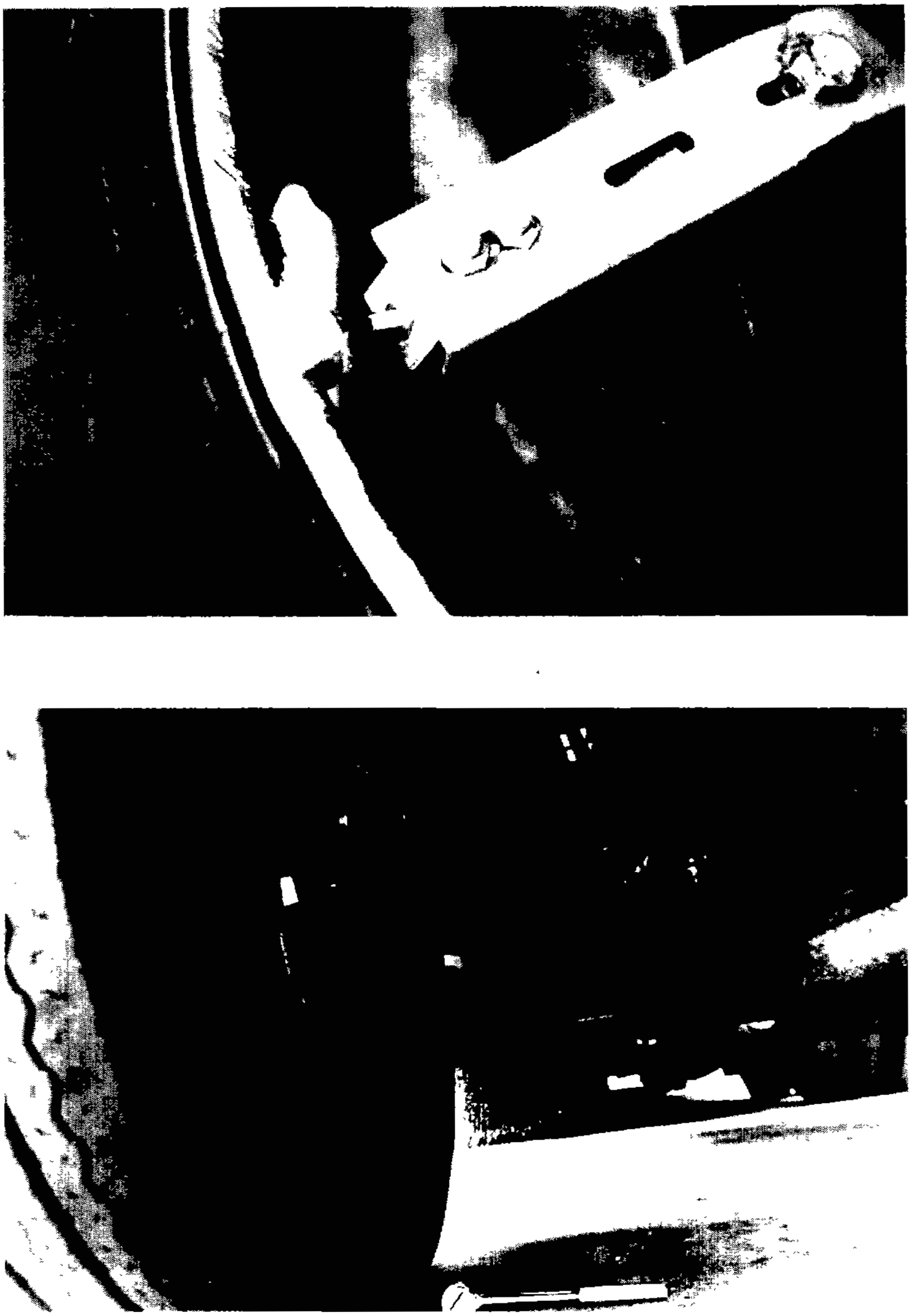
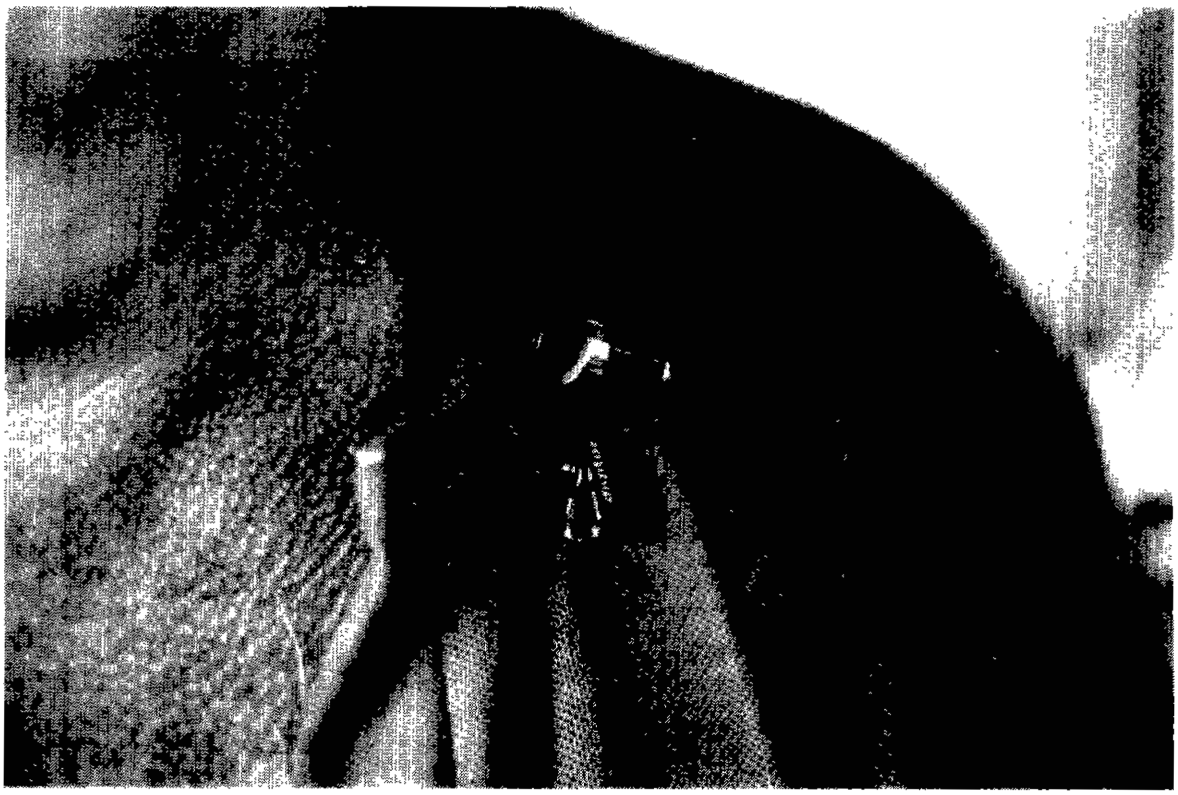


Figure 2.5: Apparatus for heart rate monitoring

Figure 2.6: Microphone to capture responses for on-board reaction time test



seconds. Blocks were distributed across the trip such that they occurred 3 hours after departure, and each 2 hours thereafter. When a break was taken from driving, the timing structure reset to 2 hours after recommencing driving, and each 2 hours thereafter. The test yielded two measures, reaction time and the number of missed signals (errors).

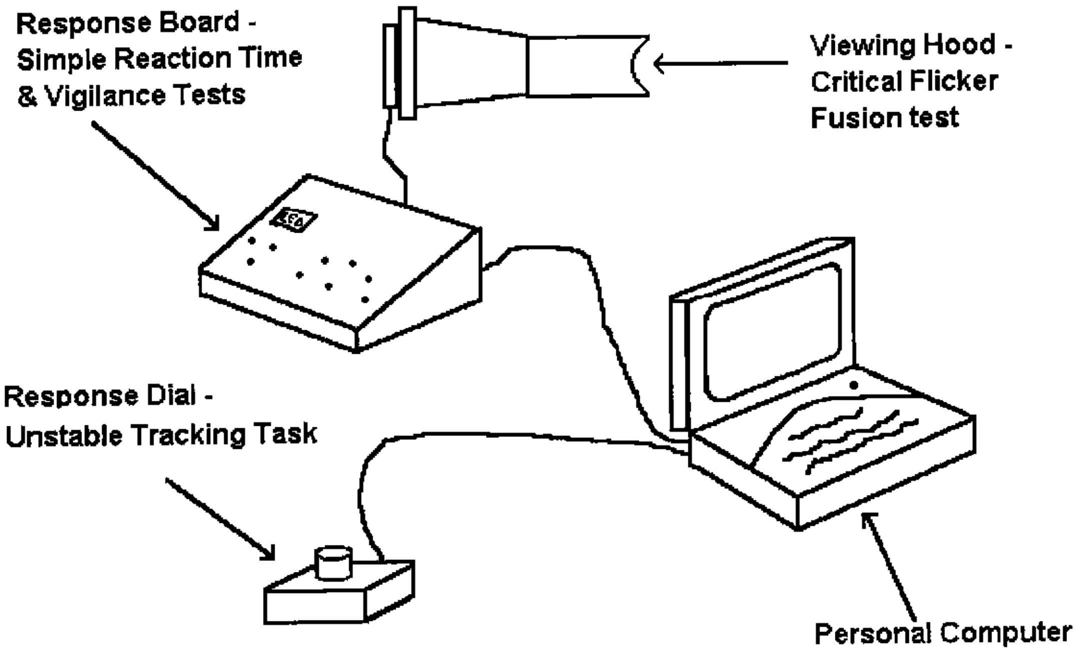
A shorter version of the task was also completed by drivers at the time of off-road cognitive testing. The task was identical in all features, with the exception of the timing. The inter-trial interval in these blocks varied randomly between 500 and 2000 milliseconds, with a timeout of 2000 milliseconds.

In addition to collecting and storing data from the various sensors, the logger also had an inbuilt timing device which allowed time-stamping of all data . Because the logger automatically took its power from the backup battery if truck power was removed , the clock continued to function during breaks from driving. In this way, the topography of the trip was available for analysis, data could be related to milestones in the trip, and different measures could be compared at identical times in the trip.

2. Off-road cognitive functioning

A selection of tests from the Information Processing and Performance Test System developed by the senior authors (e.g., Feyer, Williamson, & Rassack, 1992) was used in this study (see Figure 2.7). 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 were all ones which were known to elicit stable responding over

Figure 2.7: Cognitive test apparatus



relatively few trials. Accordingly, practice trials were included as part of 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 was to watch an LED display at the end of a viewing hood (see Figure 2.7) and to press a response button on the hood as soon as the stimulus light appeared to stop flickering (ascending version), or to start flickering (descending version). The frequency of flicker at which the subject detected the change provided a measure of his sensitivity to subtle changes in the visual environment.

The rate of increase/decrease in the flickering rate was 2 Hz/second within the range 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 was detected on the previous trial. There was a fixed 6 sec interval between the subject's response and the onset of the next trial.

Separate sets of either ascending or descending trials were administered to both eyes 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 testing session, 5 trials of each task type were administered to each eye, yielding 20 trials per subject in total. Subjects were given 2 practice trials before each condition.

(ii) Simple manual reaction time

This test provides the most basic estimate of stimulus response capabilities. Initially, subjects depressed a 'home' button located beneath an LED display (see Figure 2.7). The subject's task was to release the home button and press the nearby response button as quickly as possible when a signal stimulus (a circle) appeared on the LED. In this way, the time needed for the decision to respond (decision time) and the time taken to then execute the response (movement time) were both measurable.

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

Subjects in the study were administered one block of 30 trials in each testing session, with only the last 15 used for analysis. The task was always preceded by 10 practice trials.

(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 was 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 were located equidistant from each endpoint and the top of the semicircle (see Figure 2.7). Individual lights were illuminated in a quasi-random sequence, and the subject's task was to hover above the display and press the button indicated by the light. Occasionally, with a predetermined frequency, two lights were illuminated simultaneously, in which case the subjects' task was 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 the testing sessions at the beginning and end of trips. At the beginning of each session a 30 second (30 trial) practice 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 was based on the Critical Tracking Task designed by Jex and colleagues (Smith and Jex, 1986). The subject was asked to counteract the horizontal movements of a pointer on a computer screen, using an external control dial (see Figure 2.7), and to keep the pointer within a target zone in the centre of the screen. The pointer changed direction unexpectedly and became increasingly difficult to control with the dial, until the subject eventually lost control of it. Two measures were yielded at the end of each trial, the level of difficulty as reflected by the level of instability at the time when the subject lost control of the pointer, and also the length of time that the subject was able to maintain control. Together these measures reflect perceptual motor capabilities in terms of hand/eye co-ordination.

During each 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. However, a shortened form (including all tests except vigilance) was performed at midtrip to avoid overly compromising drivers' break time. Test order was always as follows: critical flicker fusion , vigilance (for those test occasions where it was included), simple reaction time, and unstable tracking.

3. Subjective evaluation of fatigue

At the beginning and end of the trip and at the beginning and end of each break, drivers were asked to complete a set of ratings of fatigue (see Appendix 1). Breaks included any periods of 15 minutes or more when a driver was not driving along the main trip route. Such periods incorporated other work tasks and stints of local driving necessary for loading and unloading, as well as rest and recuperation activities. Two forms of fatigue rating 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 focussed on feelings of sleepiness, whereas the VAS dimensions (fresh - tired, clear headed - muzzy headed, very alert - very drowsy) focussed on various aspects of the experience of fatigue.

4. Trip diaries

All drivers were questioned about their activities during and immediately before their experimental trip (see Appendix 1). Prior to each trip, information was obtained about activities in the 12 hours immediately before the trip. During the trip, drivers kept a diary containing information about the timing of breaks, activities during breaks, and about food and drink intake during breaks. The diary also contained self-report forms for drivers to record their level of fatigue at the beginning and end of each break.

5. Health and work history

Details of the general health and lifestyle status of each driver were obtained via questionnaire, prior to his trip (see Appendix 2). This information allowed possible health-related influences on fatigue during the experimental trips to be identified. Drivers were asked to report some basic demographic information, as well as information about health-related lifestyle factors such as regular exercise and 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). This was 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 & 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 & Tingvall, 1992; Kapuniai, Andrew, Crowell & Pearce, 1988) were included in the questionnaire.

The questionnaire also obtained details of the driver's work/rest schedule in the week prior to participation in the study. Drivers were asked to describe the week in terms of when they worked and when they rested. This provided information about possible influences on fatigue during the experimental trips emanating from the ongoing work/rest context in which the trip occurred.

Procedure

Drivers at participating companies were provided with information about the study through personal visits by the investigators, and an information leaflet circulated in advance. Amenable drivers, engaged in the transport of freight between Perth and Broome, in single or two-up operations, were enlisted as subjects.

The researcher stationed in Perth set up the on-board recording apparatus on the truck as early as practical on the day of each scheduled trip and met the driver/s approximately 1.5 hours before departure. At this time the driver/s formally consented to participate (see Appendix 3), completed the health and work history questionnaire, undertook the pre-trip cognitive performance tests, and rated their fatigue. Prior to departure, the researcher explained the trip diary, the use of the on-board equipment (in particular the devices for measuring heart rate), and initiated logger recording when the drivers indicated that they were preparing to depart. Once the truck had departed, the member of the research team in Broome was notified of the approximate time and day when the truck was due to arrive. Drivers were asked to phone the Broome researcher directly when they were nearing Broome, to schedule midtrip data collection. The same notification procedure was followed when the drivers departed Broome on the homeward leg of the trip. At the end of the trip, the Perth-based researcher administered the post trip cognitive performance tests, collected the completed trip diaries, and stripped the equipment from the truck. An overview of the data collection process is shown in Figure 2.8.

The exact nature of midtrip testing varied depending on the length of the midtrip break, and on the operating constraints placed on the drivers. Initially, it was intended that drivers would be tested twice at midtrip; once as close to the time of arrival as possible, and once again, as close as possible to the time of departure on the homeward leg of the trip. Frequently, however, the driver's work schedules did not permit repeated mid trip testing, particularly when drivers had a relatively short stop in Broome before returning to Perth. In these cases, the drivers were tested only once. Because two-up drivers were more likely than single drivers to have short Broome turnaround times, only 45% were tested twice at midtrip, compared to 73% of single drivers. As a result, only the data from the first midtrip cognitive testing session were analysed further. This session typically occurred soon after arrival in Broome (Table 2.1) for both groups of drivers, but variability was inevitable, given the demands of the work schedules.

Figure 2.8: Measures taken across the trip

Pretrip	Health & work history questionnaires Offroad cognitive testing Subjective ratings
Onroad: Outward Leg	Steering Speed Heart rate Vocal reaction time Subjective ratings
Midtrip	Offroad cognitive testing Subjective ratings
Onroad: Homeward Leg	Steering Speed Heart rate Vocal reaction time Subjective ratings
Posttrip	Offroad cognitive testing Subjective ratings

Table 2.1: Time (hrs:min) between cognitive testing and drivers' arrival in Broome.

DRIVING OPERATION	TWO-UP	SINGLE
Median	0:42	1:00
Mean *(SD)*	3:13 *(4:14)*	2:47 *(3:59)*

RESULTS

Characteristics of the sample

The drivers participating in this study were experienced drivers of heavy vehicles, the majority having over 10 years experience (Table 3.1), with two-up drivers tending to be slightly, but not significantly, more experienced. Only 3 single and 2 two-up drivers had less than 5 years experience. Consequently, it is not surprising that for both groups, there were few very young drivers. Most drivers were married or living in defacto relationships, with this being the case slightly more often for single drivers. All single drivers and the vast majority of two-up drivers were employees. Overall, the

TABLE 3.1: Characteristics of drivers in the study.

	Single (N=15)	Two-up (N=22)
Mean age *(sd)*	37.3 *(8.93)*	37.4 *(8.18)*
Marital status:		
• **%single**	13.3	22.7
• **% married**	73.3	54.5
• **% defacto**	13.3	22.7
Driving experience:		
• **Mean years***(sd)*	13.33 *(9.39)*	15.39 *(7.33)*
• **% <= 10 years**	60.0	31.8
• **% 11-20 years**	20.0	50.0
• **> 20 years**	20.0	18.2
Employment status:		
• **% employee**	100.0	76.2
• **% owner**	0	18.2

characteristics of this sample are consistent with the findings of the large national survey of long distance truck drivers (Williamson et al., 1992) showing that they are fairly typical of drivers working for medium to large companies, and of two-up and single drivers.

Health status of the drivers

In general, the drivers in the sample were a healthy group, with very few reporting any diagnosed medical problems requiring time off from work in the previous 12 months (Table 3.2).

TABLE 3.2: Characteristics of drivers in the study.

	Single	% Drivers	Two-up
Diagnosed medical condition in the last 12 months	6.7 (N=1)		4.5 (N=1)
Currently smoke	60.0		59.1
Currently use alcohol	80.0		77.3
*** Frequency of alcohol use:**			
• 2-3 times/week	33.3		27.3
• once per week	20.0		13.6
• 1-2 times/month	6.7 (N=1)		18.2
• rarely	20.0		18.2
• non-drinkers	20.0		22.7
*** Amount of alcohol consumed:**			
• > 3 drinks at a time	13.3		50.0
Exercise:			
• at least 2-3 times/week	20.0		41 1
Currently use pills to stay awake while driving	0		4.5 (N=1)

Examination of lifestyle factors revealed that almost half of the drivers reported taking regular exercise. Two-up drivers reported being more regular takers of exercise, with twice as many two-up drivers reporting that they exercised 2 to 3 times per week. The majority of drivers in both groups were smokers and regular although relatively infrequent users of alcohol. Approximately two thirds of drivers reported drinking less often than once per week. The groups differed however in the amount that they reported typically drinking at one time. Half of the two-up drivers reported drinking 3 or more drinks at one time, compared with just over one tenth of single drivers. While this amount could be regarded as high for a single session, the total amount consumed seems within the acceptable range of social drinking. Further, it seems that drivers regulate their alcohol consumption so that the overall amount being consumed is unlikely to interfere with their work capabilities. About half of the drivers who reported taking three or more drinks at one time also reported that they consumed alcohol no more than weekly.

Drivers also reported on problems associated with their sleep (Table 3.3). It should be noted that drivers were asked to report on sleep in general rather than sleep in the truck. Sleep problems are particularly relevant to very long distance drivers who do much of their work at night and take much of their sleep away from home. In addition, when working, two-up drivers take their sleep in the moving vehicle (Feyer and Williamson, 1995), and apparently share the optimal times for sleep with their team mate. Recent attention has also suggested that long distance truck drivers are in a high risk group for sleep apnea (Bearpark et al., 1990; Stoohs, Guilleminault, Itoi and Dement, 1994). Issues associated with sleep are, therefore particularly important with this group.

Table 3.3 shows that this group of drivers have few sleep problems. Few drivers reported having difficulty getting to sleep, and no drivers reported having difficulty staying asleep. The majority of drivers in both groups reported rarely or never falling asleep during the day. Questions about some qualitative aspects of sleep revealed that the majority of drivers in both groups reported snoring loudly at least sometimes, but very few drivers reported that they stopped breathing during sleep. The majority of two-up drivers reported moving around a lot during their sleep, which was about twice the rate reported by single drivers.

TABLE 3.3: Sleep problems among drivers in the study.

Problem	Single % Drivers	Two-up
Getting to sleep	0	9.1
Staying asleep	0	0
Falling asleep during day:		
• **Never**	33.3	40.9
• **Rarely**	26.7	36.4
• **At least sometimes**	40.2	22.6
Snore loudly:		
• **Never**	20.0	18.2
• **Rarely**	20.0	22.7
• **At least sometimes**	60.0	59.1
Stop breathing:		
• **Never**	78.6	86 4
• **Rarely**	14.3	4.5
• **At least sometimes**	7.1	9.1
Move around a lot during sleep:		
• **Never**	26.7	0
• **Rarely**	33.3	13.6
• **At least sometimes**	39.4	86.3

Together, the questions in Table 3.3 have been used to predict individuals at risk of sleep apnea related problems (Harraldsson et al., 1992; Kapuniai et al., 1988). The results of responses to these questions were analysed using two different criteria for discriminating individuals at risk for sleep apnea. The first criterion used responses to the snoring and stop breathing questions (Kapuniai et al, 1988). On the basis of this criterion, only 2 two-up drivers and 1 single driver were classified as being at risk. A second broader criterion was also examined, combining responses to all three questions about qualitative aspects of sleep as well as responses to the questions about daytime sleepiness and difficulty staying asleep (Haraldsson et al., 1992). On the basis of the second criterion, no drivers in this study could be classified as being at risk of being a sleep apneic individual.

The low levels of reported daytime sleepiness by drivers were also evident in the results for the Epworth Sleepiness Scale (Johns, 1991, 1992). This scale asks about problems of sleepiness during a range of activities. For most of the activities, most drivers reported no more than a slight chance of dozing (Table 3.4). Only while resting during the afternoon and while watching TV did a substantial proportion of drivers report a moderate to high chance of dozing. The overall results for the Epworth scale show that both two-up and single drivers in this study can be classified as having relatively little problem with daytime sleepiness. Johns (1992) reported that sleep apneic patients scored 14.3, while medical students scored 7.4 in a study of the reliability of the scale. Both groups of drivers in the current study scored considerably lower on this scale than either of the groups studied by Johns (1992).

Overall, the results of the data on sleep problems indicate that, despite the fact that all of the participants in the study are night workers, they are managing the demands that are a part of such a job. Clearly, the low incidence of problems of sleep and sleepiness is consistent with the finding that only one driver in the sample reported taking pills at any time to stay awake while driving.

TABLE 3.4: Response of drivers in the study to the Epworth Sleepiness Scale.

Experience sleepiness when:	Rating for Chance of Dozing			
	Never	Slight Chance	Moderate Chance	High Chance
		% Drivers		
Sitting reading:				
•**Single**	66.7	33.3	0	0
•**Two-up**	50.0	31.8	9.1	9.1
Watching TV:				
•**Single**	33.3	40.0	20.0	6.7
•**Two-up**	27.3	27.3	31.8	13.6
Sitting inactive:				
•**Single**	80.0	20.0	0	0
•**Two-up**	63.6	31.8	0	4.5
As a passenger in a car:				
•**Single**	86.7	13.3	0	0
•**Two-up**	68.2	22.7	9.1	0
Resting in the afternoon:				
•**Single**	20.0	20.0	40.0	20.0
•**Two-up**	13.6	18.2	22.7	45.5
Sitting talking:				
•**Single**	93.3	6.7	0	0
•**Two-up**	90.9	9.1	0	0
Sitting after lunch:				
•**Single**	80.0	0	20.0	0
•**Two-up**	68.2	31.8	0	0
In a car, stopped in traffic:				
•**Single**	100	0	0	0
•**Two-up**	100	0	0	0

EPWORTH SLEEPINESS SCORE:	**Single**	**Two-up**
mean *(sd)*	3.73 *(2.37)*	5.36 *(2.84)*

Recent work history

Drivers were asked about their work and rest in the 7 days prior to the study (Table 3.5). The average total hours worked, including yard work and loading as well as driving, did not differ significantly between the groups, with single drivers reporting an average of close to 80 hours and two-up drivers reporting an average of about 66 hours. Not surprisingly, analysis of variance revealed that the total amount of time spent driving tended to be higher for single drivers than two-up drivers ($F_{(1,30)} = 3.36$, $p<0.08$). Although there was no difference in the total amount of time drivers reported driving at night, clearly the *proportion* of total driving time done at night was significantly higher for two-up drivers than for single drivers ($t_{(28)} = 2.67$, $p=0.01$). The proportion of night driving clearly reflects the operational distinction between the two groups, with two-up work involving round the clock driving and single work tending not to involve driving between midnight and dawn.

Table 3.5 also shows the amount and pattern of rest taken in the past week by drivers in the sample. There was only a trend for single drivers to obtain less rest in total compared with two-up drivers ($F_{(1,28)} = 3.42$, $p=0.08$). However, examination of the pattern of rest taken revealed marked differences between the two groups. Single drivers took significantly fewer of their rest periods during the day ($F_{(1,28)} = 14.28$, $p=0.0008$), and also significantly less rest in total during the day ($F_{(1,28)} = 22.88$, $p=0.0001$). Although the groups did not differ significantly in the total amount of night rest obtained during the past week, the proportion of total rest taken at night by single drivers was significantly higher than for two-up drivers ($F_{(1,28)} = 21.84$, $p=0.0001$). These results suggest that, since on average almost all of their rest was obtained as night rest, single drivers as a group would be a better rested group than the two-up drivers.

Compared with the weekly working hours reported by two-up drivers in the national survey of long distance drivers (Williamson et al, 1992) the work hours reported in this study seem reasonably typical. In the survey, two-up drivers reported working an

TABLE 3.5: Work and rest in the previous week by drivers in each operation.

	Single	Two-up
WORK	(N=13)*	(N=19)**
Mean total hours *(sd)*	79.2 *(30.9)*	66.2 *(18.8)*
Driving:		
• **Mean total hours** *(sd)*	47.5 *(23.1)*	34.8 *(16.4)*
• **Mean night hours** *(sd)*	18.4 *(10.1)*	20.6 *(10.8)*
• **Mean proportion of driving done at night** *(sd)*	0.40 *(0.19)*	0.59 *(0.19)*
REST	(N=11)*	(N=19)**
Mean total hours *(sd)*	43.4 *(5.03)*	49.6 *(10.4)*
Night rest:		
• **Mean total hours** *(sd)*	41.1 *(4.4)*	37.5 *(8.7)*
• **Mean number of periods** *(sd)*	6.6 *(0.7)*	7.6 *(1.8)*
• **Mean proportion of rest taken at night** *(sd)*	0.95 *(0.06)*	0.76 *(0.13)*
Day rest:		
• **Mean total hours** *(sd)*	2.4 *(3.6)*	12.5 *(6.4)*
• **Mean number of periods** *(sd)*	1.5 *(1.2)*	4.2 *(2.1)*

N reduced due to:
* drivers provided inadequate data for coding
** drivers on annual leave/sick leave.

average of 81 hours (sd = 44.7), clearly encompassing the hours reported by the drivers in the present study. Single drivers are not entirely comparable to the group described in the survey because those participating in this study were specially selected to be typical of single driving in remote zones, and in particular to be comparable with the two-up trips in this study. In contrast, single drivers described in the survey included the range of single driving nationally. This is reflected in the fact that in the survey single drivers reporting about two-way trips described average weekly working hours of 50.9 hours (sd =30.0) and single drivers reporting about one-way trips described average weekly working hours of 65.1 hours (sd = 32.1). The single drivers in the present sample are clearly working in the upper ranges of the weekly working hours previously reported.

Trip characteristics for each driving operation

Pre-trip activities

Drivers in both groups were fairly consistent in terms of their preparation for the trip. Table 3.6 shows details of activities for drivers in each group in the 12 hours before the trip.

TABLE 3.6: Pre-trip activities: Preparation by drivers for the trip.

In the past 12 hours:	Single	Two-up
	% Drivers	
% consuming at least one meal	86.7	77.3
% consuming alcohol	0	4.5 (N=1)
% taking medication	13.3	18.2
Amount of sleep taken mean hrs *(sd)*	7.3 *(1.7)*	8.45 *(2.2)*
Time since sleep taken mean hrs *(sd)*	5.1 *(3.3)*	3.8 *(2.0)*

The majority of drivers consumed at least one meal. Only one driver reported consuming alcohol before the trip, and only a small proportion of drivers reported taking prescription medication for conditions including asthma, stomach ulcers, and infections. No drivers reported taking drugs to stay awake before the trip.

There were no significant differences between the groups in terms of either the amount of sleep obtained or the recency of the sleep period before the trip. Drivers obtained in the vicinity of 7 to 8 hours sleep, with the sleep period ending 4 to 5 hours before starting work.

The groups did differ significantly, however, in terms of their pretrip work activities (Table 3.7). Two-up drivers spent almost twice as long working in the yard prior to starting their trips ($F_{(1,35)} = 1.63$, $p<0.002$). This difference in work routine seemed to be accounted for by involvement in loading activities, with single drivers being significantly less likely to be involved in loading activities than two-up drivers ($X^2_{(1)} = 11.01$, $p<0.001$). When they were involved, the amount of time drivers spent loading did not differ. Besides loading, pre-trip work included truck maintenance and local driving duties.

TABLE 3.7: Pre-trip activities : On-site before trip start.

	Single	Two-up
Time spent at work area		
mean hrs ***(sd)***	5.4 *(4.1)*	9.4 *(3.0)*
Loading		
% drivers	33.3	86.4
mean hrs ***(sd)***	6.6 *(4.0)*	7.9 *(2.5)*

Trip chronology

For both single and two-up drivers, the trips started after regular working hours, in the early to late evening (Table 3.8). Although all trips commenced before midnight, the majority of two-up trips started later than the single trips, in the late evening. For most drivers in both groups, the trip ended in the night hours (Table 3.8). Again, for the majority of two-up drivers, the trip ended later than for single drivers, with more than half of two-up trips ending between midnight and 8.00am compared with only one fifth of single trips. The pattern of start and finish times indicates that two-up trips were likely to start closer to the vulnerable period for the circadian rhythm, the midnight to dawn hours, which may result in greater acute fatigue at the start of the trip. The later trip end times mean that for two-up drivers the first night of rest after the trip may also be truncated, compared with single drivers. A regular pattern of such shortened rest on one of their rest days may well predispose two-up drivers to greater levels of accumulated fatigue. The pattern of interrupted night rest is clearly consistent with the finding that the proportion of night time rest obtained by two-up drivers in the previous week was significantly less than for single drivers.

TABLE 3.8: Start time and finish time of trips for each operation.

	Single	**Two-up**
	% trips	
Start time:		
• **0800-1559**	26.7	0
• **1600-1959**	60.0	36.4
• **2000-2359**	13.3	63.6
• **0000-0759**	0	0
Finish time:		
• **0800-1559**	13.3	18.2
• **1600-1959**	20.0	9.1
• **2000-2359**	46.7	18.2
• **0000-0759**	20.0	54.6

Table 3.9 provides a summary of trip characteristics and activities. Not surprisingly, single trips were of significantly longer duration overall ($t_{(35)} = 3.3$, $p<0.002$) than two-up trips. Also not surprisingly, single drivers spent more time in total driving ($t_{(35)} = 8.86$, $p<0.001$) as well as spending a greater proportion of the trip driving ($t_{(35)} = 6.97$, $p<0.001$). In short, the average single trip lasted approximately 5 days and involved the equivalent of 2.6 days of driving. In contrast, the average two-up trip spanned 4 days with each driver spending approximately 1.6 days driving. There was also a tendency for the average length of driving periods during the trip to be slightly longer for single drivers ($t_{(35)} = 1.80$, $p<0.08$) and to be more variable than those for two-up drivers ($t_{(35)} = 4.66$, $p<0.001$).

Examination of the other main aspect of work on the trip for these drivers, loading activities, revealed no differences between single and two-up drivers. Both groups spent just over one fifth of the total trip time in loading activities. Such activities occupied more than one third of time spent in breaks from driving for both groups.

Breaks were defined as periods of longer than 15 minutes that did not involving driving. Nevertheless, breaks from driving could involve work activities. Two-up drivers took significantly fewer breaks from driving than did single drivers ($t_{(35)} = 3.2$, $p<0.003$). However, the total time spent in breaks from driving during the trip did not differ for the two operations. This finding, together with the fact that their total trip time was shorter, indicates that two-up drivers spent a much greater proportion of the trip in breaks ($t_{(35)} = 6.99$, $p<0.001$). On average, two-up drivers also spent longer in each break ($t_{(35)} = 3.5$, $p<0.001$) than single drivers. Since loading work during breaks accounted for an equivalent proportion of break time for both groups, it seems that two-up drivers were able to devote proportionally more time to managing fatigue across the trip and during each break.

Examination of the time spent sleeping on the trip revealed that although the total amount of sleep obtained by both groups did not differ, two-up drivers spent a significantly greater proportion of their total break time asleep ($t_{(19)} = 3.21$, $p<0.005$). The distribution of sleep also differed. Two-up drivers reported obtaining some sleep

TABLE 3.9: Characteristics of the trip for each operation.

	Single	Two-up
Trip duration:		
• **mean hrs** ***(sd)***	117.1 *(18.0)*	98.6 *(16.1)*
Time spent driving:		
• **Total mean hrs** ***(sd)***	61.4 *(7.9)*	39.4 *(7.1)*
• **Mean proportion of trip** ***(sd)***	0.53 *(0.05)*	0.40 *(0.06)*
• **Average driving period means hrs** ***(sd)***	4.5 *(0.9)*	4.0 *(0.6)*
Time spent loading:		
• **Total mean hrs** ***(sd)***	15.6 *(6.7)*	11.8 *(3.9)*
• **Mean proportion of trip** ***(sd)***	0.13 *(0.5)*	0.13 *(0.4)*
• **Mean proportion of breaks involving loading** ***(sd)***	0.37 *(0.15)*	0.4 *(0.20)*
Time spent in breaks:		
• **Total mean hrs** ***(sd)***	55.7 *(12.3)*	59.3 *(12.2)*
• **Total Number taken mean** ***(sd)***	13.3 *(3.6)*	10.1 *(2.6)*
• **Mean proportion of trip** ***(sd)***	0.47 *(0.05)*	0.60 *(0.06)*
• **Average break length mean hrs** ***(sd)***	4.4 *(1.4)*	6.1 *(1.3)*
Time spent sleeping:		
• **Total mean hrs** ***(sd)***	25.1 *(7.7)*	31.1 *(9.0)*
• **Mean proportion of breaks involving sleep** ***(sd)***	0.41 *(0.10)*	0.94 *(0.08)*
• **Mean proportion of total breaktime** ***(sd)***	0.46 *(0.07)*	0.56 *(0.07)*
Average sleep time per break:		
• **Mean hrs** ***(sd)***	5.0 *(1.4)*	3.5 *(0.6)*

in the vast majority of their breaks ($t_{(28)} = 15.66$, $p<0.001$) compared with less than half of breaks for single drivers. However, during breaks where sleep was obtained, the average time spent sleeping in each break was significantly longer for single drivers compared with two-up drivers ($t_{(19)} = 3.31$, $p<0.004$), and the average proportion of each break spent asleep was significantly greater for single subjects than for two-up subjects ($t_{(19)} = 2.63$, $p<0.02$). Thus, sleep was obtained in shorter but more frequent periods for two-up drivers, while single drivers consolidated sleep into fewer but longer periods.

Tables 3.10A and 3.10B show details of the timing of breaks and break activities, break by break across the trip. Most single drivers (75%) completed the trip with 16 or fewer breaks, with a few drivers taking up to 20 breaks, and most two-up drivers (81%) completed the trip with less than 13 breaks, although some drivers took as many as 16 breaks. Initial arrival in Broome, the turnaround point, occurred between breaks 3 and 6 for two-up drivers, and between breaks 5 and 10 for single drivers. However, 12 two-up drivers and 4 single drivers did not immediately turn around after their break in Broome. For these drivers, several further breaks and periods of driving occurred between the initial arrival in Broome and their final, Perth-bound departure from Broome. As a result, these drivers did not begin the homeward leg of their trip until breaks 5 to 12 (two-up) and breaks 7 to 14 (single). Thus, despite the variation in the middle of the trips, the number of breaks taken during the outward (Perth to Broome) and homeward (Broome to Perth) legs of each trip were typically equal.

On average, the longest break periods were taken between breaks 5 to 7 for most single drivers, reflecting the time spent in and around Broome, the turnaround point (see Table 3.10A). Similarly, for most two-up drivers the longer periods were taken at breaks 4 to 5, reflecting their initial arrival in Broome at a relatively earlier point in the trip (see Table 3.10B). There appeared to be greater fluctuation in both break duration and time since last break for single drivers than was the case for two-up drivers.

The pattern of activities during breaks also differed for the two groups. Breaks were classified as involving solely work activities, solely non-work activities (including

TABLE 3.10A: Timing of breaks and break activities for each operation. - Single Drivers

Break Number *	(N)	Time Since Last Break	Duration of Break	Break Start Time 20:00-03:59	Break Activities: Mixed	Work Only	Non Work Only	Sleep
		Mean hrs:min *(sd)*		% Drivers		% Drivers		% Drivers
1	(15)	5:33 *(2:09)*	4:05 *(2:52)*	80.0	40.0	6.7	53.3	60.0
2	(15)	4:13 *(2:00)*	1:50 *(1:38)*	26.6	58.3	8.3	33.3	21.4
3	(15)	5:38 *(3:13)*	1:37 *(1:44)*	26.7	58.3	8.3	33.3	20.0
4	(15)	3:42 *(2:24)*	4:23 *(3:00)*	46.7	50.0	7.1	42.9	50.0
5	(15)	4:52 *(2:46)*	8:38 *(8:37)*	33.3	60.0	13.3	26.7	60.0
6	(15)	4:21 *(2:27)*	8:23 *(9:30)*	26.7	73.3	13.3	13.3	40.0
7	(15)	2:55 *(2:02)*	5:22 *(8:28)*	46.6	46.2	15.4	38.5	40.0
8	(15)	2:52 *(2:15)*	3:30 *(3:40)*	40.0	46.7	13.3	40.0	40.0
9	(14)	4:56 *(3:06)*	4:05 *(3:41)*	35.7	64.3	7.1	28.6	42.9
10	(14)	4:14 *(2:16)*	4:13 *(3:34)*	42.8	30.8	15.4	53.8	38.5
11	(12)	2:47 *(2:19)*	2:53 *(2:40)*	33.3	45.5	18.2	36.4	36.4
12	(10)	3:43 *(2:52)*	1:59 *(1:47)*	10.0	44.4	22.2	33.3	20.0
13	(7)	4:56 *(2:25)*	2:26 *(2:32)*	66.2	28.6	14.3	57.1	28.6
14	(5)	3:17 *(2:00)*	4:21 *(2:28)*	60.0	60.0	0	40.0	40.0
15	(4)	3:55 *(3:07)*	2:53 *(2:45)*	0	50.0	25.0	25.0	0
16	(4)	2:30 *(1:31)*	4:26 *(6:13)*	50.0	75.0	25.0	0	25.0
17	(3)	4:33 *(3:46)*	6:25 *(0:53)*	66.6	50.0	0	50.0	50.0
18	(2)	3:00 *(2:07)*	3:45 *(3:53)*	50.0	50.0	0	50.0	50.0
19	(2)	4:45 *(1:46)*	0:45 *(0:21)*	0	100.0	0	0	50.0
20	(2)	5:30 *(1:25)*	0:45 *(0:21)*	50.0	100.0	0	0	100.0

* Shading denotes the range of breaks corresponding to drivers' initial arrival at Broome

TABLE 3.10B: Timing of breaks and break activities for each operation - Two-up Drivers

Break Number *	(N)	Time Since Last Break	Duration of Break	Break Start Time 20:00-03:59	Break Activities			Sleep
		Mean hrs:min *(sd)*			Mixed	Work Only	Non Work Only	
				% Drivers		% Drivers		% Drivers
1	(22)	4:27 *(2:00)*	4:24 *(1:43)*	81.9	5.0	0	95.0	90.9
2	(22)	3:48 *(1:17)*	4:24 *(1:21)*	13.6	42.9	0	57.1	100.0
3	(22)	3:44 *(0:38)*	5:06 *(2:07)*	9.1	50.0	0	50.0	95.5
4	(22)	3:52 *(1:14)*	7:53 *(8:11)*	68.2	81.8	0	18.2	81.8
5	(22)	4:24 *(1:52)*	9:56 *(10:31)*	31.8	59.1	0	40.9	95.5
6	(22)	3:58 *(2:03)*	6:47 *(5:30)*	31.8	68.2	0	31.8	100.0
7	(22)	3:37 *(1:35)*	6:44 *(5:18)*	40.9	54.5	4.5	40.9	95.5
8	(19)	4:24 *(2:35)*	5:39 *(4:48)*	26.3	36.8	5.3	57.9	89.5
9	(15)	3:31 *(1:23)*	4:13 *(1:32)*	60.0	26.7	0	73.3	100.0
10	(10)	3:32 *(1:39)*	4:13 *(1:37)*	50.0	22.2	0	77.8	100.0
11	(8)	3:26 *(0:42)*	3:48 *(0:51)*	37.5	28.6	0	71.4	100.0
12	(7)	3:02 *(1:19)*	4:04 *(0:35)*	28.6	50.0	0	50.0	100.0
13	(4)	3:19 *(0:54)*	4:28 *(0:32)*	50.0	50.0	0	50.0	100.0
14	(2)	3:00 *(0:00)*	4:00 *(1:25)*	50.0	0	0	100.0	100.0
15	(2)	4:00 *(0:42)*	3:15 *(1:46)*	0	50.0	0	50.0	100.0
16	(1)	3:00 *(-)*	4:30 *(-)*	0	0	0	100.0	100.0

* Shading denotes the range of breaks corresponding to drivers' initial arrival at Broome.

sleep), or a mixture of the two. For single drivers, breaks most commonly consisted of a mixture of work and rest activities whereas for two-up drivers, exclusively non-work breaks were most common. Two thirds of the breaks involved at least half of the single drivers in a combination of work and rest activities, compared with just on half of breaks for two-up drivers. In contrast, only one third of breaks involved exclusively non-work activities for at least half of single drivers, compared with two thirds of breaks taken by two-up drivers. Breaks involving exclusively work activities were rare for both groups, particularly so for two-up drivers.

In general, activities during breaks did not appear to influence their timing for either group. Nor was there any systematic change in break activities across the trip. The average length of the drive period preceding breaks involving exclusively work, exclusively non-work or a mixture of the two was examined. For breaks involving *exclusively work* activities, the average length of the preceding drive period was 3:33 hrs (sd = 3:14) for two-up drivers and 3:45 hrs (sd = 2:00) for single drivers, for breaks involving *exclusively non-work* activities, the average length of the preceding drive period was 4:01 hrs (sd = 0:45) for two-up drivers and 4:07 hrs (sd = 1:06) for single drivers, and for breaks involving a *mixture of work and non-work* activities, the average length of the preceding drive period was 3:42 hrs (sd = 1:00) for two-up drivers and 4:37 hrs (sd = 1:30) for single drivers. Thus, irrespective of activity, breaks were taken after approximately 4 hours of driving by both groups.

Breaks were also examined specifically for the occurrence of sleep. As described earlier, most two-up drivers reported obtaining some sleep on virtually all breaks (see Table 3.10B). In contrast, only one third of breaks involved sleep for at least half of single drivers (see Table 3.10A). However, examination of the relationship between the timing of the breaks and break activity revealed that single drivers were more likely to take breaks including sleep at the biologically appropriate times, compared with two-up drivers. Break start time was categorised for each break to obtain the percentage of drivers for whom the break spanned the midnight to dawn hours. Overall, on just over one third of breaks, at least half of the drivers in each group commenced their breaks between 20:00 and 03:59. For most of the breaks in which single drivers more commonly reported obtaining sleep, the proportion of drivers for whom the break spanned the midnight to dawn hours also increased ($r^2 = 0.62$, $p<0.005$). These also tended to be the longer breaks taken by single drivers ($r^2 = 0.73$, $p<0.001$)).

Clearly, two-up drivers share the driving task in a fairly regulated fashion, alternating at 3 to 4 hourly intervals. This means that at least part of the biologically most vulnerable time of the day is available to each driver for rest. Single drivers, on the other hand seem to regulate the timing of their breaks according to the activities involved. This means presumably attending to the work-related activities on a needs basis, but also allowing the possibility of strategic timing for those breaks which are to include sleep.

Comparison of the trip for the two drivers in the two-up team

There were no substantial differences in the characteristics of the two drivers in each two-up team (Table 3.11). Both drivers were of similar age, marital status and driving experience. The data of major interest however, were those relating to work and rest on the trip.

TABLE 3.11: Comparison of characteristics of the drivers in each two-up pair.

	Driver 1	**Driver 2**
Mean age *(sd)*	40.0 *(8.15)*	34.82 *(7.70)*
Marital status:		
• **% married**	63.6	45.5
• **% defacto**	18.2	27.3
• **%single**	18.2	27.3
Driving experience, mean years *(sd)*	15.32 *(8.44)*	13.45 *(7.53)*

From Table 3.12 it is clear that characteristics of the trip were quite similar for the two drivers. Both the amount of work and rest, and their distribution across the trip were virtually identical for the two drivers. These data further underscore the regulated way in which the two drivers in the team share the work and rest demands of the trip. From the point of view of further analysis of this study, it suggests that the two members of each pair can be considered equivalent, without the need for separate analysis.

Different trip types within each operation

Although the study sought drivers undertaking round trips between Perth and Broome, in fact important differences emerged in the nature of the trips undertaken. These different trip types essentially involved classification of 3 subgroups among the two-up trips. The first two-up group undertook a trip well beyond Broome, before returning to Perth. Their trips were approximately 1/3 longer than trips for the other two-up groups and involved increased driving for both drivers and also a proportionate increase in time spent in breaks. The trip involved a short stop in Broome, essentially to rendezvous with the research team, before these drivers continued to their final destination. Consistent with the other two-up groups, the drivers going beyond Broome undertook loading activities at their final destination before commencing their return journey with a brief stop in Broome. For the drivers in the second and the third groups, the trips went no further than the region around Broome, but they differed substantially in terms of the time spent in Broome and the activities undertaken. For one group, the trip included a long stop-over in Broome, incorporating an overnight rest period for both drivers. In contrast, the drivers in the other group had a relatively short stop-over in Broome, commencing the return leg of the journey once their work in Broome was completed.

Single drivers were essentially a homogeneous group, and required no reclassification. However, in order to further ensure the internal consistency of this group, 2 drivers were removed for all analyses using the four trip types because their trips were

TABLE 3.12: Comparison of trip characteristics for drivers in each two-up team.

	Driver 1	**Driver 2**
Time spent driving:		
• **total mean hours** ***(sd,n)***	39:36 *(6:21, 11)*	39:09 *(8:03, 11)*
• **average driving period mean hrs:min** ***(sd,n)***	3:58 *(0:34, 11)*	4:03 *(0:47, 11)*
Time spent loading:		
• **total hrs:min mean hours** ***(sd,n)***	11:49 *(3:21, 7)*	11:51 *(5:00, 5)*
• **total number of breaks involving loading mean** ***(sd,n)***	3.67 *(2.18, 9)*	4.00 *(2.26, 10)*
Time spent in breaks:		
• **total hrs:min mean** ***(sd,n)***	59:05 *(12:22, 11)*	59:29 *(12:32, 11)*
• **total number taken mean** ***(sd,n)***	9.91 *(2.59, 11)*	10.27 *(2.69, 11)*
• **average break length mean hrs:min** ***(sd,n)***	6:09 *(1:28, 11)*	5:56 *(1:15, 11)*
• **proportion of breaks starting 20:00-03:59 mean** ***(sd,n)***	0.44 *(0.14, 11)*	0.36 *(0.06, 11)*
Time spent sleeping:		
• **total hrs:min mean hours** ***(sd,n)***	29:53 *(8:57, 7)*	33:07 *(10:05, 4)*
• **total number of breaks involving sleep mean** ***(sd,n)***	8.67 *(2.50, 9)*	9.60 *(2.88, 10)*
• **average sleep time per break, mean hrs:min** ***(sd,n)***	3:24 *(0:29, 11)*	3:06 *(0:43, 11)*
• **mean proportion of breaks involving sleep** ***(sd,n)***	0.93 *(0.10, 9)*	0.94 *(0.06, 10)*

considered to be outliers in terms of distance covered by single drivers in the sample. One driver completed only two thirds of the trip to Broome before returning to Perth, and the other driver went one third again further than Broome.

Table 3.13 summarises the characteristics of each of the different trip types. Differences among the four trip types were analysed using ANOVA, with group differences contributing to significant effects being identified using a modified least-significant-difference test, including the Bonferroni correction for multiple comparisons to maintain the Type I error rate at 0.05.

<u>**TABLE 3.13:**</u> Characteristics of the trip for each trip type.

	Single (N=13)	**Two-up, Beyond Broome** (N=8)	**Two-up, Long Broome** (N=6)	**Two-up, Short Broome** (N=8)
Trip duration: • **mean hrs** ***(sd)***	119.0 *(8.4)*	115.2 *(4.8)*	102.1 *(2.5)*	79.5 *(3.5)*
Time spent driving: • **total mean hrs** ***(sd)***	61.7 *(4.6)*	46.0 *(3.0)*	36.8 *(6.8)*	34.7 *(5.2)*
Time spent in breaks: • **total mean hrs** ***(sd)***	57.3 *(7.9)*	69.2 *(4.9)*	65.3 *(5.8)*	44.9 *(3.8)*
• **total number taken mean** ***(sd)***	12.8 *(3.3)*	13.0 *(1.7)*	8.8 *(1.2)*	8.1 *(0.8)*
• **proportion of total trip time mean** ***(sd)***	0.48 *(0.04)*	0.60 *(0.03)*	0.64 *(0.06)*	0.57 *(0.06)*
Broome turnaround interval: • **mean hrs** ***(sd)***	20.7 *(7.7)*	50.8 *(5.8)*	28.8 *(1.4)*	10.5 *(4.2)*

Trip duration differed significantly among the four groups ($F_{(3,31)} = 82.06$, $p < 0.001$). Drivers in the two-up group going beyond Broome and drivers in the single group did not differ in terms of trip duration, but their trips were of longer average duration than those completed by the other two-up groups. Total trip hours for drivers in the two-up group who had a long Broome stop were significantly longer than those for drivers who had a short Broome stop.

The total hours spent driving also differed significantly among the four groups ($F_{(3,31)}$= 64.68, p<0.001). Drivers in the single group spent more hours driving than drivers in two-up groups. However, drivers in the two-up group going beyond Broome spent significantly longer total hours driving than did either of the other two-up groups, which did not differ.

Given the differences in trip durations, the time spent in breaks also varied significantly among the four groups, both in terms of the mean number of breaks taken during the trip ($F_{(3,31)}$ = 10.77, p=0.0001) and also in the total time spent in breaks ($F_{(3,31)}$ = 23.43, p<0.001). Essentially, the shorter trips involved fewer breaks. Post hoc comparisons revealed that the total break hours taken by drivers in the two-up short Broome stop group were less than those taken by either the two-up group going beyond Broome or those taken by the two-up long Broome stop group. The latter two groups did not differ. Drivers in the single group took significantly less total break hours than the two-up group going beyond Broome, more total break hours than the group with a short Broome stop, and were no different to the two-up group with a long Broome stop.

More informatively, analysis of the proportion of total trip time spent in breaks revealed different patterns of work and rest between the groups (see Table 3.13; $F_{(3,31)}$ = 20.35, p<0.0001). Post hoc comparisons (least significant difference tests with Bonferroni correction) revealed that the two-up group going beyond Broome did not differ significantly from either of the other two-up groups. This indicates that despite covering considerably greater distances, the group going beyond Broome, on average, maintained a work/rest ratio across the whole trip which resulted in proportionally similar amounts of rest being obtained as was the case for the other two-up drivers. Those with a long stop in Broome spent a significantly greater proportion of the trip in breaks than did two-up drivers with a short stop in Broome, simply reflecting the long versus short stop as part of a trip of similar duration for the two groups with Broome turnaround point. Most obviously, two-up drivers spent a greater proportion of their trips in breaks than single drivers. Two-up drivers appear to maintain a pattern of work and rest, irrespective of distance travelled, that is different to the pattern maintained by single drivers.

Finally, the trips undertaken by the four groups differed in the amount of time that elapsed between the end of the outbound leg of the trip from Perth to Broome, and the commencement of the homeward leg of the trip, from Broome to Perth. This interval is termed the Broome turnaround interval in Table 3.13. For all drivers, the interval involved work activities as well as rest, with extended driving only being undertaken by the two-up group going beyond Broome. The duration of the interval differed significantly among the four trip types ($F_{(3,31)} = 68.84$, $p<0.001$), reflecting the different operational practices under which the drivers were working. The two-up group with a short Broome stop did indeed have a significantly shorter Broome turnaround interval than the other two-up groups and also shorter than the single group. The two-up group going beyond Broome had a significantly longer interval than both two-up groups with a Broome destination, and also longer than the single group. The single group and the two-up long Broome stop group did not differ.

In summary, the four trip types involved reliable differences along dimensions of considerable operational importance. These differences represent important points of comparison between single and two-up operations, and between different aspects of two-up operations. The two-up group going beyond Broome had relatively longer total trip hours and relatively greater total driving hours but not proportionally greater total break time, compared with the other two-up groups. In terms of trip duration and hours spent driving, this group was more similar to the single group than to the other two-up groups. The two-up group with a long Broome stop had relatively longer total trip duration with proportionally more time spent in breaks over the trip, and proportionally less time spent in driving, compared with the other two-up groups. In terms of the Broome interval, this group was more similar to single drivers than to the other two-up groups, with a similar time spent in the turnaround interval and the inclusion of an overnight rest period during the interval. The two-up group with a short Broome stop had the shortest total trip duration, but also spent a smaller proportion of the trip in breaks than the other two-up groups. This pattern of differences among the trip types allowed examination of the impact on drivers of three important trip parameters: total trip hours, total driving hours and proportion of time spent in breaks over the trip.

Inspection of Table 3.14 reveals that for both work patterns and rest patterns, drivers in the two-up groups were similar. Statistical analysis confirmed that the differences in work and rest patterns for the previous week were those already discussed, that is differences between single drivers and two-up drivers overall. Essentially, therefore, the main finding regarding recent work and rest patterns was that single drivers obtained a greater proportion of their rest at night in the previous week.

COMPARISON OF TYPE OF OPERATION AND TYPE OF TRIP

Classification of type of operation and type of trip

Analysis of the data obtained in this study about the impact of the trip on drivers involved classification of drivers in two-ways. First, the influence of the ***type of operation*** driven, two-up or single, was examined. The major focus of the present study was to examine the differences between single and two-up operations as general operational strategies for covering long distances in remote zones.

Second, the influence of differences in ***type of trip*** undertaken were also investigated. As described earlier, two-up trips fell into one of three quite distinct categories: those drivers for whom the trip went substantially beyond Broome, those drivers for whom the trip included a long stop in Broome before commencing the homeward leg of the journey, and those drivers for whom the trip included a short stop in Broome prior to

TABLE 3.14: Work and rest in the previous week by drivers doing each trip type.

	Single	Two-up, Beyond Broome	Two-up, Long Broome	Two-up, Short Broome
WORK	(N=12)*	(N=5)**	(N=6)	(N=8)
Mean total hours *(sd)*	79.2 *(32.2)*	67.2 *(26.3)*	67.5 *(21.6)*	64.7 *(13.2)*
Driving:				
• **Mean total hours *(sd)***	48.0 *(24.1)*	38.0 *(18.8)*	36.8 *(13.6)*	31.2 *(18.1)*
• **Mean night hours *(sd)***	18.9 *(10.5)*	20.3 *(8.3)*	23.3 *(11.4)*	18.6 *(12.4)*
REST	(N=11)*	(N=5)**	(N=6)	(N=8)
Mean total hours *(sd)*	43.4 *(5.0)*	52.6 *(10.1)*	53.8 *(12.9)*	45.8 *(8.4)*
Night rest:				
• **Mean total hours *(sd)***	41.2 *(4.4)*	38.0 *(8.6)*	39.5 *(10.0)*	35.5 *(8.4)*
• **Mean number of periods *(sd)***	6.6 *(0.7)*	7.8 *(2.7)*	8.2 *(1.5)*	7.1 *(1.6)*
Day rest:				
• **Mean total hours *(sd)***	2.4 *(3.7)*	14.5 *(5.1)*	14.3 *(5.4)*	10.0 *(7.7)*
• **Mean number of periods *(sd)***	1.6 *(1.2)*	4.6 *(2.3)*	4.7 *(1.4)*	3.5 *(2.5)*
Mean proportion of rest taken at night *(sd)*	0.95 *(0.06)*	0.76 *(0.10)*	0.76 *(0.07)*	0.79 *(0.18)*

N reduced due to:
* drivers provided inadequate data for coding
** drivers on annual leave/sick leave.

the return journey to Perth. Although trips for single drivers were reasonably consistent, two outlier trips (described earlier) were always excluded from the single group in the analyses examining types of trips. This classification provided the basis for comparison of entirely equivalent two-up and single trips, which all turned around in Broome.

Data reduction

The large body of data obtained was reduced for analysis by selecting meaningful milestones in the trip as points of comparison between the groups of drivers. The milestones were defined in two ways. First, because exact trip chronology varied from driver to driver, and from team to team, it was essential to define points in the trip which occurred for all drivers, to provide a basis for effective comparison. Four major trip milestones were defined. These were at the beginning of the trip, arrival at and departure from Broome, and the end of the trip. The first two define the beginning and the end of the outward leg of the trip (Perth to Broome), while the latter two define the beginning and the end of the homeward leg of the trip (Broome to Perth).

The milestones at arrival in and departure from Broome have been labelled throughout as *Before Broome* and *After Broome*. As described in the method section, arrival at and departure from Broome are more accurately described as the beginning of the break from driving taken at or near Broome, and end of the break taken before leaving Broome. Conceptually, these milestones reflect the end of driving for each driver before Broome, and the beginning of driving after Broome. However, the end of this break occurred early in the homeward journey, after actually leaving Broome, for half of the two-up drivers. Therefore, there was some variation about the actual timings, due to one driver resting while the other drove.

More importantly, however, it should be recalled that trips diverged in significant ways after arrival at Broome. Although the time between arrival at and departure from Broome involved both work and rest activities for all drivers, the ways in which these activities occurred differed. Single drivers had a break incorporating overnight rest.

This was also the case for the two-up group with a long Broome stop, with both drivers in each pair obtaining overnight rest in Broome and the overall time spent in Broome being similar to that spent by single drivers. For the two-up group with a short stop the pattern of alternating work and rest between drivers, with all rest being taken in the vehicle, continued throughout the trip, and Broome was simply another stop during the trip. This was also the case for the two-up group going beyond Broome. However, for this group, the trip was extended beyond Broome so that the time between Broome arrival (on the outward leg of the trip) and departure (on the homeward leg of the trip) was substantially increased. Despite this increase in total time, the ratio of work to rest remained unchanged. The measurement milestones before and after Broome therefore provided an important basis for comparing the influences of the different trip types.

Under the second method used to define milestones in the data, epochs for analysis were determined on a driver by driver basis, using the data across the whole trip. This involved sequential ordering of measurement periods from the start of the trip for each driver. Subjective evaluations of fatigue obtained before and after each break from driving were analysed, break by break, for each driver. Similarly, the data collected during driving were analysed, driving period by driving period, for each driver. For these analyses, data were aggregated on the basis of relative chronology. For example, the first break or driving period for each driver was aggregated, and so on for each period in the trip. Therefore, although the actual timing at which these epochs occurred varied from driver to driver, the relative ordering was consistent. In this way, the changes in driver functioning could be examined for groups of drivers on an episode by episode basis across the entire trip.

Experiences of fatigue during the trip

1. Comparison of fatigue at beginning of trip, turnaround point and end of trip milestones

The results for the two methods used for assessing drivers' subjective state of fatigue, the Stanford Sleepiness Scale (SSS) and the Visual Analogue Scales (VAS), at the four major milestones and for each trip type were examined. For analysis, the three visual analogue scales were averaged. Fully orthogonal repeated measures multivariate analysis of variance was used to compare the operations, two-up and single, over the four milestones in the trip. Differences over the course of the four milestones were examined using 3 tests of trend (linear, quadratic and cubic). All interactions were also tested. In all, 9 planned comparisons were made between operations using critical values for alpha (type I error rate) adjusted according to the Modified Bonferroni correction method (Keppel, 1982, pp. 147-149). This resulted in a corrected significance level of 0.03 for evaluating comparisons of reported subjective fatigue between operations.

The adjustment of the significance level with the Bonferroni correction in these and subsequent analyses acknowledges that whenever a number of comparisons are conducted on a set of means, the type I error rate is inflated to some extent. However, the correction introduces considerable conservatism into the analysis. It must also be acknowledged, on the other hand, that the data collected in this study are exploratory, being the first such data collected in Australia. To avoid the risk of missing important implications in the results those findings approaching significance at the uncorrected level (0.05) have been signalled as trends, worthy of note, although not statistically significant (Keppel, 1982).

Differences in fatigue ratings between the four trip types (single, two-up beyond Broome, two-up long Broome stop and two-up short Broome stop) were also evaluated using repeated measures multivariate analysis of variance. The same orthogonal trend comparisons were used to compare ratings by drivers at the milestones in the trip. Three non-orthogonal group comparisons were included to compare the trip types: The first compared the two-up group for whom trips were much longer in terms of both trip time and driving time (two-up, beyond Broome) against the average of the remaining two-up groups (two-up, long Broome stop and two-up, short Broome stop). The second contrast compared the single group (all of whom turned around in Broome, as describer earlier) against the average of the two-up groups going no further than Broome (two-up, long Broome stop and two-up, short Broome stop). The third contrast compared the long Broome stop with the short Broome stop group. To conserve statistical power, subjective fatigue reported by the single group was not compared directly to the two-up group going beyond Broome in this analysis. In all, 18 planned comparisons were made resulting in a corrected significance level of 0.016, using the Modified Bonferroni correction (Keppel, 1982).

Table 3.15 and 3.16 show results for the 7- point Stanford Sleepiness Scale (SSS) for type of operation and type of trip, respectively. Analysis, by type of operation, of mean ratings of alertness reported on the SSS at each of the four trip milestones revealed a near significant multivariate effect of point in trip ($F_{(1,34)} = 4.17$, $p=0.04$). All main effects for type of operation and all interactions were non-significant. Table 3.15 shows that the proportion of drivers reporting their alertness at or above category 3, where they are reporting not being at full alertness, increased among single drivers from 35.7% before the trip to just over 57.2% at the end of the trip, whereas the proportion of two-up drivers did not change substantially (41.9% at pre-trip compared with 40.9% at post-trip). However, the percentage of drivers giving ratings at or above category 3 seemed to peak much earlier in two-up trips than in single trips, with the peak occurring before Broome for two-up drivers but not until the post-trip milestone for single drivers (Figure 3.1).

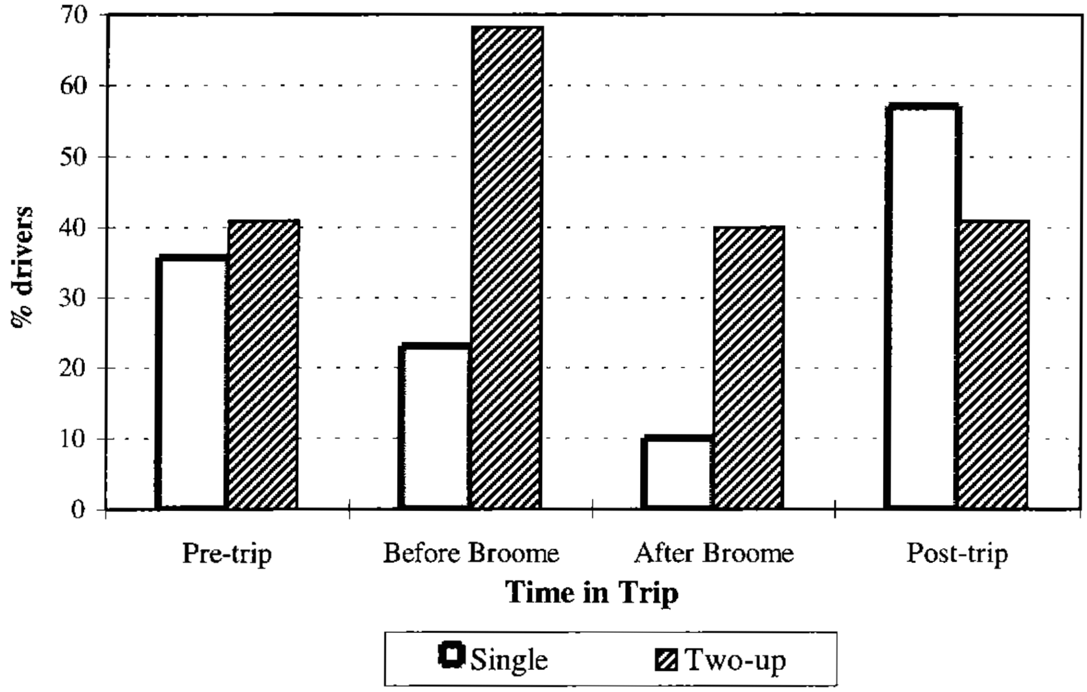
TABLE 3.15: Reported alertness of drivers in each operation at milestones in the trip- Stanford Sleepiness Scale.

OPERATION TYPE	FATIGUE RATING	PRE-TRIP	BEFORE BROOME	AFTER BROOME	POST-TRIP
		% Drivers			
	1	35.7	46.2	40.0	14.3
	2	28.6	30.8	50.0	28.6
Single (N=15)	3	21.4	7.7	0	28.6
	4	14.3	7.7	10.0	14.3
	5	0	0	0	14.3
	6	0	0	0	0
	7	0	0	0	0
	1	18.2	18.2	25.0	18.2
	2	40.9	13.6	35.0	40.9
Two-up (N=22)	3	36.4	40.2	10.0	18.2
	4	4.5	9.1	20.0	13.6
	5	0	0	10.0	9.1
	6	0	0	0	0
	7	0	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.

FIGURE 3.1: The percentage of drivers in each operation rating their alertness at or above category 3 on the Stanford Sleepiness Scale, at each milestone in the trip.



No significant differences were found between the trip types for mean ratings on the SSS at each trip milestone (Table 3.16). Inspection of the pattern of ratings made by drivers doing each trip type (Figure 3.2) suggests that drivers in the group going beyond Broome reported alertness to be waning (at or above category 3) more frequently at points after Broome, but not before, compared with the other two-up groups. In contrast, among drivers stopping at Broome for either short or long periods the proportion reporting alertness levels at or above category 3 decreased after Broome. The frequency of drivers reporting alertness as waning dropped by 75% for the long stop group and by just over 40% in short stop group. Even fewer drivers in the short stop group reported waning alertness at post-trip, with only one tenth of the drivers in the group rating alertness at or above category 3. Among all other groups, alertness waned at post-trip. Thus, the pattern of ratings suggests that changes in subjective alertness did not follow the same pattern for drivers in each operation, or for drivers doing each trip type. The pattern of ratings for single drivers differed to those of two-up drivers throughout the trip, while differences among two-up drivers emerged after Broome.

TABLE 3.16: Reported alertness of drivers doing each trip type at milestones in the trip- Stanford Sleepiness Scale.

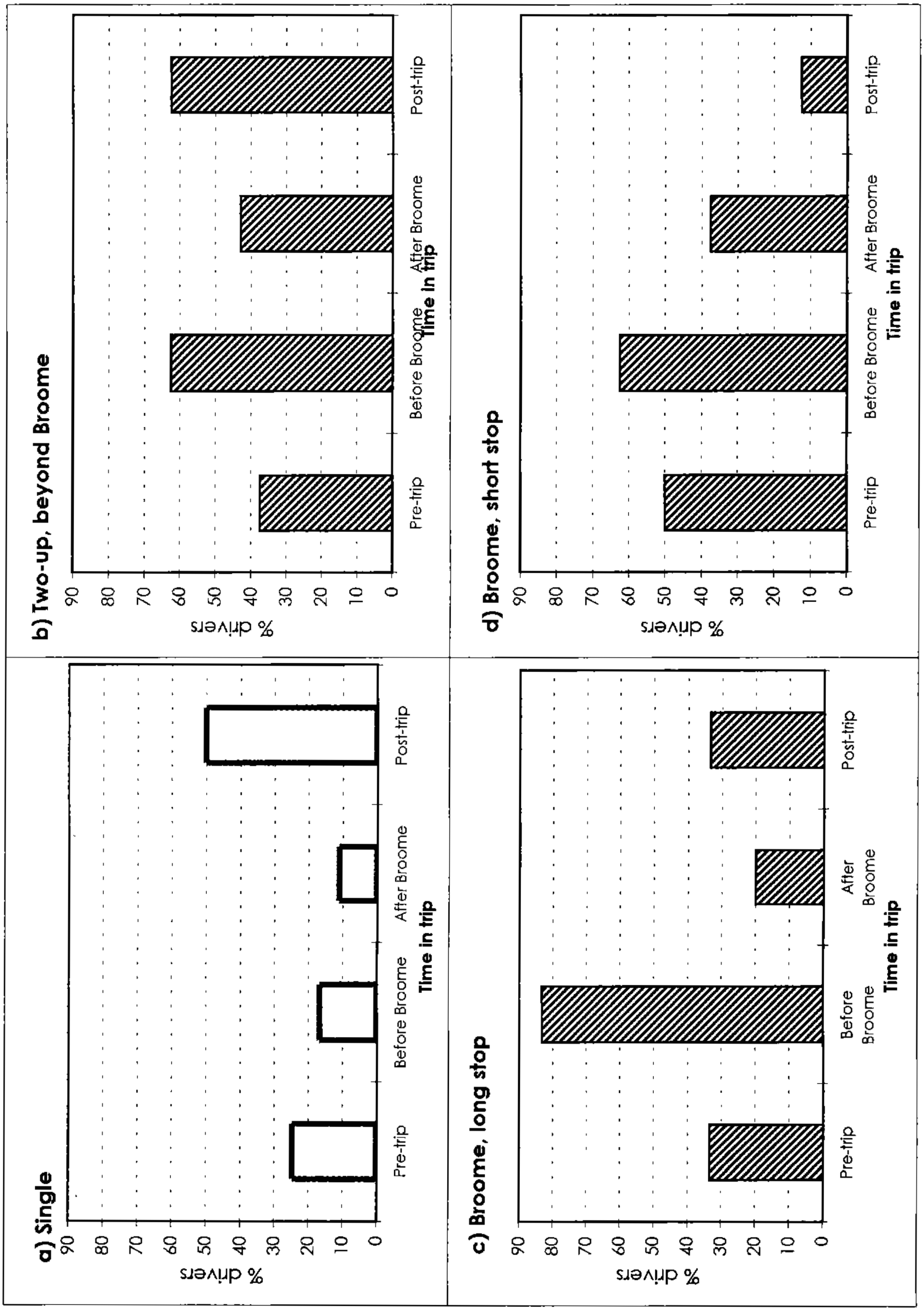
OPERATION TYPE	FATIGUE RATING	PRE-TRIP	BEFORE BROOME	AFTER BROOME	POST-TRIP
			% Drivers		
	1	41.7	50.0	33.3	16.7
	2	33.3	33.3	55.6	33.3
	3	16.7	0	0	25.0
Single*	4	8.3	8.3	11.1	16.7
	5	0	0	0	8.3
(N=13)	6	0	8.3	0	0
	7	0	0	0	0
	1	50.0	25.0	14.3	0
Two-up,	2	12.5	12.5	42.9	37.5
Beyond	3	37.5	37.5	14.3	37.5
Broome	4	0	12 5	14.3	25.0
	5	0	12.5	14 3	0
(N=8)	6	0	0	0	0
	7	0	0	0	0
	1	0	16.7	40.0	33.3
Two-up,	2	66.7	0	40.0	33 3
Long Broome	3	16.7	50.0	0	0
Stop	4	16.7	33.3	20.0	0
	5	0	0	0	33.3
(N=6)	6	0	0	0	0
	7	0	0	0	0
	1	0	12.5	25.0	25.0
Two-up,	2	50.0	25.0	25.0	50.0
Short Broome	3	50.0	37.5	12.5	12.5
Stop	4	0	12.5	25.0	12.5
	5	0	12.5	12.5	0
(N=8)	6	0	0	0	0
	7	0	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.

* Drivers going beyond Broome or not reaching Broome were omitted.

FIGURE 3.2: The Percentage of drivers doing each trip type rating their alertness at or above category 3 on the Stanford Sleepiness Scale, at each milestone in the trip.



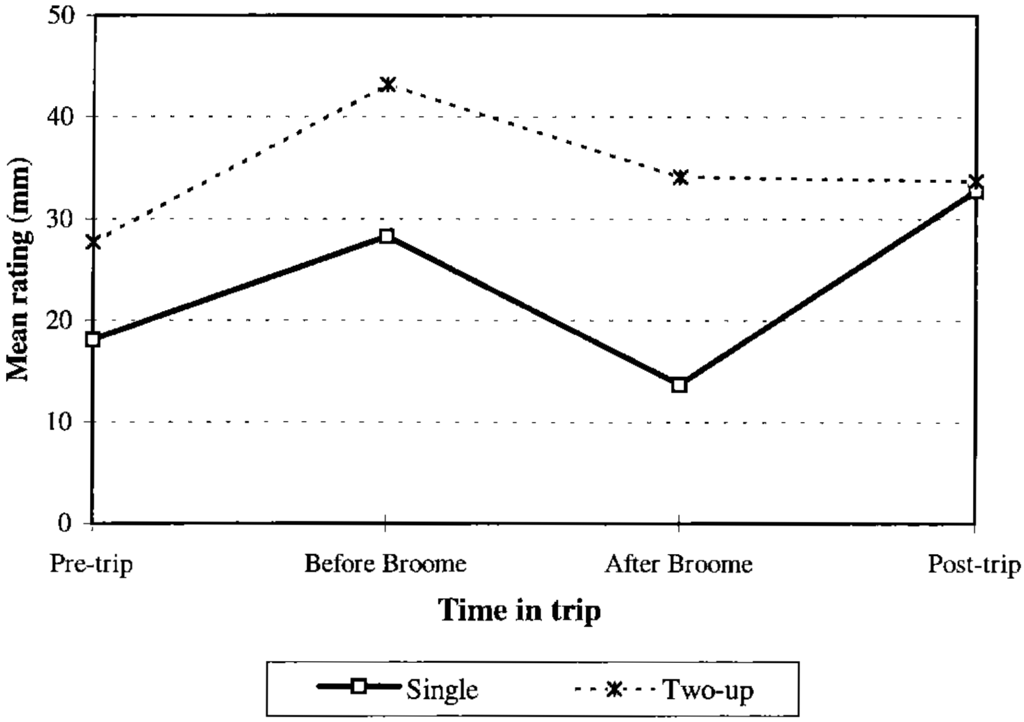
The trends identified in the SSS ratings were amplified by the findings for the other subjective measure of fatigue, the visual analogue scales (Table 3.17 and Table 3.18). For analysis, the ratings on the three scales were averaged. The results for the averaged ratings are presented in Figure 3.3 for each operation and Figure 3.4 for each trip type.

TABLE 3.17: Ratings on the Visual Analogue Scales at milestones in the trip for drivers in each operation (higher numbers indicate greater fatigue).

OPERATION TYPE	SCALE	PRE-TRIP	BEFORE BROOME	AFTER BROOME	POST-TRIP
		Mean *(sd)*			
Single (N=15)	**Tired**	22.1 *(22.4)*	33.4 *(30.9)*	14.0 *(11.7)*	44.1 *(21.6)*
	Muzzy	17.3 *(18.5)*	25.8 *(28.5)*	12.8 *(10.3)*	33.0 *(23.2)*
	Drowsy	23.2 *(17.9)*	23.3 *(22.5)*	14.2 *(10.2)*	31.1 *(14.1)*
Two-up (N=22)	**Tired**	32.4 *(18.3)*	47.6 *(26.8)*	38.1 *(31.5)*	38.0 *(21.2)*
	Muzzy	23.5 *(14.9)*	39.6 *(22.2)*	30.9 *(24.1)*	31.4 *(17.4)*
	Drowsy	29.3 *(17.1)*	41.1 *(21.9)*	33.2 *(25.8)*	34.2 *(17.9)*

Analysis of changes in alertness reported by drivers in each operation across the four trip milestones (Figure 3.3) revealed a significant multivariate effect of operation ($F_{(1,30)} = 6.97$, p=0.013), a near significant multivariate effect for trip milestone ($F_{(3,28)} = 3.30$, p=0.035), but no multivariate interaction effect between these factors. Univariate comparisons revealed a significant cubic trend in the data across the measurement occasions ($F_{(1,30)} = 6.54$, p=0.016). As Figure 3.3 shows, for all but the post-trip milestone, single drivers were consistently lower raters of fatigue than two-up drivers. The analysis confirmed that the changes in reported current state of fatigue did not show a simple linear relationship for either operation. As the significant cubic trend

<u>FIGURE 3.3:</u> Averaged ratings on the Visual Analogue Scales at milestones in the trip for drivers in each operation type.



suggests, drivers in both groups reported a similar magnitude of increase in fatigue over the first leg of trip, from Perth to Broome. Fatigue then decreased after the Broome interval for both operations, and, at the end of the trip, levels of fatigue were either at the same level as reported after Broome, or were increased.

Analysis of the impact of different trip types on reported fatigue across the four milestones revealed a trend towards effect for type of trip ($F_{(3,27)} = 3.10$, $p=0.043$), a trend towards effect of trip milestone ($F_{(3,25)} = 2.88$, $p=0.056$) and a significant multivariate interaction effect between trip milestone and trip type ($F_{(9,71)} = 2,48$, $p=0.016$). Univariate comparisons revealed a trend towards a main effect for the single group compared to the two-up groups going no further than Broome ($t_{(30)} = 2.2$, $p=0.037$). The main effect for cubic trend approached significance ($F_{(1,27)} = 6.39$, $p=0.018$). Univariate comparisons also revealed that there was a significant interaction of type of trip with linear trend ($F_{(3,27)} = 6.04$, $p=0.003$). In particular, the linear trend for the group going beyond Broome was significantly different to that for the

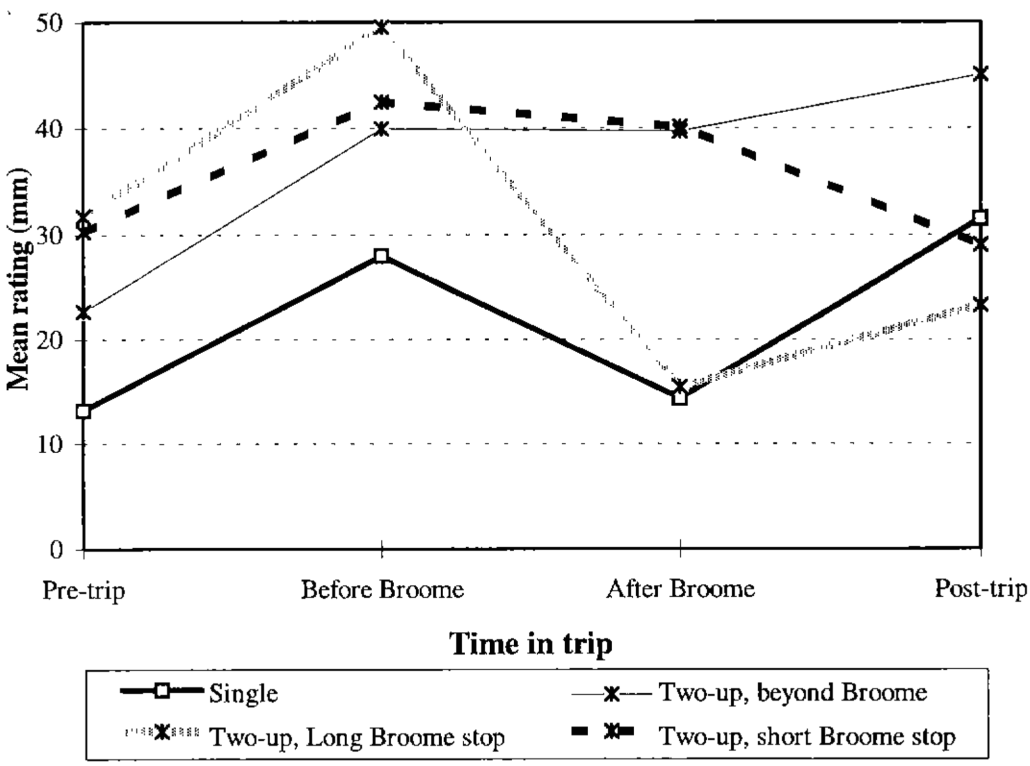
TABLE 3.18: Ratings on the Visual Analogue Scales at milestones in the trip for drivers doing each trip type (higher numbers indicate greater fatigue).

TRIP TYPE	**SCALE**	**PRE-TRIP**	**BEFORE BROOME**	**AFTER BROOME**	**POST-TRIP**
		Mean *(sd)*			
Single (N=13)	**Tired**	18.3 *(16.5)*	33.8 *(33.2)*	14.8 *(12.0)*	27.8 *(24.5)*
	Muzzy	13.8 *(13.8)*	25.2 *(29.7)*	13.2 *(10.8)*	12.8 *(11.9)*
	Drowsy	18.2 *(13.3)*	22.8 *(23.4)*	15.1 *(10.3)*	10.8 *(13.0)*
Two-up, Beyond Broome (N=8)	**Tired**	19.8 *(18.7)*	42.8 *(28.5)*	42.1 *(30.0)*	50.1 *(13.4)*
	Muzzy	19.9 *(19.6)*	38.5 *(25.6)*	35.3 *(19.4)*	40.3 *(13.1)*
	Drowsy	28.4 *(23.6)*	38.5 *(25.9)*	38.6 *(28.1)*	44.5 *(15.7)*
Two-up, Long Broome Stop (N=6)	**Tired**	47.0 *(12.6)*	57.8 *(31.8)*	23.6 *(39.0)*	32.5 *(30.5)*
	Muzzy	24.0 *(11.4)*	37.2 *(23.9)*	7.8 *(5.9)*	22.8 *(24.4)*
	Drowsy	29.5 *(10.5)*	45.3 *(22.4)*	15.0 *(20.0)*	29.0 *(23.0)*
Two-up, Short Broome Stop (N=8)	**Tired**	34.0 *(13.2)*	44.6 *(22.2)*	40.0 *(29.1)*	30.0 *(15.5)*
	Muzzy	26.6 *(12.7)*	42.4 *(20.1)*	41.0 *(27.3)*	29.0 *(12.3)*
	Drowsy	30.1 *(15.4)*	40.6 *(19.8)*	39.3 *(24.1)*	27.9 *(12.4)*

remaining two-up groups ($t_{(30)} = 3.84$, $p<0.0007$), as was the linear trend for the single group ($t_{(30)} = 3.06$, $p<0.005$). The two-up short stop and long stop groups did not differ significantly from each other.

These results confirm that the four trip types did not differ substantially before Broome, with fatigue increasing at a similar rate for all drivers across this leg of the trip (Figure 3.4). During the Broome interval, single drivers, achieved considerable recovery of alertness, with increased fatigue being reported again at the end of the trip at levels considerably above those reported at pre-trip. At all points other than post-trip, single drivers reported lower levels of fatigue than two-up drivers in the two Broome stop groups. Both the two-up group with a long stop and the group with a short stop achieved some recovery after the Broome interval, with their ratings not significantly different on any comparison. At post-trip, both groups reported that their levels of fatigue remained at about pre-trip levels. In contrast to the other two-up groups, the group going beyond Broome, rated their level of fatigue as little or no lower at the end of the Broome interval than before it. Like the single group, increases in fatigue levels were reported at the end of the trip by this group, with levels reported well above those at the beginning of the trip.

<u>FIGURE 3.4:</u> Averaged ratings on the Visual Analogue Scales at milestones in the trip for drivers doing each trip type.



As with the SSS, fatigue at the beginning of the trip was reported at a much lower level for single drivers than for two-up drivers. There were also differences among the two-up groups. Analysis of variance using pre-trip fatigue levels as a covariate revealed that ratings at the beginning of the trip were not significantly related to group differences in the pattern of subsequent fatigue ratings. The lower fatigue levels at the outset for single drivers suggests that they were better rested at the outset of the trip, most likely reflecting the earlier findings that these drivers obtained a greater proportion of rest in the previous week at night, were less likely to have engaged in loading activities immediately prior to the trip, and tended to start their trips earlier in the evening, at a less vulnerable time for the human circadian system.

In summary, the results of the two methods for assessing subjective fatigue indicated that different activities undertaken by the four groups during the Broome interval appeared to have very different impact. For single drivers, fatigue was higher at the end of each leg of the journey, compared with the beginning but substantial recovery occurred during the Broome interval. However, recovery was not fully maintained with final fatigue levels being higher than initial ones. Two-up drivers having a long or short stop in Broome showed a similar pattern of findings for the first leg of the trip with fatigue levels increasing before Broome. However, reported fatigue for two-up drivers going only as far as Broome differed to that for the single group on the return leg of the trip. Some recovery of alertness was reported by these drivers after the Broome interval but without substantial deterioration over the return trip, with final fatigue levels being reported at much the same levels as at the beginning of the trip. A completely different pattern was reported by two-up drivers going beyond Broome. It should be recalled that for these drivers, the Broome interval involved extended driving time, with rest taken at the same relative proportion as at for the rest of the trip and at the same relative proportion as taken by the other two-up groups. After the expected increase in fatigue levels at the end of the first leg of the trip, drivers going beyond Broome reported little or no recovery of alertness over the Broome interval, and fatigue levels continued to increase for these drivers to levels well above pre trip levels.

2. Changes in fatigue experience break by break across the trip

Figure 3.5 shows the proportion of drivers in each operation reporting waning levels of alertness on the SSS (at or above category 3) at the beginning of each break taken over the trip, while Table 3.19 shows changes in tiredness after each break. The actual ratings are provided in Appendix 4. Breaks were defined as periods, spanning at least 15 minutes, when a driver was not driving the main trip route. On most breaks, one third to one half of drivers reported that their alertness was waning at the beginning of the break. From break 5 to break 12, a greater proportion of two-up drivers (closer to one half of drivers) rated themselves at least in category 3, compared with single drivers (closer to one third of drivers). From break 12 onwards at least one half of single drivers also rated themselves in category 3 of the SSS. These results would suggest a cumulative effect reflected fairly late in the trip for single drivers. For two-up drivers, it seems that the levels of fatigue were more constant at a higher level across the trip.

Table 3.19 provides information about the recovery rate reported by drivers taking each break. Change in SSS rating, before each break compared with after each break, is shown. For the first 8 breaks, similar proportions of drivers in each operation reported increased alertness on the SSS after the break. After break 8, an increasing proportion of two-up drivers reported that alertness did not improve after the break. In fact, the proportion of two-up drivers for whom alertness deteriorated after the break increased steadily after break 8. The proportion of single drivers reporting decreased alertness after the break was consistently low.

A similar pattern of results was found for the other measure of fatigue, the visual analogue scales. Figure 3.6 shows the ratings for drivers in each operation before and after each break trip, while Figure 3.7 shows the ratings for drivers doing each trip type. The actual ratings are shown in Appendix 4. Examination of the difference between the ratings for each break revealed that the utility of breaks deteriorated after break 8 for two-up drivers overall, and tended to fluctuate after break 15 for single drivers overall (Figure 3.6).

FIGURE 3.5: Percentage of drivers rating fatigue at category 3 or higher on Stanford Sleepiness Scale at the beginning of each break across the trip.

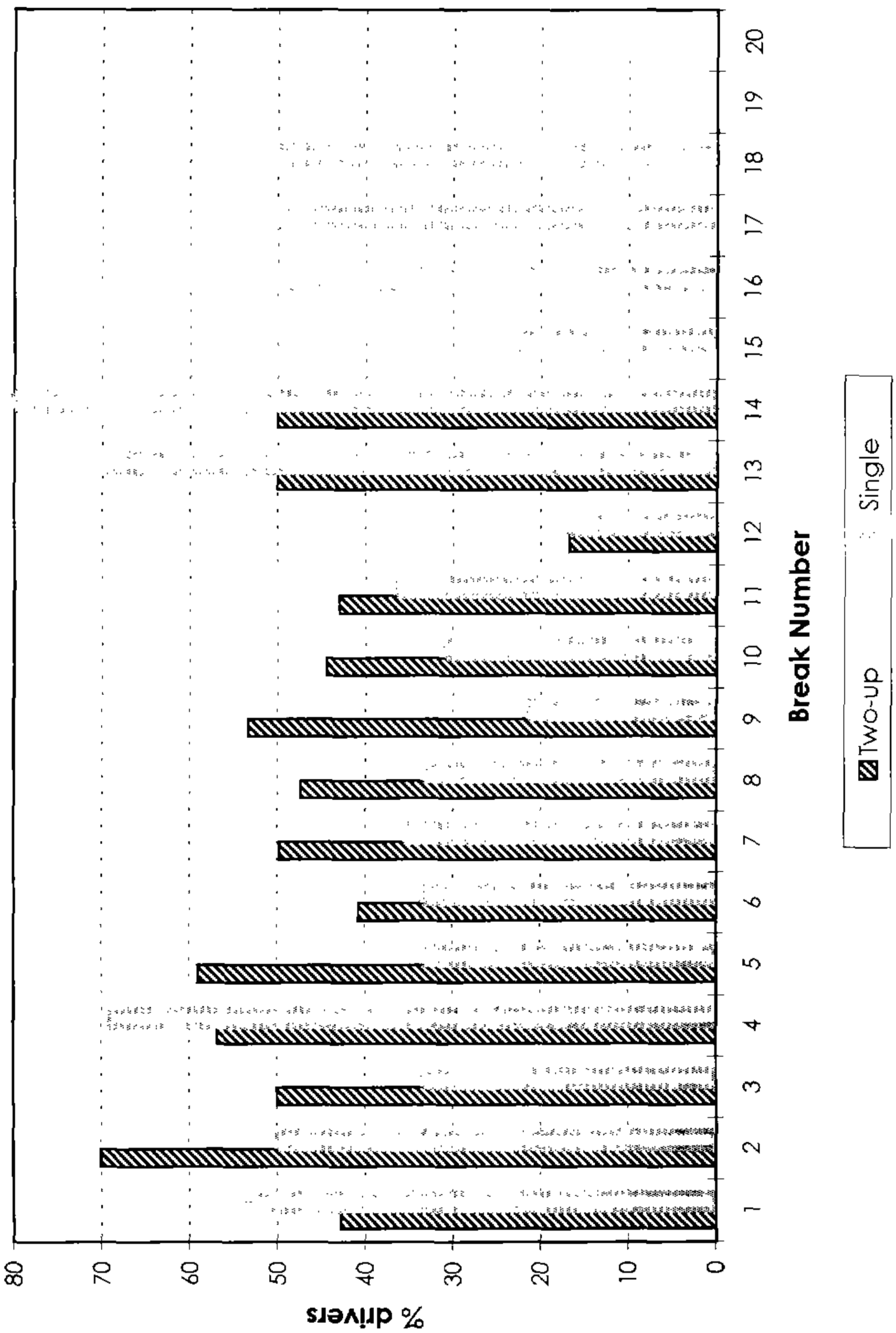


TABLE 3.19: Change in reported alertness on Stanford Sleepiness Scale for drivers in each operation after each break in the trip .

Operation Type	Change Fatigue Rating*	BREAK NUMBER (% Drivers) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	5	7	0	0	8	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	14	0	7	0	7	0	0	0	17	0	0	0	0	50	0	0
	3	7	0	0	8	7	7	0	0	0	8	10	0	0	40	0	0	0	0	0	0
	2	20	17	13	31	14	7	14	20	14	15	0	10	17	0	0	25	50	0	0	0
	1	7	25	13	8	14	14	0	40	43	8	20	20	33	40	25	0	0	50	0	0
SINGLE	0	40	58	67	31	50	50	64	27	36	54	70	70	17	20	50	75	0	0	100	100
	-1	20	0	7	8	0	7	14	13	0	8	0	0	17	0	25	0	50	0	0	0
	-2	0	0	0	8	0	7	0	0	0	8	0	0	0	0	0	0	0	0	0	0
	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-
	4	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-
	3	5	10	10	0	10	5	10	0	0	0	0	0	0	0	0	0	-	-	-	-
	2	15	20	19	29	25	29	20	6	0	13	0	0	0	0	0	0	-	-	-	-
	1	20	40	29	5	15	10	25	39	33	13	33	17	50	50	0	0	-	-	-	-
TWO-UP	0	40	20	24	52	35	52	30	33	40	25	33	50	50	0	0	100	-	-	-	-
	-1	5	5	19	10	5	0	15	11	13	38	0	17	0	50	50	0	-	-	-	-
	-2	10	0	0	0	5	0	0	6	7	13	17	0	0	0	0	0	-	-	-	-
	-3	0	0	0	0	5	5	0	6	7	0	17	0	0	0	50	0	-	-	-	-
	-4	5	0	0	5	0	0	0	0	0	0	0	17	0	0	0	0	-	-	-	-

Positive *numbers indicate an* ***increase*** *in alertness over the break.*
Negative *numbers indicate a* ***decrease*** *in alertness over the break.*
Zero *indicates* ***no change*** *in alertness over the break.*

The impact of trip type is clear from inspection of Figure 3.7. Later breaks appeared to be less consistently restorative for the group going beyond Broome. For the first 6 breaks from driving, only one break did not result in some recovery after the break, while from break 7 onwards half of the breaks showed deterioration in alertness after the break. For later breaks, fatigue level before the break was also tending to increase, suggesting that the lack of restorative benefit from breaks was accompanied by accumulated fatigue. For the group with a long stop in Broome, breaks were highly restorative with the exception of break 8, where their impact was somewhat reduced. For most breaks, fatigue level before the break tended to be decreased or similar to the previous break, suggesting that for these drivers there was little accumulated fatigue from one break to the next. Breaks were consistently restorative for the group with a short Broome stop, with the exception of the third break, and becoming increasingly restorative over the second half of the trip. Fatigue levels at the beginning of the break tended to increase for the short stop group, until the latter breaks of the trip, suggesting evidence of cumulative fatigue for much of the trip for these drivers but becoming somewhat less evident in the latter part of the trip.

These results of the two measures of subjective fatigue suggest that as two-up trips became longer, breaks became less restorative in the latter part of the trip. Moreover, for those drivers with a long stop in Broome, accumulated fatigue seemed to be less evident than for drivers who had a short stop and either returned home or continued their journey. For single drivers, on the other hand, the utility of breaks did not decline as substantially, and not until much later in the trip. Among single drivers, there is some flexibility in the number of breaks taken making it possible that over the same distance more breaks were taken by more tired drivers. However, the largely consistent pre-break fatigue rating by single drivers over the breaks and the low levels reported for drivers taking the most breaks would suggest that, in this study, operational constraints played a major role in the number of breaks taken by single drivers.

Off-road cognitive performance test results

For analysis of the cognitive performance results the strategy used was similar to that used to analyse the subjective fatigue data. For each of the tests, the effect of type of operation and type of trip were analysed using repeated measures multivariate analysis of variance. Orthogonal polynomial contrasts were used to compare results across occasions for performance data collected at the beginning of the trip, on arrival at Broome and at the end of the trip. Throughout, the same contrasts as those described previously were used to compare trip types, with the both the two-up group going beyond Broome and the single group being compared to the average of the two Broome turnaround two-up groups. The two-up drivers with Broome turnaround, the long stop and the short stop groups, were also compared. A corrected type I error rate of 0.02 was used to evaluate comparisons for each analysis.

For the simple reaction time test, the critical tracking task and the vigilance test, the last half of the trials administered were used for analysis in order to include the most stable part of performance on each test. For each of these tests, repeated measures multivariate analysis of variance was also used to examine within and between session practice effects. For these analyses, results for both the first and the second half of each test was included in the analysis, and compared across measurement occasions, between measurement occasions, and between type of operation and type of trip. The auditory reaction time task was analysed as a block of 30 trials in order to keep it more comparable to the on-board reaction time test which was administered as blocks of 30 trials.

1. Critical flicker fusion test

The results of this test were analysed separately for the ascending and the descending parts of the test. Table 3.20 shows the results of this test of drivers in each operation. For the descending part of the test, the analysis revealed a near significant multivariate effect of time of test ($F_{(2,29)}$ = 4.14, p=.026), which univariate tests showed was due to a significant linear trend in the data ($F_{(1,30)}$ = 8.4, p=.007). There was no significant difference between the operations, nor were there were any significant interactions between the time of test and type of operation. For both operations, threshold decreased over the trip, indicating deteriorating performance. For the ascending measure, there was also a multivariate effect for time of test ($F_{(2,29)}$ = 4.74, p=0.017) which univariate comparisons again showed to be due to a significant linear trend in the data ($F_{(1,30)}$ = 8.06, p=0.008). The operations did not differ, nor were there any interaction effects. Inspection of the data indicates that the ascending thresholds increased over the trip for drivers in both operations.

TABLE 3.20: Results for the Critical Flicker Fusion test (CFF) for drivers in each operation type at milestones in the trip.

TRIP TYPE	MILESTONE	FLICKER FUSION THRESHOLD	
		Ascending Measures	**Descending Measures**
		Mean Hz, *(sd)*	
Single (N=12)	**Pre-trip**	38.56 *(4.38)*	47.11 *(6.40)*
	Broome	40.44 *(4.54)*	45.93 *(5.08)*
	Post-trip	40.97 *(3.19)*	44.66 *(5.93)*
Two-up (N=20)	**Pre-trip**	39.78 *(3.62)*	48.47 *(6.66)*
	Broome	40.26 *(4.27)*	44.90 *(3.96)*
	Post-trip	41.00 *(3.11)*	44.93 *(3.78)*

Similar results were obtained when the effect of trip type on CFF thresholds was examined (Table 3.21). Analysis of the descending threshold results revealed that there was a significant multivariate effect of time of test ($F_{(2,26)}$ =4.42, p=0.022), which univariate tests showed to be due to a significant linear trend ($F_{(1,27)}$ = 8.21, p=0.008) and a near significant quadratic trend ($F_{(1,27)} = 4.2$, p=0.05). There were no significant effects of trip type, nor was the multivariate interaction effect significant. There was a trend towards a significant univariate interaction between linear trend and the comparison between the two-up group going beyond Broome and the other two-up groups ($t_{(30)} = 1.86$, p=0.07). There were also near significant univariate interactions between quadratic trend and the comparison between the single trip type and the short and long Broome stop two-up groups ($t_{(30)} = 2.26$, p=0.03) and between the two Broome stop groups ($t_{(30)} = 1.85$, p=0.08). These results confirm that, irrespective of trip type, descending thresholds decreased across the trip, with generally more of the overall decrease occurring on the outward leg of the trip, from Perth to Broome. Two-up drivers going beyond Broome showed greater deterioration in CFF threshold on the descending measure than the two-up groups turning around in Broome. Further, the two-up drivers with a short Broome stop showed a greater reduction in descending CFF thresholds than two-up drivers with a long Broome stop. Single drivers differed from the two-up drivers turning around in Broome in that the major deterioration in performance on this measure occurred on the homeward leg of the trip, whereas for the two-up drivers the deterioration was more marked on the first leg of the trip. For the ascending measure, there was a trend towards a multivariate effect for time ($F_{(2,26)} = .94$, p=.071), with a near significant linear trend also present ($F_{(1,27)} = 5.36$, p=0.028). There were no other significant effects for the ascending threshold measure. Inspection of Table 3.21 indicates that ascending thresholds either increased, albeit only slightly, across the trip for each two-up trip type and somewhat more substantially for the single group.

Performance on the Critical Flicker Fusion test was only partly sensitive to changes in alertness of drivers in this study. The descending threshold measures suggested that alertness among the drivers was deteriorating across the trip, while ascending threshold performance did not. The test is a measure of central nervous system arousal, with the two parts, ascending and descending, providing information about different but complimentary aspects of the same phenomenon. The results suggest that drivers were indeed becoming fatigued but that only their capacity to respond to suprathreshold

TABLE 3.21: Results for the Critical Flicker Fusion test (CFF) for drivers of each trip type at milestones in the trip.

TRIP TYPE	MILESTONE	FLICKER FUSION THRESHOLD	
		Ascending Measures Mean Hz *(sd)*	Descending Measures
SINGLE (N=11)	**Pre-trip**	37.87 *(3.87)*	46.26 *(5.96)*
	Broome	39.99 *(4.47)*	46.05 *(5.31)*
	Post-trip	40.54 *(2.95)*	44.18 *(5.97)*
TWO-UP, BEYOND BROOME (N=8)	**Pre-trip**	39.16 *(3.13)*	49.78 *(9.50)*
	Broome	40.19 *(4.11)*	45.24 *(3.34)*
	Post-trip	40.62 *(2.56)*	43.41 *(1.76)*
TWO-UP, LONG BROOME STOP (N=6)	**Pre-trip**	40.07 *(4.10)*	47.98 *(3.26)*
	Broome	39.16 *(2.82)*	45.51 *(2.37)*
	Post-trip	40.65 *(3.73)*	47.16 *(1.72)*
TWO-UP, SHORT BROOME STOP (N=6)	**Pre-trip**	40.33 *(4.25)*	47.22 *(5.15)*
	Broome	41.45 *(5.87)*	43.92 *(6.04)*
	Post-trip	41.86 *(3.53)*	44.72 *(6.10)*

flicker (descending measure) was decreased, while their responsivity to subthreshold intermittent light (ascending measure) remained intact. The fact that there is a considerable body of evidence reporting that descending thresholds are often lower than ascending ones attests to the possible independent variation of the two measures. Age, for example, has been shown to affect descending thresholds but not ascending ones (Curran, Hindmarch, Wattis and Shillingford, 1990).

2. Simple manual reaction time test

Tables 3.22 and 3.23 show results for the simple manual reaction time test for each operation and each trip type respectively. The analysis of the last 15 trials at each measurement occasion revealed no significant effect of operation, time of test or any interaction between these two factors for either decision or movement components of reaction time performance. Analysis of decision time for each trip type also revealed no significant effects for trip type, time of test or any interaction between these factors. The results for the movement time component did not show multivariate or univariate main effects for trip type. A trend towards a significant multivariate effect of time of test ($F_{(2,28)} = 3.53$, p=0.043) was evident, which univariate comparisons showed was due to a significant quadratic trend in the data ($F_{(1,29)} = 6.74$, p=0.015). There was no multivariate interaction effect, but univariate comparisons revealed a near significant interaction between quadratic trend and the comparison of the single trip type against the two-up trips with turnaround point in Broome ($t_{(31)} = 2.24$, p=0.033).

These results show that there was no change in the decision making component of reaction time performance from beginning to end of trip, either for single drivers or for two-up drivers, irrespective of type of trip. For two-up drivers, irrespective of trip type, however, there was an improvement in the movement time component of the test at Broome, and a deterioration again at the end of the trip compared with Broome performance, but not compared to performance at the beginning of the trip (Table 3.23).

TABLE 3.22: Results for the Simple Manual Reaction Time test for drivers in each operation type at milestones in the trip.

TRIP TYPE	MILESTONE	DECISION TIME 1st 15 trials	DECISION TIME 2nd 15 trials	MOVEMENT TIME 1st 15 trials	MOVEMENT TIME 2nd 15 trials
		Mean msecs, *(sd)*			
SINGLE (N=14)	**Pre-trip**	261.6 *(33.9)*	255.9 *(42.3)*	116.6 *(28.5)*	123.3 *(35.5)*
	Broome	260.5 *(33.8)*	252.1 *(30.0)*	117.0 *(26.9)*	121.7 *(36.3)*
	Post-trip	251.0 *(32.3)*	252.3 *(49.3)*	114.0 *(25.1)*	116.3 *(35.9)*
TWO-UP, (N=20)	**Pre-trip**	277.3 *(67.0)*	269.5 *(71.9)*	143.6 *(40.2)*	137.5 *(39.1)*
	Broome	280.7 *(48.4)*	269.6 *(48.5)*	124.2 *(31.6)*	114.7 *(25.2)*
	Post-trip	262.1 *(47.0)*	268.2 *(52.8)*	136.3 *(31.6)*	137.9 *(35.0)*

Performance for both the first 15 trials and the second 15 trials on each measurement occasion were compared for each operation, and each trip type to evaluate the pattern of practice effects. Analysis by type of operation revealed no significant multivariate effects for the decision time component of the test. This result shows that there was no practice effect for either operation in decision time on this test. Analysis of decision time for drivers doing each type of trip revealed no significant main effect for practice. There was, however, a significant multivariate interaction between trip type and within session practice ($F_{(3,29)} = 4.27$, $p=0.01$). Univariate tests showed that, overall, within session practice effects were greater for the two-up group going beyond Broome compared to two-up drivers with Broome turnaround ($t_{(31)} = 3.08$, $p=0.004$). The latter groups did not differ significantly either from each other or from single drivers.

TABLE 3.23: Results for the Simple Manual Reaction Time test for drivers of each trip type at milestones in the trip.

TRIP TYPE	MILESTONE	DECISION TIME		MOVEMENT TIME	
		1st 15 trials	2nd 15 trials	1st 15 trials	2nd 15 trials
		Mean msecs, *(sd)*			
SINGLE (N=13)	**Pre-trip**	260.31 *(34.90)*	256.90 *(43.83)*	118.10 *(29.09)*	125.01 *(32.25)*
	Broome	258.87 *(34.57)*	252.02 *(31.19)*	117.49 *(27.97)*	123.85 *(36.82)*
	Post-trip	250.00 *(33.35)*	251.03 *(51.09)*	114.28 *(26.12)*	115.95 *(37.35)*
TWO-UP, BEYOND BROOME (N=8)	**Pre-trip**	285.71 *(49.16)*	262.57 *(33.76)*	128.13 *(34.28)*	125.44 *(25.29)*
	Broome	286.86 *(43.41)*	261.75 *(45.35)*	136.62 *(33.85)*	117.00 *(23.95)*
	Post-trip	246.92 *(34.49)*	242.41 *(36.89)*	129.75 *(21.30)*	136.61 *(22.01)*
TWO-UP, LONG BROOME STOP (N=6)	**Pre-trip**	303.14 *(89.87)*	304.20 *(101.16)*	169.75 *(51.41)*	159.60 *(51.75)*
	Broome	300.43 *(62.60)*	283.22 *(60.15)*	117.66 *(28.60)*	122.22 *(25.38)*
	Post-trip	290.46 *(66.27)*	295.82 *(57.64)*	145.76 *(36.76)*	153.26 *(54.69)*
TWO-UP, SHORT BROOME STOP (N=6)	**Pre-trip**	240.23 *(54.92)*	244.17 *(74.20)*	137.96 *(24.95)*	131.48 *(36.96)*
	Broome	252.67 *(29.83)*	266.52 *(45.92)*	114.11 *(30.84)*	104.09 *(27.51)*
	Post-trip	254.07 *(30.45)*	274.94 *(57.62)*	114.28 *(26.12)*	124.18 *(21.71)*

For movement time, there were no significant main effects of type of operation for practice effects. The main effect for within session practice effects, with performance on the first and the second half of the test compared across the measurement occasions was not significant. There was a near significant two-way interaction between this factor and operation type ($F_{(1,32)} = 4.49$, p=0.04), but no interaction of within session practice effects and measurement occasion, with the three-way interaction between type of operation, practice effect and measurement occasion also being nonsignificant. Analysis of the impact of trip type on practice effects in movement time showed that there were no main effects or interactions for within session practice. These results suggest that overall, there was little variation of within session practice effects across the trip for the movement component of reaction time performance, with a tendency for two-up drivers in general to show somewhat more pronounced practice effects for movement time than single drivers.

Overall, the results of performance on the simple manual reaction time task indicate that only movement time, that is the response execution part of the task, changed during the trip. The decision making component of the task remained intact throughout the trip. For two-up drivers, irrespective of trip type, movement time performance improved at Broome, compared with pre-trip. This result may, in part, indicate a practice effect, since within session performance also improved for two-up drivers. However, the improvement was not sustained with post-trip performance deteriorating to pre-trip levels, indicating decreasing alertness at the end of the return leg of the trip. For single drivers, no significant improvement was seen at Broome, nor had performance deteriorated at post-trip, indicating no loss of alertness, at least on this measure.

3. Unstable (critical) tracking task

Two measures were analysed for the last five trials of this test, time on target and the level of difficulty or critical instability reached in the test. Table 3.24 and Table 3.25 show the results at each measurement occasion for each operation and each type of trip, respectively.

TABLE 3.24: Results for the Critical Tracking Task (CTT) for drivers in each operation type at milestones in the trip.

OPERATION TYPE	MILESTONE	TIME ON TARGET (secs)		LEVEL OF DIFFICULTY ACHIEVED	
		1st 5 trials	2nd 5 trials	1st 5 trials	2nd 5 trials
		Mean *(sd)*			
SINGLE (N=14)	**Pre-trip**	8.1 *(1.9)*	8.3 *(2.0)*	4.0 *(0.9)*	4.1 *(0.9)*
	Broome	7.5 *(1.8)*	8.3 *(2.0)*	4.4 *(0.7)*	4.7 *(0.8)*
	Post-trip	9.5 *(1.4)*	9.80 *(1.7)*	4.5 *(0.7)*	4.6 *(0.7)*
TWO-UP, (N=20)	**Pre-trip**	8.5 *(1.8)*	9.4 *(2.3)*	4.1 *(0.8)*	4.4 *(0.8)*
	Broome	6.9 *(2.0)*	8.2 *(2.0)*	4.2 *(0.9)*	4.7 *(0.9)*
	Post-trip	9.0 *(2.2)*	9.5 *(2.1)*	4.4 *(0.7)*	4.7 *(1.0)*

For the time on target, there was no significant main effect of type of operation. There was a significant multivariate effect for measurement occasion ($F_{(2,31)} = 9.9$, $p<0.01$), with both a significant univariate linear component ($F_{(1,32)} = 6.2$, $p=0.018$) and a significant univariate quadratic component ($F_{(1,32)} = 9.8$, $p=0.004$). The multivariate interaction effect between operation and time of test was not significant, however, there was a near significant univariate interaction between linear trend and type of operation ($F_{(1,32)} = 3.99$, $p=0.054$). These results show that time on target increased across the trip, with post-trip performance being better than pre-trip performance.

Performance did not improve however at the Broome measurement occasion, deteriorating for two-up drivers and remaining unchanged for single drivers. At post-trip, performance improved over Broome levels for both groups, with single drivers performing above pre-trip levels and two-up drivers recovering to pre-trip levels.

Analysis of time on target by type of trip also revealed no main effect of trip type (see Table 3.25). The multivariate main effect for time of test was significant ($F_{(2,28)} = 7.54$, $p=0.002$), with only a significant quadratic component ($F_{(1,29)} = 12.44$, $p=0.001$). The results also showed a near significant multivariate interaction between type of trip and measurement occasion ($F_{(6,58)} = 2.24$, $p=0.052$). Univariate tests showed that this was due to a significant interaction between linear trend and trip type ($F_{(3,29)} = 6.75$, $p=0.013$). In particular, there was an interaction between linear trend and comparison of the single trip type against the two-up groups with turnaround point in Broome ($t_{(31)} = 2.67$, $p=0.012$) and between linear trend and the difference between the two-up short Broome stop and two-up long Broome stop groups ($t_{(31)} = 2.4$, $p=0.023$). As Table 3.25 shows, these results indicate that for all groups, time on target performance improved at post-trip compared with Broome performance. For the two-up short stop group, the two-up group going beyond Broome and the single group, performance at Broome was at about pre-trip levels, and performance at post-trip improved over pre-trip levels. Time on target performance of the two-up long stop group deteriorated substantially on the Broome measurement occasion, and did not fully recover to pre-trip levels at the end of the trip.

Analysis of the level of difficulty measure revealed that there was no main effect for type of operation on this measure. There was a significant multivariate effect for measurement occasion ($F_{(2,31)} = 11.8$, $p<0.001$), with a significant linear component ($F_{(1,32)} = 15$, $p<0.001$) and a near significant quadratic component ($F_{(1,32)} = 4.9$, $p=0.035$). There was no significant interaction between the two factors. These results indicate that drivers were able to achieve significantly higher levels of difficulty at the end of the trip, compared with the beginning, and that the majority of the improvement

TABLE 3.25: Results for the Critical Tracking Task (CTT) for drivers of each trip type at milestones in the trip.

TRIP TYPE	MILESTONE	TIME ON TARGET (secs)		LEVEL OF DIFFICULTY ACHIEVED	
		1st 5 trials	2nd 5 trials	1st 5 trials	2nd 5 trials
		Mean *(sd)*			
SINGLE (N=13)	**Pre-trip**	7.98 *(1.99)*	8.13 *(1.97)*	3.92 *(0.89)*	4.09 *(0.89)*
	Broome	7.50 *(1.89)*	8.27 *(2.12)*	4.34 *(0.76)*	4.67 *(0.85)*
	Post-trip	9.45 *(1.50)*	9.76 *(1.74)*	4.46 *(0.68)*	4.63 *(0.75)*
TWO-UP, BEYOND BROOME (N=8)	**Pre-trip**	8.55 *(2.04)*	8.46 *(1.24)*	4.18 *(0.91)*	4.30 *(0.69)*
	Broome	5.90 *(1.59)*	8.43 *(2.42)*	3.79 *(0.78)*	4.67 *(0.94)*
	Post-trip	9.09 *(2.45)*	9.26 *(2.37)*	4.48 *(1.16)*	4.57 *(1.16)*
TWO-UP, LONG BROOME STOP (N=6)	**Pre-trip**	7.81 *(1.93)*	10.86 *(3.31)*	3.91 *(0.85)*	4.40 *(0.94)*
	Broome	6.19 *(1.11)*	7.85 *(2.27)*	3.94 *(0.57)*	4.55 *(0.95)*
	Post-trip	7.99 *(2.59)*	9.37 *(1.76)*	3.95 *(1.13)*	4.58 *(0.77)*
TWO-UP, SHORT BROOME STOP (N=6)	**Pre-trip**	9.20 *(1.34)*	9.09 *(1.70)*	4.33 *(0.44)*	4.51 *(0.92)*
	Broome	8.99 *(1.57)*	8.33 *(1.45)*	5.07 *(0.78)*	4.83 *(0.78)*
	Post-trip	9.71 *(1.41)*	10.05 *(2.25)*	4.69 *(0.58)*	4.98 *(1.06)*

tended to occur between pre-trip levels, and those achieved at Broome. The results also show that this pattern did not vary for the two operations (Table 3.24). Similar results were obtained in the analysis by type of trip. There were no significant multivariate main effects or interactions in this analysis. However, there was a significant univariate linear trend in the data ($F_{(1,29)} = 10.43$, $p=0.003$). These results confirm that, irrespective of trip type, significantly higher levels of difficulty were achieved by drivers at post-trip, compared with pre-trip (Table 3.25).

For time on target, comparison of performance on the first 5 trials with that on the second 5 trials at each measurement occasion revealed that there was a significant multivariate main effect for improvement with practice ($F_{(1,32)} = 14.94$, $p=0.001$) for comparison by type of operation. There were no significant interactions between type of operation and practice effect, between practice effect and measurement occasion, nor was the three-way interaction between practice effect, measurement occasion and type of operation significant.

Analysis of within session practice effects for each trip type, revealed a significant main effect for practice ($F_{(1,29)} = 9.87$, $p<0.001$), and a significant multivariate interaction between practice and trip type ($F_{(3,29)} = 8.61$, $p<0.001$). Univariate tests showed that there was a significant difference between the two-up groups with Broome turnaround ($t_{(31)} = 4.76$, $p<0.0001$) such that drivers with a long turnaround time showed greater practice effects than drivers with a short turnabout time. In contrast, neither the single group nor the group going beyond Broome differed significantly from the Broome turnaround groups. The multivariate three-way interaction between practice effect, trip type and measurement occasion also approached significance ($F_{(6,58)} = 2.06$, $p=0.07$). Univariate tests showed that this was due to a quadratic trend differing for the two-up group going beyond Broome compared with the groups with short or long Broome stops ($t_{(31)} = 3.21$, $p=0.003$)

As Table 3.25 shows, these results indicate that moderate practice effects for time on target were achieved by most drivers on most measurement occasions. However, for the two-up group going beyond Broome and the group with a long stop in Broome, performance at the beginning of the Broome testing session was markedly poorer than performance at the end of this session, and was also lower than pretrip performance. This improvement across the Broome testing session is more likely to reflect a rearousal effect following initial fatigue than a practice effect because performance started at such low levels. Performance at Broome did not surpass pre-trip levels for any two-up group.

Analysis of practice effects for each operation in the level of difficulty achieved on the test revealed a main effect for practice ($F_{(1,32)} = 19.32$, $p<0.001$), but no significant two-way or three-way interactions between type of operation, measurement occasion, and practice effect. Analysis by trip type also showed a significant main effect for practice ($F_{(1,29)} = 26.26$, $p<0.001$). There were no significant multivariate two-way or three-way interactions with trip-type. The univariate three-way interaction comparing quadratic trend across measurement occasions for practice effect by two-up drivers going beyond Broome and two-up drivers with Broome turnaround was significant ($t_{(31)} = 2.85$, $p=0.008$). As Table 3.25 shows, these results reflect that, overall, on the majority of measurement occasions most drivers moderately improved the level of difficulty achieved on the second five trials, with this effect being particularly evident for two-up drivers going beyond Broome at the Broome measurement occasion due to marked deterioration of performance on the first 5 trials.

Overall, the results for the tracking test revealed that most drivers improved on both aspects of the critical tracking task across the trip. The analysis of within session practice effects revealed that, by and large, practice effects were evident within and across measurement occasions for both the time on task measure and the level of difficulty measure. These findings suggest that the improvement in unstable tracking task performance represents practice effects which to some extent overshadowed sensitivity of the test to fatigue. However, a dip in performance for the time on task measure at the Broome measurement occasion, relative to pre-trip and post-trip, was more apparent for two-up drivers than for single drivers. For two-up drivers going beyond Broome the dip in performance was also evident to some extent on the other measure, level of difficulty achieved. These dips in performance most likely indicate that the practice effect from one measurement occasion to the next was vulnerable to the effects of decreased alertness, resulting in decreased performance capacity for two-up drivers on the first five trials at the Broome measurement occasion. This deterioration was only partially recovered, however, by the second five trials.

4. Vigilance test

Two measures of performance were analysed, the speed of correct responses and the number of errors made. Table 3.26 displays the results for type of operation and Table 3.27 the results for type of trip. Again, the second half of the test was used for analysis.

The results for type of operation on the speed of correct responses measure revealed no significant main effect for type of operation, a significant main effect for measurement occasion ($F_{(1,33)} = 13.19$, p=0.001), and no significant interaction between the two factors. These results indicate that for both operations, vigilance performance improved at the end of the trip and that there were no significant differences between the operations.

Analysis of speed of correct responses for each trip type revealed a trend towards a significant multivariate effect for group ($F_{(3,29)} = 2.56$, p=.07), which univariate tests showed was due to performance of the two-up short Broome stop group having significantly faster reaction time overall, compared with the two-up long Broome stop group ($t_{(32)} = 2.48$, p=0.019). There was a significant main effect for measurement occasion ($F_{(1,29)} = 17.28$, p<0.001), and no significant interactions between the trip types. These results indicated that, irrespective of trip type, performance improved at the end of the trip.

Within session practice effects were analysed by examining performance summarised as 10 blocks of 60 trials. This method is likely to be more sensitive to the gradual degradation of performance that would be expected on a sustained attention task such

TABLE 3.26: Results for the first and second half of the Vigilance test for drivers in each operation type before and after the trip.

OPERATION TYPE	MILESTONE IN TRIP	SPEED OF CORRECT RESPONSES (msecs)		NUMBER OF ERRORS	
		1st half	2nd half	1st half	2nd half
		Mean *(sd)*			
SINGLE (N=13)	**Pre-trip**	572.14 *(74.93)*	547.30 *(57.71)*	12.85 *(14.78)*	11.31 *(12.99)*
	Post-trip	539.32 *(69.19)*	533.16 *(65.04)*	12.46 *(19.29)*	10.46 *(13.61)*
TWO-UP, (N=22)	**Pre-trip**	570.99 *(82.13)*	553.47 *(82.39)*	12.59 *(18.26)*	11.41 *(20.09)*
	Post-trip	534.31 *(72.24)*	521.36 *(72.35)*	10.00 *(22.16)*	11.82 *(26.15)*

as this one than comparing the first and second halves of the test. Figure 3.8 shows reaction time for correct responses block by block across the test at each measurement occasion for each operation (see also Appendix 5). Multivariate repeated measures analysis of variance revealed a significant main effect for blocks ($F_{(9,25)} = 3.71$, p=0.005). Univariate tests showed that this effect was due to a significant linear component ($F_{(1,33)} = 13.8$, p=0.001). There was no significant multivariate interaction between measurement occasion and change across blocks, but there was a univariate interaction between measurement occasion and linear trend across blocks ($F_{(1,33)} =$ 6.33, p=0.017). These results indicate that there was an improvement in performance within a session, with this improvement being more marked before the trip than after the trip.

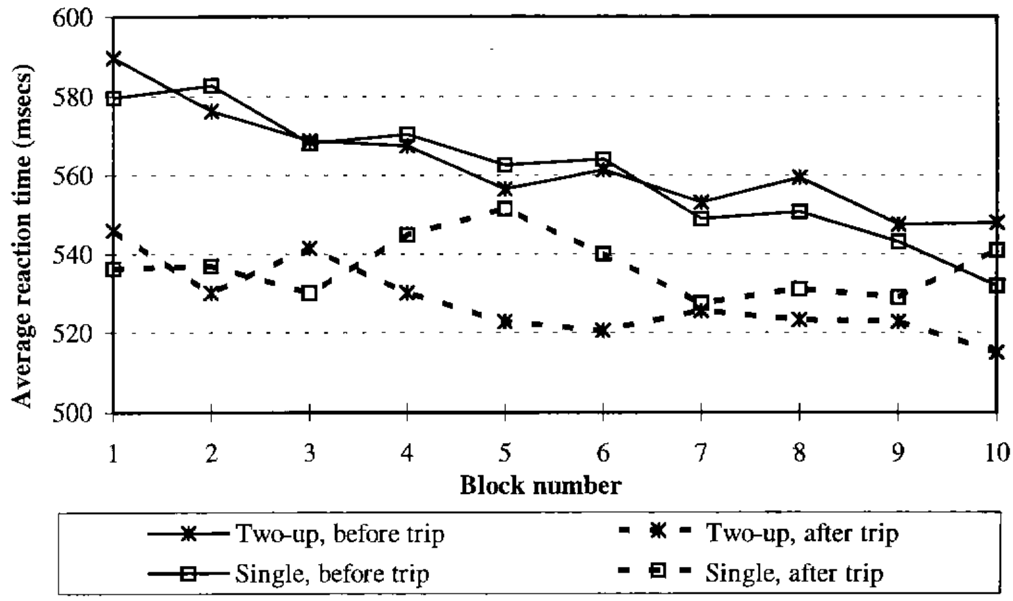
Examination of differences between the operations in vigilance performance across blocks revealed that there was a trend towards a significant univariate interaction

TABLE 3.27: Results for the first and second half of the Vigilance test for drivers doing each trip type before and after the trip.

TRIP TYPE	MILESTONE IN TRIP	SPEED OF CORRECT RESPONSES (msecs)		NUMBER OF ERRORS	
		1st half	**2nd half**	**1st half**	**2nd half**
		Mean *(sd)*			
SINGLE (N=11)	**Pre-trip**	555.20 *(67.73)*	535.46 *(54.41)*	8.75 *(11.76)*	8.50 *(11.89)*
	Post-trip	527.36 *(65.66)*	523.75 *(59.98)*	12.83 *(19.90)*	9.75 *(13.92)*
TWO-UP, BEYOND BROOME (N=8)	**Pre-trip**	603.73 *(63.17)*	577.15 *(85.76)*	17.00 *(24.27)*	15.13 *(27.23)*
	Post-trip	560.49 *(76.21)*	540.67 *(78.94)*	11.63 *(26.84)*	10.75 *(19.72)*
TWO-UP, LONG BROOME STOP (N=6)	**Pre-trip**	606.25 *(89.42)*	586.75 *(84.81)*	16.00 *(20.66)*	16.33 *(22.37)*
	Post-trip	562.55 *(59.52)*	561.41 *(59.33)*	16.50 *(30.38)*	23.50 *(45.39)*
TWO-UP, SHORT BROOME STOP (N=6)	**Pre-trip**	511.80 *(65.12)*	504.84 *(59.85)*	5.63 *(4.27)*	4.00 *(3.46)*
	Post-trip	486.95 *(57.34)*	472.02 *(48.71)*	3.50 *(2.33)*	4.13 *(2.17)*

between type of operation and change in performance across blocks represented by the sixth degree polynomial ($F_{(1,33)} = 5.03$, p=0.032). The multivariate three-way interaction of type of operation, measurement occasion and change in performance across blocks was not significant, but a trend towards a significant univariate 3-way interaction was found for the seventh degree polynomial ($F_{(1,33)} = 2.97$, p=0.09). These results indicate that for single drivers, the pattern of change across blocks became

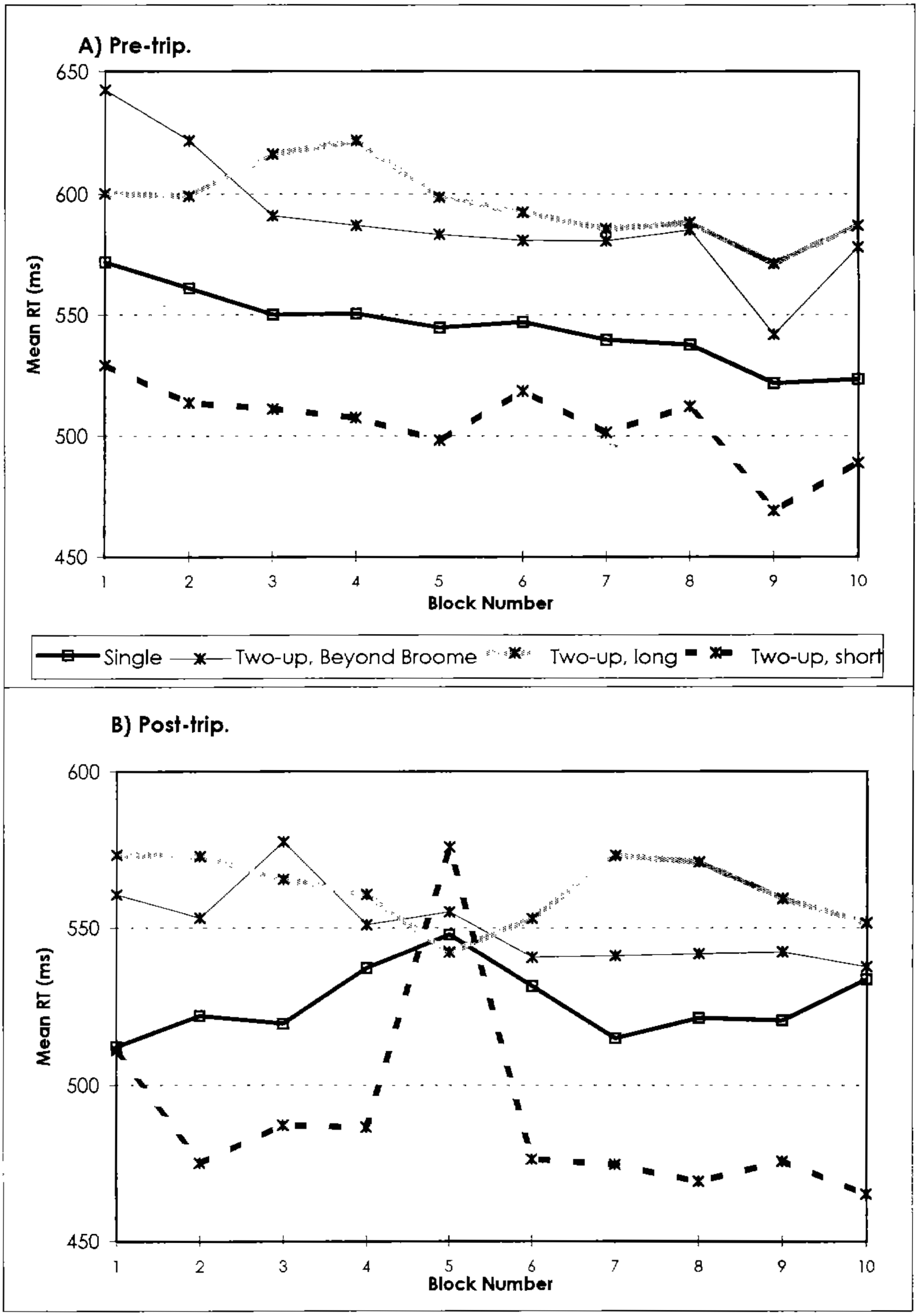
FIGURE 3.8: Correct responses for the Vigilance test, summarised in blocks of 60 trials, for drivers in each operation before and after the trip.



more variable at the post-trip measurement occasion, compared with two-up drivers. This finding suggests that single drivers were having more difficulty maintaining the gains of practice across blocks at post trip, but not at pre-trip.

Figure 3.9 shows reaction time for correct responses block by block across the test at each measurement occasion for each trip type (see also Appendix 5). Analysis of within session practice effects revealed a significant multivariate main effect for change in performance across blocks ($F_{(9,21)} = 3.03$, p=0.02), due to a significant linear trend in these data ($F_{(1,29)} = 11.75$, p=0.002). There was no significant multivariate interaction between measurement occasion and change across blocks, but there was a trend towards a univariate interaction between measurement occasion and linear trend across blocks ($F_{(1,29)} = 3.27$, p=0.08). There was no significant multivariate or univariate interaction between type of trip and change in performance across blocks within a session. The multivariate three-way interaction of type of operation, measurement occasion and change in performance across blocks was not significant, but a significant univariate three-way interaction was found for the cubic trend ($F_{(3,29)} = 3.66$, p=0.02)

FIGURE 3.9: Correct vigilance reaction time (ms) as a function of milestone, within-session practice and trip type.



and a trend towards significance was found for the seventh degree polynomial ($F_{(3,29)}$ = 2.65, p=0.07). However, this latter effect was not reflected in any of the selected contrasts. The significant three-way interactions were due to differences in the cubic polynomial between the single trip group and the two-up groups with turnaround in Broome ($t_{(32)}$ = 2.58, p=0.02), between the two-up groups stopping in Broome and the two-up group going beyond Broome ($t_{(32)}$ = 2.20, p=0.04), and there was a trend for differences between the two-up groups stopping in Broome ($t_{(32)}$ = 1.96, p=0.06).

These results support the earlier ones with respect to within session practice effects on the vigilance task. As Figure 3.9 shows, all groups showed a steady improvement in vigilance performance across blocks before the trip. Differences were seen, however, in the capability of drivers to sustain the benefits of practice across blocks within the session on the post-trip test. Drivers doing the single trip demonstrated less ability to maintain performance at post-trip than drivers doing two-up trips with Broome turnaround point. Two-up drivers who went beyond Broome also showed less robust practice effects at post-trip than the other two-up groups. The drivers doing the trip with the short Broome stop were more effective in maintaining vigilance performance improvement at post-trip than those two-up drivers with a long Broome stop. The decreased capability to maintain gains achieved through practice implicate deteriorating performance due to decreasing alertness.

Analysis of the number of errors made in the test showed no significant main effect for type of operation or type of trip, time of test or any interaction between these factors. As Tables 3.26 and 3.27 show, the number of errors made in the test was very small, somewhere in the order of 4% of trials. Irrespective of operation or trip type, there was no change in the level of errors made on the test after the trip compared with the beginning. Analysis of practice effects on the error measure revealed that there were no significant changes in the number of errors made within sessions. In this context, it should be noted that two of the two-up groups showed high standard deviations and inflated means as a result of a few individuals with very high error rates. Although these figures appear to belie the statistical test result, an examination of the group medians supported the outcome of the statistical analysis.

5. Vocal reaction time test

Reaction time for the simple vocal response time test are displayed in Table 3.28 for each operation, and in Table 3.29 for each trip type. The analysis revealed no significant main effects or interactions for either operation type or trip type. Clearly, if there are differences in fatigue for drivers in each operation or doing different trips, these are not manifest in performance of this task.

TABLE 3.28: Results for the Vocal Reaction Time task for drivers in each operations at milestones in the trip.

OPERATION TYPE	**MILESTONE IN TRIP**					
	Pre-trip		**Broome** Mean msecs *(sd)*		**Post-trip**	
Single (N=12)	479.63	*(166.48)*	413.89	*(111.52)*	442.78	*(105.19)*
Two=up (N=18)	405.97	*(64.95)*	401.52	*(70.21)*	390.50	*(59.66)*

On-road measures

1. On-board vocal reaction time test

Since presentation of the blocks of trials for this test depended on individual trip schedules (see method), it was impossible to get blocks of trials at identical times throughout the trip for each driver. However, it was possible to select blocks that were in the same relative chronological order for all drivers. For analysis, blocks were selected as close as possible to the beginning, midpoint and end of driving for each leg of the trip, outward (between Perth and Broome) and homeward (between Broome

TABLE 3.29: Results for the Vocal Reaction Time task for drivers doing each trip type at milestones in the trip.

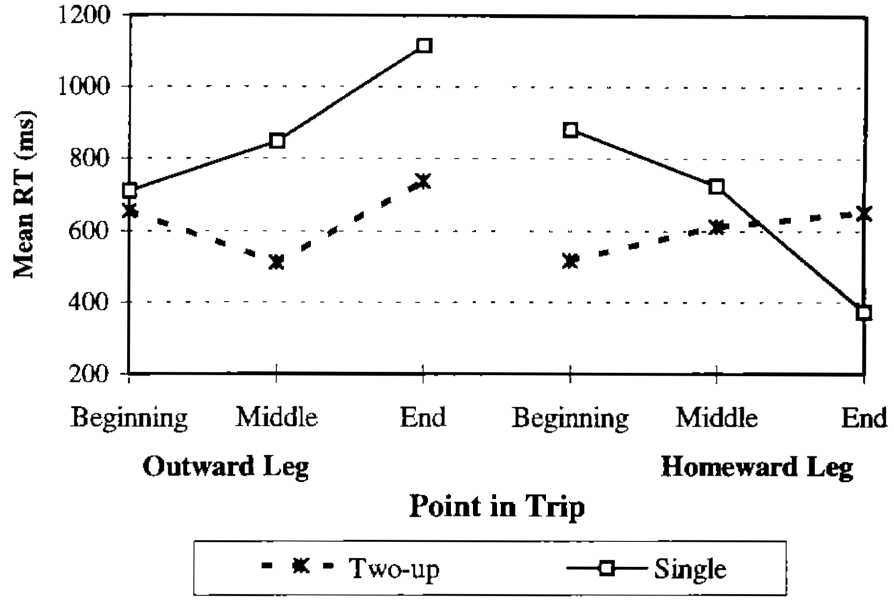
TRIP TYPE	MILESTONE IN TRIP		
	Pre-trip	**Broome** Mean msecs *(sd)*	**Post-trip**
Single (N=11)	456.15 *(152.35)*	389.39 *(75.89)*	434.97 *(106.61)*
Two-up, **Beyond Broome** (N=8)	432.00 *(85.45)*	438.35 *(86.05)*	404.55 *(75.99)*
Two-up, **Long Broome Stop** (N=4)	364.06 *(40.31)*	372.49 *(35.54)*	371.57 *(33.06)*
Two-up, **Short Broome Stop** (N=6)	399.21 *(24.53)*	371.76 *(41.57)*	384.36 *(52.12)*

and Perth). These points were individually determined for each driver, and related directly to the chronology of driving determined from the data logger.

There were two measures of performance for this test, reaction time and number of missed signals. Repeated measures multivariate analysis of variance was used to compare performance at the beginning middle and end points of each leg of the trip separately (to conserve sample size). Orthogonal polynomial contrasts were used to compare results across blocks, with the same contrasts as described previously used to compare trip types. In addition, analysis of variance was used to compare levels of performance at the beginning point of each leg of the trip. The corrected type I error rate used to evaluate significance for these analyses was 0.02.

Reaction time performance for each operation on the outward and homeward leg of the trip, is shown in Figure 3.10 (see also Appendix 6). Analysis of performance on

FIGURE 3.10: Mean on-board reaction time by type of operation and point in trip.



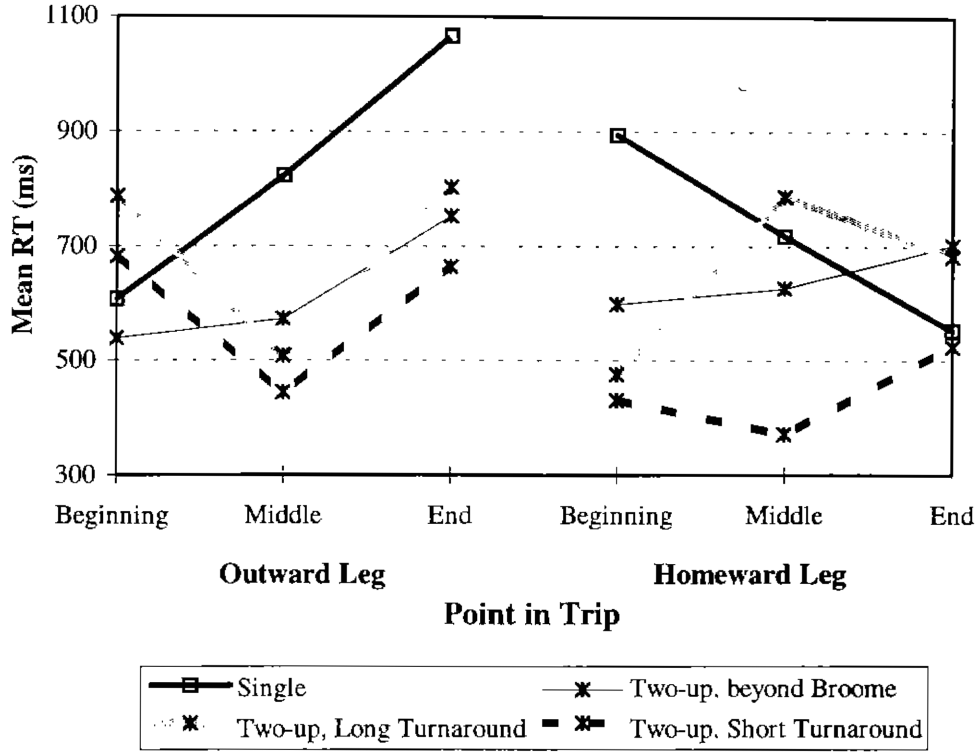
the outward leg of the trip, from Perth to Broome, revealed that there was a multivariate main effect for time of block ($F_{(2,28)} = 11.05$, $p<0.001$), which univariate tests showed was due to a significant linear component ($F_{(1,29)} = 3.87$, $p=0.001$) and a near significant quadratic component ($F_{(1,29)} = 4.01$, $p=0.06$). The main effect for type of operation showed a trend toward significance ($F_{(1,29)} = 3.42$, $p=0.08$), and there was a trend towards a multivariate interaction between time of block and type of operation ($F_{(2,28)} = 3.02$, $p=0.07$). Univariate tests showed that this was due to an interaction between operation type and linear trend ($F_{(1,29)} = 6.13$, $p=0.02$). These results show that reaction time lengthened over the outward leg of the trip mainly for single drivers (Figure 3.10). For two-up drivers, performance improved at the midpoint of the outward leg, and then deteriorated again but only to levels minimally above beginning of trip. Deterioration in performance tended to be more marked from the midpoint to the end for single drivers also, with much greater deterioration evident for them than for two-up drivers.

Comparison of performance at the beginning of each leg of the trip revealed that reaction time at the beginning of the homeward leg of the trip had increased over levels at the beginning of the trip for single drivers, and had decreased for two-up drivers, with this effect approaching significance ($F_{(1,28)} = 5.61$, p=0.03). Analysis of performance over the homeward leg, from Broome to Perth, revealed that there were no significant main effects for type of operation or for time of test, nor was there a multivariate interaction between these factors. There was, however, a near significant univariate interaction between linear trend and type of operation ($F_{(1,27)} = 5.24$, p=0.03).)

These results indicate that, the two operations showed largely linear changes in performance over the homeward leg of the trip, but in opposite directions (Figure 3.10). For two-up drivers, performance, although largely recovered over the Broome interval, steadily deteriorated over the second leg of the trip. In contrast, performance of single drivers, although not fully recovered over the Broome interval, steadily improved over the second leg of the trip.

Figure 3.11 shows reaction time performance over the outward and homeward leg of the trip for drivers doing each trip type (see also Appendix 6). Analysis of the impact of trip type on reaction time performance over the outward leg of the trip, confirmed the findings for each type of operation. There was no significant main effect for trip type and a significant multivariate main effect for time of test ($F_{(2,25)} = 6.37$, p=0.006), which univariate tests showed was due to a significant linear component ($F_{(1,26)} = 6.47$, p=0.02) and a near significant quadratic component ($F_{(1,26)} = 5.61$, p=0.03). The multivariate interaction between trip type and time of test was not significant, however, univariate comparisons revealed a near significant interaction between trip type and linear trend for time of test ($F_{(3,26)} = 3.5$, p=0.03). The interaction reflected the difference of linear trend for single drivers compared against two-up drivers with a turnaround point in Broome ($t_{(28)} = 3.21$, p=0.003). There were no differences between two-up drivers. These results confirm that, over the outward leg of the journey, reaction time performance deteriorated substantially for single drivers but not for two-up drivers. For two-up drivers, reaction time performance improved or remained unchanged at the midpoint and then returned to around baseline levels at the end of the outward leg of the trip.

FIGURE 3.11: Mean on-board reaction time (ms) by trip type and point in trip.



Analysis of reaction time performance at the beginning of each leg of the trip revealed that the trip types differed ($F_{(3,26)} = 4.34$, $p=0.01$). Univariate comparisons revealed that this finding was due to differences between the single trip type and the two-up groups with turnaround in Broome ($t_{(28)} = 3.44$, $p=0.002$), and between the two-up group going beyond Broome compared with the other two-up groups ($t_{(28)} = 2.55$, $p=0.02$). Two-up groups with Broome turnaround, with either short or long stop, did not differ. From Figure 3.11 it can be seen that reaction time performance was poorer for single drivers at the beginning of the second leg of the trip, compared with the beginning of the first leg of the trip. Reaction time performance was similar for two-up drivers going beyond Broome. In contrast, for two-up drivers having either a long or a short Broome stop, reaction time performance had improved at the beginning of the second leg of the trip compared with the beginning of the first leg.

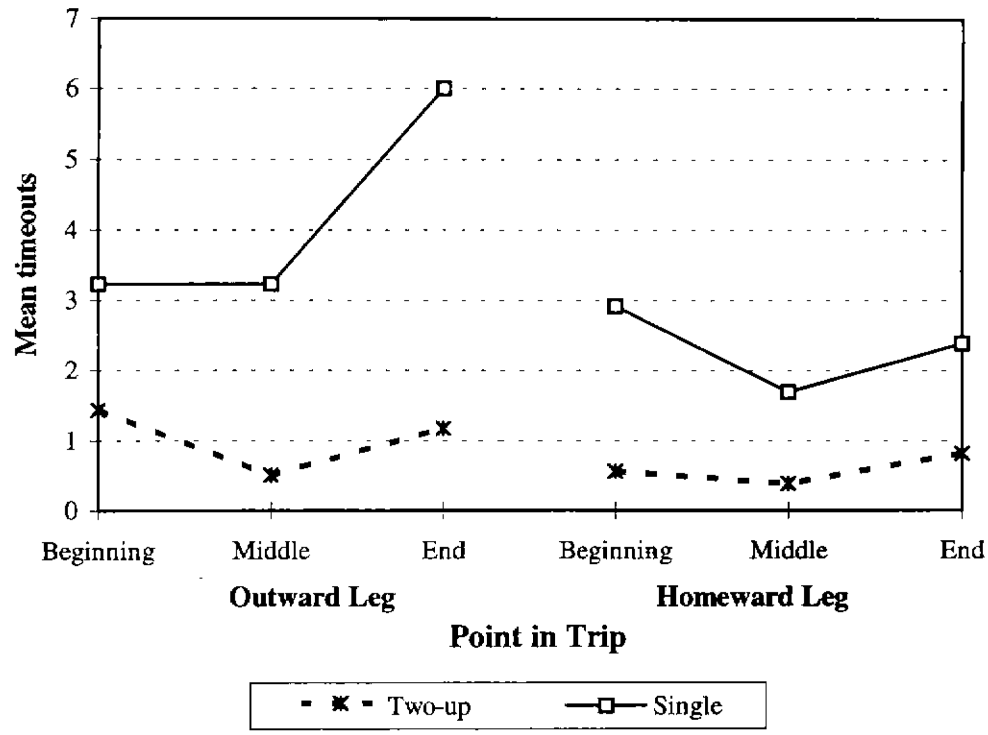
Analysis of the changes in performance across the second leg of the trip showed that there were no significant main effects of trip type or time of test. The multivariate interaction effect was not significant, however, there was a near significant univariate interaction between linear trend and time of test ($F_{(3,24)} = 3.52$, p=0.03). This interaction was due to the difference in linear trend between the single group and the two-up groups stopping in Broome ($t_{(28)} = 3.21$, p=0.003). There were no significant differences between the three two-up groups. It is noteworthy that at the end of the trip, reaction time performance had essentially returned to beginning of trip levels for all groups (Figure 3.11).

These results indicate that the major differences in this test over the second leg of the trip occurred between single and two-up drivers, and was largely unaffected by trip type. For single drivers, performance gradually improved over this part of the trip, while for two-up drivers performance steadily deteriorated over the second leg of the trip.

Results for the other measure of performance on this test, the number of timeouts per block of trials, are shown in Figure 3.12 (see also Appendix 6). Analysis of the number of missed signals at the beginning, midpoint and end of the outward leg of the trip for each operation revealed a significant main effect for type of operation ($F_{(1,29)} =$ 5.89, p=0.02). The multivariate main effect for time of test approached significance ($F_{(2,28)} = 3.05$, p=0.06). Univariate comparisons for time of test showed a trend towards a significant quadratic component in the data ($F_{(1,29)} = 3.55$, p=0.07), but no linear component. The multivariate interaction effect was not significant, but univariate comparisons showed a near significant interaction between the linear component for time of test, and type of operation ($F_{(1,29)} = 4.44$, p=0.04).

In general, the results for missed signals over the outward leg of the trip parallel those for reaction time performance. Overall, missed signals were more common among single drivers. The rate also increased across this leg of the trip for single drivers with most of the deterioration occurring after the midpoint of this leg of the trip. In contrast, for two-up drivers, performance on this measure improved from beginning to

FIGURE 3.12: Mean number of timeout trials in on-board reaction time by type of operation and point in trip.

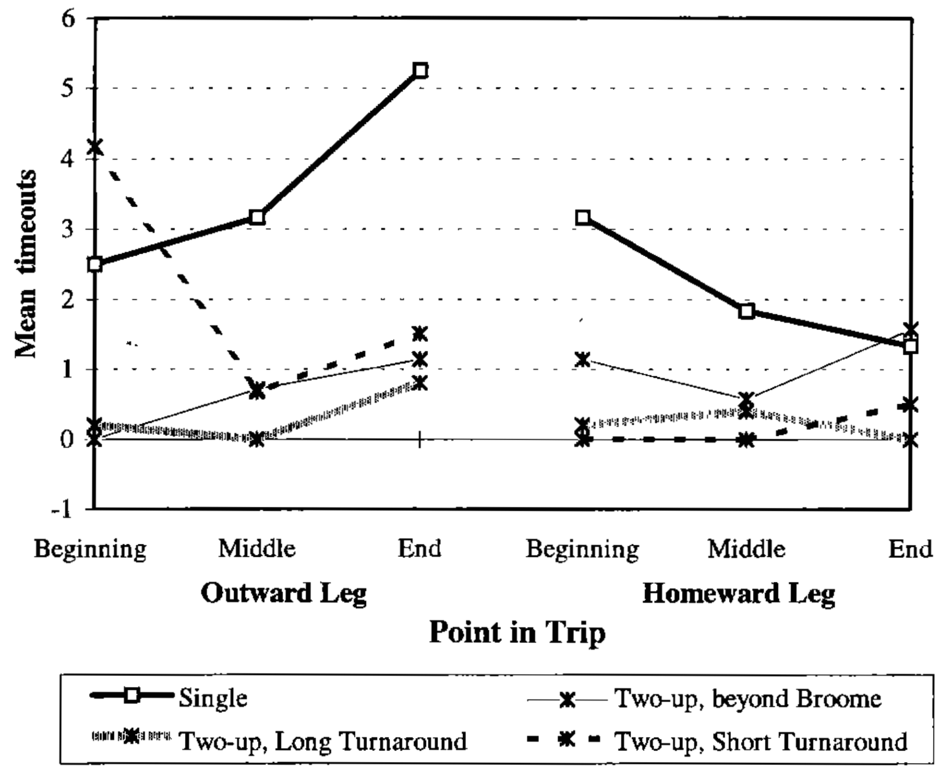


mid point, but, while this improvement was not sustained, at the end of the first leg the number of missed signals for two-up drivers was about the same as at the beginning of the trip.

At the beginning of the return leg of the trip, the rate of missed signals had returned to beginning of trip levels for both operations. Analysis of this performance measure over the return leg of the trip revealed a significant main effect for type of operation ($F_{(1,27)} = 7.36$, $p=0.01$) but no significant main effect for time of test, and no significant interactions between time of test and type of operation. These results indicate that, overall, the rate of missed targets was higher for single drivers on the return leg of the trip but that there was no deterioration in this performance measure for either operation over this part of the trip. These results only partly correspond with those for the reaction time measure, on which performance of single drivers was improving and performance of two-up drivers was deteriorating over the homeward leg.

Because of the small number of timeouts recorded on the test, analysis by the fourway trip classification was not undertaken. However, Figure 3.13 suggests that the results largely confirm those for type of operation (see also Appendix 6). All the two-up groups showed a consistently low number of timeouts across the entire trip, with the only exception being an elevated number of timeouts early in the outward leg for the short Broome turnaround group. The single group, however, showed an increasing number of timeouts across the outward trip leg followed by an apparent recovery of performance at Broome and further but slight recovery across the homeward trip leg.

FIGURE 3.13: Mean number of timeout trials in on-board reaction time by trip type and point of trip.



2. Heart rate and associated measures

Heart rate for each driver, measured as interbeat interval and interbeat variability was obtained during all periods of driving throughout the trip. These measures were summarised as means for five minute blocks across the trip. Lowered arousal is manifested in heart rate measures as longer interbeat interval (slower heart rate) and increased interbeat variability.

2.1 Comparison of heart rate at beginning of trip, turnaround point and end of trip milestones

Change in interbeat length and interbeat variability at the four major milestones in the trip were analysed by plotting lines of best fit for:

a) the second hour of driving at the *beginning of the trip*,
b) the second to last hour of driving *before Broome*,
c) the second hour of driving *after Broome* and
d) the second to last hour of driving at the *end of the trip*.

The first and last hour of each leg of the trip were not used in these analyses to avoid the confounding influence of negotiating the urban environments in Perth.

For both interbeat interval and interbeat variability, analysis of differences between the operations and across the beginning and the end of each leg of the trip for the two measures, slopes and intercepts, were by multiple independent t-tests (see Kleinbaum, Kupper & Muller, 1988, pp. 265-275) using the modified Bonferroni correction for type I error rate. In all, 19 comparisons were made, resulting in a corrected significance level of 0.016. The comparisons included 7 comparisons for each type of operation, and 12 comparisons for type of trip.

For type of operation, comparisons were made of measures at the beginning and end of each leg of the trip and before and after the Broome interval within each operation, as well as comparison between the operations at each point in the trip. To conserve statistical power, trip types were only compared after the Broome interval, where trips diverged, resulting in 12 comparisons. Comparisons of the hour before Broome, the hour after Broome and the hour at the end of the trip were made **within each two-up trip type**. Each two-up group was also **compared to the single group** at the milestones after Broome and at the end of the trip.

Tables 3.30 and 3.31 display the elapsed time spent driving and in breaks preceding each of the four measurement milestones for each operation and each trip type respectively.

TABLE 3.30: Elapsed break and drive time preceding each of the four major on-road measurement milestones for each operation, and as a function of which two-up driver drove first.

	MILESTONE			
	Beginning of Trip	**Before Broome**	**After Broome**	**End of Trip**
	Mean hrs:min (sd)			
Single				
Breaktime	0:30 (1:39)	16:35 (3:51)	40:10 (6:30)	56:12 (13:49)
Drivetime	2:32 (1:31)	28:26 (1:53)	35:18 (5:31)	57:53 (8:59)
Two-up				
Breaktime	2:43 (2:47)	15:34 (3:05)	45:28 (11:48)	59:03 (11:13)
Drivetime	1:28 (0:25)	13:43 (1:35)	24:20 (7:05)	36:54 (7:33)
Two-up, drove 1st				
Breaktime	0:06 (0:13)	13:43 (2:35)	44:24 (12:30)	58:14 (8:59)
Drivetime	1:42 (0:27)	14:18 (1:07)	25:53 (6:52)	36:44 (7:06)
Two-up, drove 2nd				
Breaktime	5:21 (1:04)	17:25 (2:26)	46:33 (11:38)	59:43 (13:12)
Drivetime	1:14 (0:13)	13:09 (1:50)	23:47 (7:38)	37:02 (8:17)

TABLE 3.31: Elapsed break and drive time preceding each of the four major on-road measurement milestones for each trip type.

	MILESTONE			
	Beginning of Trip	**Before Broome**	**After Broome**	**End of Trip**
	Mean hrs:min *(sd)*			
Single				
Breaktime	0:33 *(1:44)*	16:40 *(4:01)*	40:09 *(6:47)*	58:40 *(8:02)*
Drivetime	2:35 *(1:36)*	28:41 *(1:44)*	34:04 *(3:25)*	57:54 *(4:50)*
Two-up,beyond				
Breaktime	2:28 *(2:33)*	15:07 *(2:25)*	54:54 *(4:54)*	66:54 *(5:57)*
Drivetime	1:27 *(0:26)*	13:35 *(1:15)*	31:55 *(2:33)*	43:51 *(3:01)*
Two-up, long				
Breaktime	2:26 *(2:30)*	16:07 *(3:28)*	48:58 *(4:02)*	62:56 *(5:37)*
Drivetime	1:38 *(0:34)*	15:09 *(0:55)*	20:56 *(4:19)*	34:20 *(6:35)*
Two-up, short				
Breaktime	3:21 *(3:41)*	15:38 *(3:54)*	29:23 *(3:27)*	43:26 *(2:46)*
Drivetime	1:20 *(0:11)*	12:42 *(1:38)*	17:36 *(1:40)*	30:14 *(15:00)*

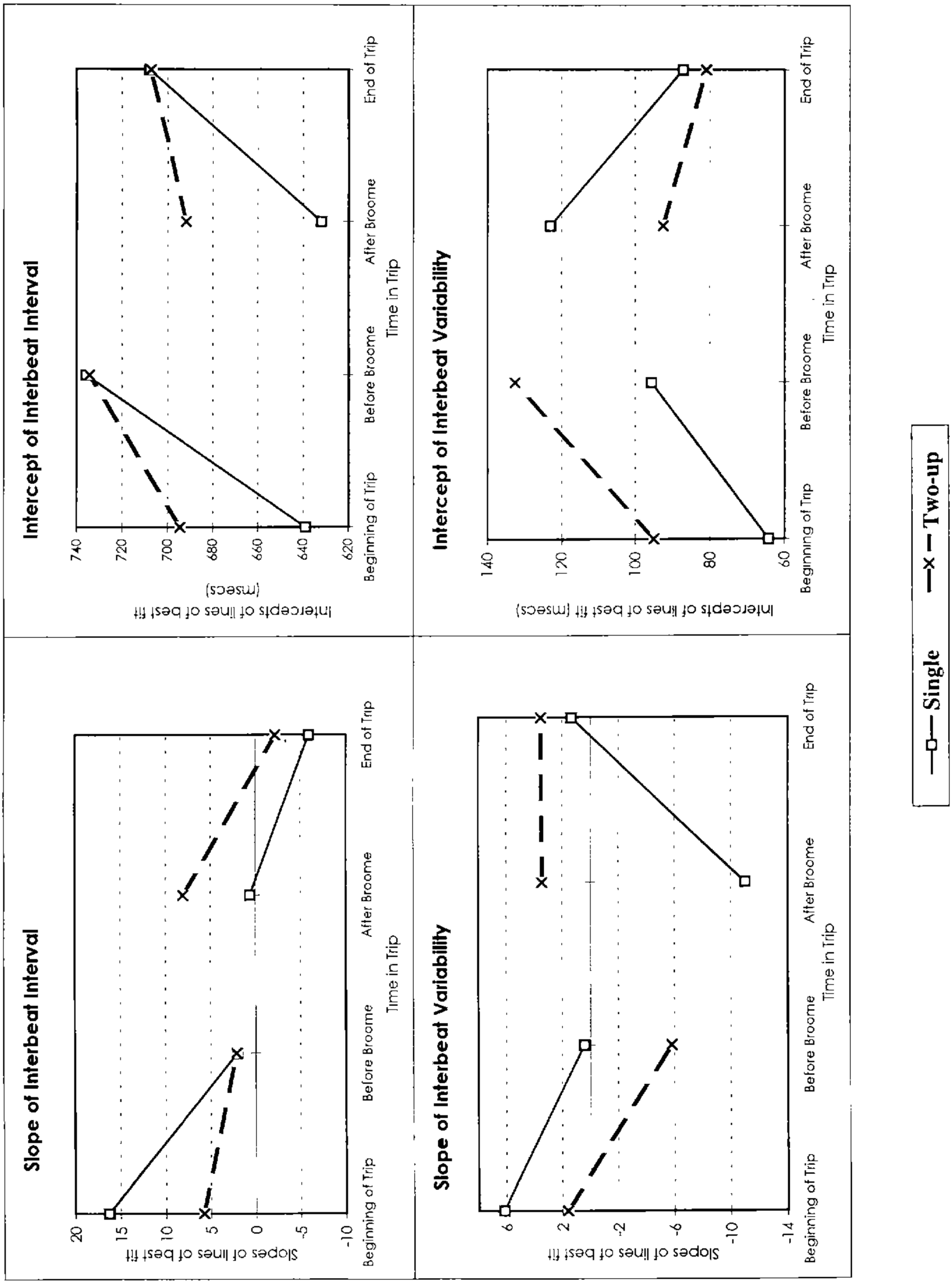
Although the measurement epochs were conceptually consistent for all drivers, operational differences resulted in differences in elapsed driving and rest time before each measurement period. The tables show all the expected differences in elapsed time before each epoch, based on the operational differences already reported. In brief, differences between two-up and single drivers fairly consistently reflected the presence of two drivers sharing the driving throughout the trip, after the first measurement epoch at the beginning of the trip, resulting in decreased time driving and increased time spent in breaks (Table 3.30). Differences between the two drivers in the two-up team were present only at the beginning of the trip, reflecting the fact that the second driver did not begin driving at the start of the trip. Rather, the second driver began the trip with a break from driving, while his partner took the first driving stint. Similarly, differences between two-up trip types emerged after arrival at Broome, as described earlier. These trip differences were entirely consistently reflected in the elapsed time preceding the measurement epochs on the return leg of the trip (Table 3.31). After Broome, time spent in breaks was greatest for the two-up group going beyond Broome and least for the two-up trip with a short stop in Broome. All of the two-up trips included less time in breaks than the single trips. Driving time for each driver was greater for the two-up group going beyond Broome, compared with the two-up trips with Broome turnaround time, but not compared with single trips.

Interbeat interval for each operation

Figure 3.14 shows the slopes of lines of best fit and their intercepts for interbeat interval and interbeat variability for each operation at the four milestones in the trip. Slopes indicated rate and direction of change, while intercepts indicated levels at the beginning of each epoch examined. Positive slopes indicate increasing interbeat interval or variability across the epoch and suggest decreasing levels of alertness. Correspondingly, negative slopes indicate decreasing interbeat interval or variability across the epoch and suggest increasing alertness. Appendix 7 shows the actual slopes and intercepts for each of the lines.

Analysis of the lines of best fit for interbeat interval across the four milestones revealed that average heart rate varied across the trip for both operations (Figure 3.15). At the *beginning of the trip*, average interbeat interval was longer for two-up drivers than for single drivers (comparison of intercepts for single and two-up, $t_{(8)} = 5.67$, $p<0.001$) and lengthening for both groups, but at a greater rate for single drivers (comparison of slopes for single and two-up, $t_{(8)} = 4.16$, $p<0.005$).

FIGURE 3.14: Slopes and intercepts for lines of best fit for Average Interbeat Interval and Interbeat Variability at the beginning, the turnaround point, and at the end of the trip for type of operation.



Before Broome, compared with the beginning of the trip, interbeat interval increased significantly for both operations (intercepts for single, $t_{(8)} = 7.9$, $p<0.001$ and for two-up $t_{(8)} = 4.97$, $p<0.005$), with average interbeat interval was not different for the two operations before Broome. The slope of the line of best fit decreased significantly for single drivers compared with the beginning of the trip ($t_{(8)} = 4.52$, $p<0.005$) but not for two-up drivers, so that interbeat interval was increasing at a lesser rate for single drivers by the end of the first leg of the trip and at a similar rate to two-up drivers.

After Broome, average interbeat interval decreased for both operations compared with interbeat interval before Broome (intercepts for single, $t_{(8)} = 6.46$, $p<0.001$ and for two-up, $t_{(8)} = 3.31$, $p<0.025$), with average interval tending to be shorter for single drivers than two-up drivers at the beginning of the hour after Broome (intercepts, $t_{(8)} = 2.7$, $p<0.05$). The slopes, indicating direction and rate of change in interbeat interval, did not differ significantly between operations over the hour, nor were they significantly different to those before Broome.

At the *end of the trip*, average interbeat interval increased significantly only for single drivers (intercepts, $t_{(8)} = 4.89$, $p<0.005$), with their average interbeat interval at the end of the trip not different to that of two-up drivers. Slopes for lines of best fit at the end of the trip were not different for the two operations. For single drivers, rate of change in interbeat interval over the hour at the end of the trip was not significantly different to the rate after Broome. There was a trend for slopes to decrease for two-up drivers ($t_{(8)} = 2.06$, $p<0.10$), however, indicating that interbeat interval was shortening at the end of the trip.

Interbeat variability for each operation

Analysis of interbeat variability across the trip milestones was also undertaken, using the same analysis strategy. Figure 3.14 displays the values for slopes and intercepts of lines of best fit for interbeat variability for each operation across the four milestones. . Appendix 7 shows the actual slopes and intercepts for each of the lines.

At the *beginning of the trip* average interbeat variability did not differ between the operations, either in terms of its level (intercept) or in terms of its rate of change across the hour (slope). *Before Broome*, at the end of the first leg of the trip, average variability increased significantly for drivers in two-up operations compared with the beginning of the trip (intercepts, $t_{(8)} = 4.06$, $p<0.005$) but not for single drivers, resulting in average variability tending to be higher for two-up drivers than single drivers before Broome(intercepts, $t_{(8)} = 2.23$, $p<0.06$). However, for two-up drivers interbeat variability was decreasing across the hour before Broome (slopes, $t_{(8)} = 3.11$, $p<0.025$) compared with their variability for the hour at the beginning of the trip, but not at a greater rate than among single drivers. The pattern of change across the hour did not differ for single drivers before Broome compared with the beginning of the trip.

After Broome, at the beginning of the homeward leg of the trip, average variability tended to decrease for two-up drivers compared with average variability before Broome (intercepts, $t_{(8)} = 2.79$, $p<0.05$), but did not change significantly for single drivers. Average variability did not differ for the two operations significantly after Broome. Across the hour after Broome, positive slopes showed that interbeat interval tended to be increasingly variable for two-up drivers ($t_{(8)} = 2.56$, $p<0.05$) and negative slopes decreasing variability for single drivers ($t_{(8)} = 2.08$, $p<0.10$), compared with the hour before Broome. This difference in direction of the slope of the line of best fit for the two operations approached significance ($t_{(8)} = 2.68$, $p=0.05$).

At the *end of the trip*, there were no significant changes in interbeat variability. Average variability (intercepts) did not change significantly for either operation, compared with the beginning of this leg of the trip, nor did variability differ between the operations at the end of the trip. Nor did the rate of change in variability over the hour (slope) differ for either operation, compared with the beginning of the return leg of the trip, and the pattern did not differ between the operations.

Interbeat interval for each trip type

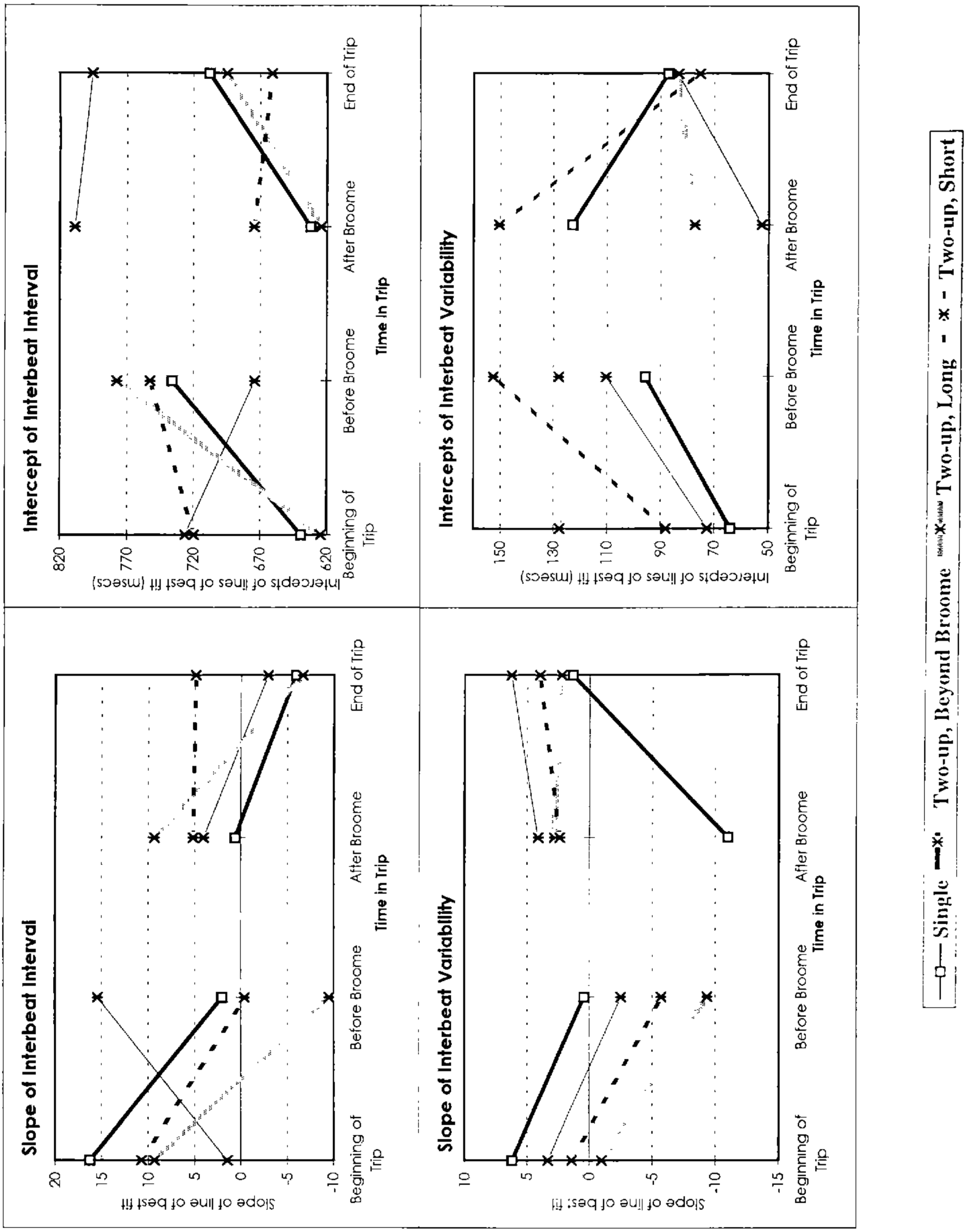
Figure 3.15 shows values for slopes and intercepts of lines of best fit for interbeat interval and interbeat variability across the four milestones for each trip type. Appendix 7 shows the actual slopes and intercepts for each of the lines.

Within each two-up group, comparison of interbeat interval *before Broome* and *after Broome* revealed that average interbeat interval increased significantly for the two-up group going beyond Broome (intercepts, $t_{(8)} = 6.99$, $p<0.001$), decreased significantly for the Broome, long stop group (intercepts, $t_{(8)} = 6.03$, $p<0.001$) and also decreased for the Broome, short stop group (intercepts, $t_{(8)} = 3.33$, $p<0.02$). Across the hour after Broome, the analysis revealed that interbeat interval tended to increase at a lesser rate for the two-up group going beyond Broome, compared with the hour before Broome (slopes, $t_{(8)} = 2.30$, $p<0.05$). In contrast, interbeat interval was increasing at a significantly greater rate after Broome for the group with a long Broome stop (slopes, $t_{(8)} = 3.28$, $p<0.02$), indicating that interbeat interval was lengthening. Change across the hour was not significantly different before and after Broome for the short stop group.

At the *end of the trip*, compared with the hour after Broome, the average interbeat interval had not changed for the two-up group going beyond Broome, nor had change across the hour been affected. For the two-up group with a long stop in Broome, the average interbeat interval had increased significantly at the end of the trip (intercepts, $t_{(8)} = 3.27$, $p<0.02$), although interbeat interval was decreasing significantly across the hour (slopes, $t_{(8)} = 2.86$, $p<0.025$). Neither the average level (intercepts) nor change across the hour (slopes) were significantly affected at the end of the trip compared to interbeat interval after Broome for the two-up short Broome stop group.

Compared with single drivers, the average interbeat interval *after Broome* was higher for the group going beyond Broome (intercepts, $t_{(8)} = 10.77$, $p<0.001$), and tended towards being higher in the group with short Broome stop (intercepts, $t_{(8)} = 2.12$, $p<0.06$), but was not different to the group with long Broome stop. Change in

FIGURE 3.15: Slopes and intercepts for lines of best fit for Average Interbeat Interval and Interbeat Variability at the beginning, the turnaround point, and at the end of the trip for each trip type.



interbeat interval across the hour did not differ for any of the two-up groups compared to the single group across the hour after Broome. *At the end of the trip*, neither the two-up long Broome stop group nor the two-up group going beyond Broome differed significantly from the single group, either in average interbeat interval (intercepts) or in pattern of change across the hour (slopes). However, the two-up group with short Broome stop had significantly shorter average interbeat interval (intercepts, $t_{(8)} = 4.46$, $p<0.01$). The pattern of change across the hour also was significantly different for this group compared with single drivers (slopes, $t_{(8)} = 4.00$, $p<0.01$), with interbeat interval increasing across the hour for the two-up group, and decreasing across the hour for single drivers.

Interbeat variability for each trip type

Values for lines of best fit for interbeat variability at the milestones for each trip type are presented in Figure 3.15. Appendix 7 shows the actual slopes and intercepts for each of the lines.

Within each two-up group, comparison of interbeat variability in the hours *before Broome* and *after Broome* revealed that average interbeat variability after Broome tended to be lower for the two-up group going beyond Broome (intercepts, $t_{(8)} = 2.26$, $p<0.05$) and for the group with a long Broome stop (intercepts, $t_{(8)} = 2.03$, $p<0.06$), and remained unchanged for the two-up group with a short Broome stop. Across the hour after Broome, the analysis revealed that slopes for interbeat variability did not change significantly from those before Broome for any two-up group. At the *end of the trip*, compared with after Broome, interbeat variability had not changed significantly for any two-up group, either in terms of slopes or intercepts.

Compared with single drivers, average interbeat variability *after Broome* was significantly lower for two-up drivers doing trips going beyond Broome (intercepts, $t_{(8)} = 3.69$, $p<0.01$), tended to be lower for the group with long Broome stop (intercepts, $t_{(8)} = 2.08$, $p<0.06$) but was not significantly different for the two-up group with a short Broome stop. Across the hour, interbeat variability was increasing at a greater rate for two-up drivers going beyond Broome (slopes, $t_{(8)} = 3.09$, $p<0.02$) and tended to increase at a greater rate for the group with a long Broome stop (slopes, $t_{(8)} = 2.45$, $p<0.05$), compared with single drivers. No significant differences were evident after Broome between the two-up group with short Broome stop and single drivers. At the <u>*end of the trip*</u>, there were no significant differences between the single group and the two-up groups, either in terms of average interbeat variability (intercepts) or in terms of rate of change across the hour (slopes).

Summary of results for heart rate measures at milestones in the trip

The results for interbeat interval revealed that initial alertness was higher for single drivers than for two-up drivers at the beginning of the trip, as evidenced by shorter interbeat intervals. Interbeat interval was lengthening across the hour however for single drivers, indicating that their alertness was waning at the beginning of the trip. At the end of the first leg of the trip, before Broome, alertness had decreased for both operations, and they no longer differed.

After Broome, in the first hour of the homeward leg of the trip, alertness increased for both operations but significantly more so for single drivers. However, examination of the three two-up trip types on the homeward leg of the trip revealed that alertness had improved only for the two groups with Broome stopping point, with short Broome stop drivers still showing longer interbeat intervals (less alertness) than single drivers and long Broome stop drivers no different to single drivers at this point in the trip. In contrast, alertness was significantly decreased at the beginning of the homeward leg of the trip for the drivers who had gone beyond Broome, with average interbeat intervals significantly longer than those shown by single drivers. Interbeat interval was not lengthening as rapidly as had been the case in the hour before Broome for these drivers however, suggesting some improvement in alertness at this point in the trip.

By the end of the trip, alertness had decreased significantly for single drivers. For two-up drivers overall alertness had been maintained, having not changed significantly from levels shown after Broome, and, moreover, alertness was increasing across the hour. Examination of the three two-up trip types revealed that this general pattern only described Broome short stop drivers. For these drivers interbeat interval remained unchanged, but increasing across the hour, indicating that alertness was beginning to wane but that improvements in alertness obtained after Broome were largely maintained. Their interbeat interval was significantly lower (alertness higher) than for single drivers at the end of the trip. Although interbeat interval was also unchanged at the end of the trip for two-up drivers going beyond Broome, for them this result indicated that the loss of alertness seen after Broome was not recovered and no further loss of alertness occurred. Drivers going beyond Broome were not significantly different from single drivers at the end of the trip. Alertness was decreased for two-up long Broome stop drivers but not different from that shown by single drivers.

Results for interbeat variability partly confirmed the pattern shown by interbeat interval. Drivers did not differ in terms of interbeat variability at he beginning of the trip. By the end of the first leg of the trip, before Broome, interbeat variability had increased significantly only for two-up drivers, indicating lowered alertness for these drivers. At this point in the trip, interbeat variability had increased more markedly for two-up drivers than single drivers, suggesting that their levels of alertness were more affected, although decreasingly so across the hour before Broome. After Broome, initial interbeat variability had not changed for single drivers, but variability was decreasing across the hour, suggesting that improvements in alertness had been obtained for these drivers. In contrast, initial variability for the hour had decreased significantly for two-up drivers overall, although it was increasing across the hour, suggesting that alertness had improved but that the improvement was not being maintained. Examination of the impact of trip type showed that alertness on this measure improved after Broome only for two-up long Broome stop drivers and those drivers going beyond Broome. Their improvements were greater than those obtained by single drivers on average, but were not maintained as well over the hour as for single drivers at the beginning of the homeward journey. Alertness, as measured by interbeat variability, was not improved at this point in the trip for two-up drivers with short Broome stop, with the level and pattern of variability not significantly different to those shown by single drivers.

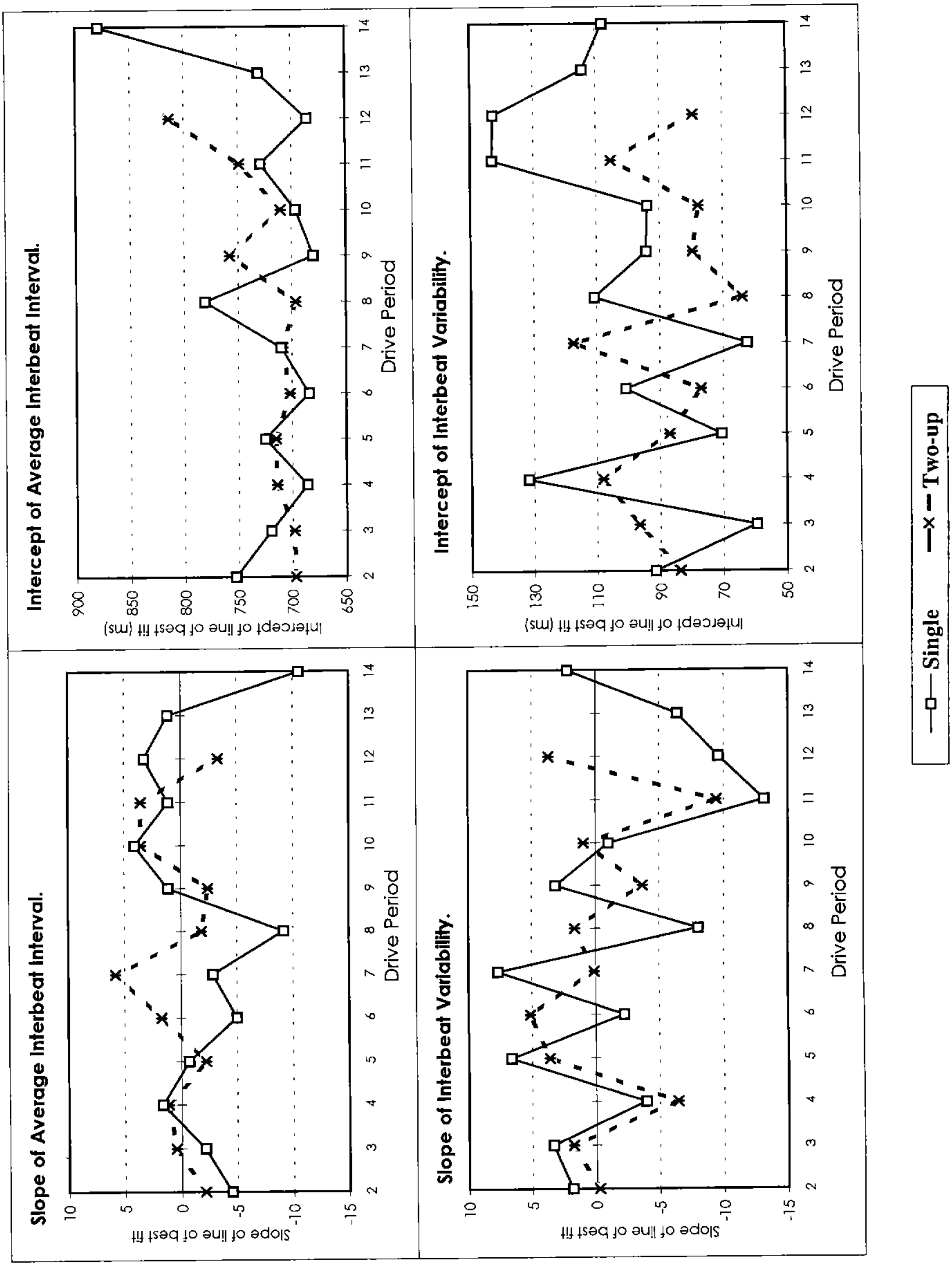
At the end of the trip, interbeat variability had not changed significantly for either operation, indicating that alertness, as evidenced by this measure was maintained. This pattern was shown by all two-up trip types, indicating no further loss of alertness over the homeward leg of the trip.

2.2 Changes in heart rate with each period of driving during the trip

Changes in interbeat interval and interbeat variability were also examined in more detail at the beginning of each period of driving. Driving periods were defined as driving stints bounded by breaks of 15 minutes or more. The first hour of each driving period, excluding the first 15 minutes, provided data for this analysis. The first drive period of the trip was not included as it had already been part of the analysis for trip milestones. The last drive period was included, as previously the last hour had been analysed for this period, not the first hour. To conserve sample size, only type of operation was examined in this detailed analysis. Although trip type was not separately examined, it should be noted that, among the two-up drivers, the later drive periods (beyond 8) essentially reflect the contribution of the two-up drivers doing the longer trips going beyond Broome.

The slopes and initial intercepts of the lines of best fit for each hour were plotted for each operation (Figure 3.16). Appendix 7 shows the actual slopes and intercepts for lines of best fit for each hour. To determine if any linear relationship described the pattern of slopes and intercepts across drive periods in the trip, the data were subjected to a regression analysis using drive period, operation type and the interaction of the two factors as independent variables. The purpose of this analysis was to summarise general patterns across the data, rather than to examine changes at particular points in the trip.

FIGURE 3.16: Slopes and intercepts for lines of best fit for Average Interbeat Interval and Interbeat Variability over the first hour of each drive period for each type of operation.



Analysis of intercepts for average interbeat interval across the trip indicated no significant effect of type of operation, nor was the regression significant overall. When fitted alone, drive period was associated with a significant increase in average interbeat interval across the trip ($F_{(1,22)} = 5.41$, $p=0.03$, $r^2=0.2$). This trend was particularly evident in the later parts of the trip (Figure 3.16). Analysis of slopes for interbeat interval across drive periods in the trip revealed that the regression was non-significant. There was no evidence for effects of type of operation, or of interaction and no indication of linear change across drive periods.

Intercepts and slopes for interbeat variability across the trip are also shown in Figure 3.16. The analysis of intercepts revealed that the regression across drive periods and operations approached significance ($F_{(3,20)} = 2.48$, $p=0.09$, $r^2=0.27$) and indicated a trend towards an interaction (test for parallelism $F_{(1,20)} = 3.05$; $p<0.1$). Examination of the interaction suggests that average interbeat variability increased over the trip for single drivers, but not for two-up drivers. Both operations showed little systematic change in average interbeat variability in the earlier parts of the trip, with the difference between the groups emerging at about the 8th driving period. Analysis of slopes for interbeat variability indicated no significant effect of type of operation and no significant interaction, nor was the regression significant overall. When fitted alone, driving period showed a significant decrease in slopes for interbeat variability across the trip. These results indicate that interbeat variability for both groups decreased more rapidly over the first hour of the drive period as the trip progressed.

Overall, the finding that average interbeat interval increased across the trip suggests that alertness was decreasing over the trip for both operations, and that this effect occurred later in the trip. These results were in part confirmed by the results for interbeat variability, which suggested that again decreased arousal as evidenced by increasing variability, occurred late in the trip, but only for single drivers. The finding that variability decreased more rapidly over the first hour of a driving period for both operations as the trip progressed most likely reflects the higher average interbeat interval found at the beginning of these hours later in the trip. The finding also suggests that the lower arousal evident at the beginning of the later driving periods did not persist over the whole hour.

3. Steering

The pattern of steering control across the trip was analysed in the same way as 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 fitted for the beginning of the trip, at the end of the first leg of the trip before Broome, at the beginning of the second leg of the trip after Broome, and at the end of the trip. Again data collected during the second hour of driving was used for the beginning of each leg of the trip and data collected during the second last hour was used for the end of each leg, with data summarised as means over five minute periods. The slopes and intercepts for both average steering and steering variability were used to compare operation type and trip type across the trip. Again, comparisons were made by multiple t-test with modified Bonferroni correction of type I error rate.

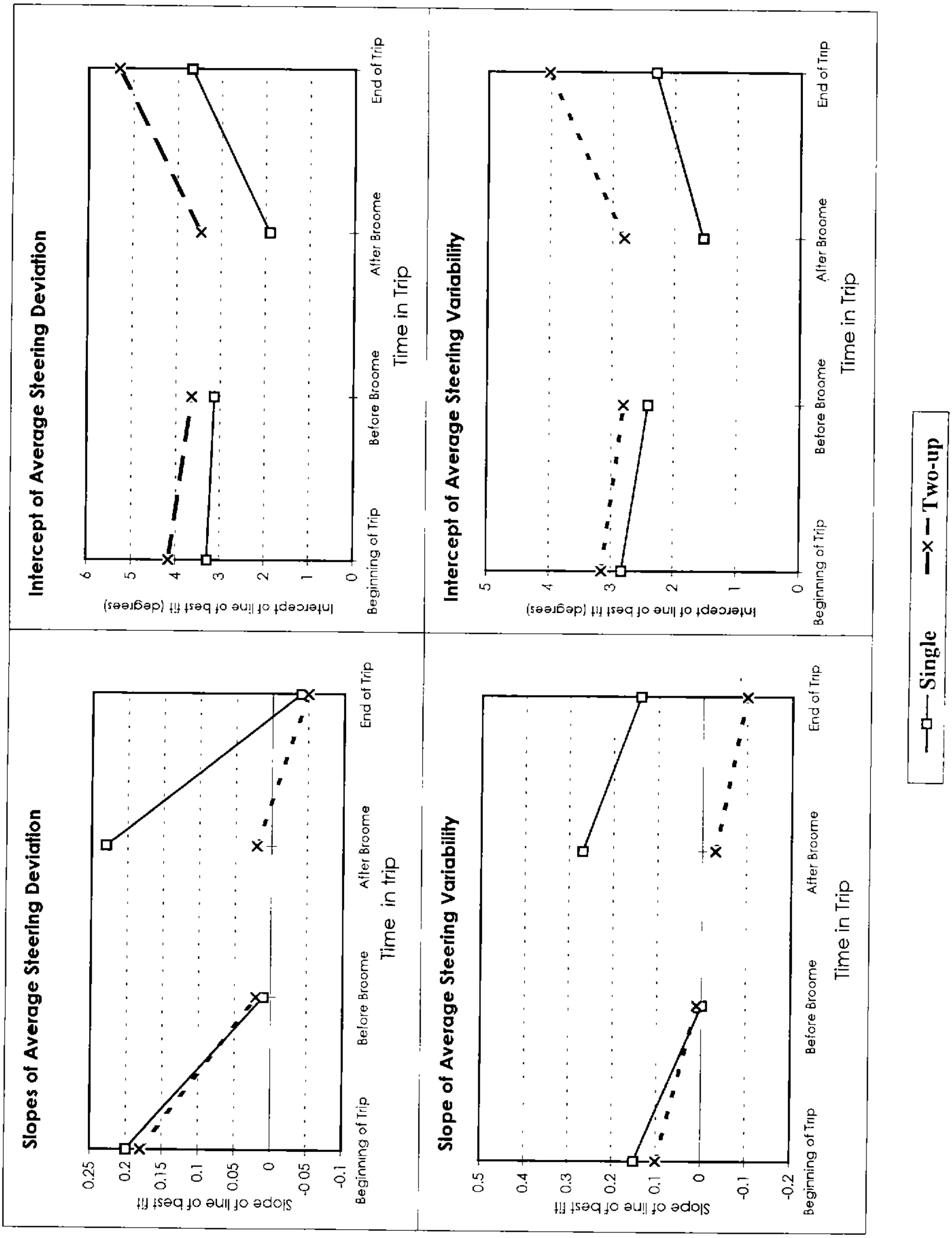
3.1 Comparison of steering at the beginning, turnaround point and end of trip milestones

Figure 3.17 shows the intercept and slope values for lines of best fit for average steering deviation and steering variability for each operation across the four milestones. Appendix 8 shows the actual slopes and intercepts for each of the lines.

Average steering deviation for each operation

At the *beginning of the trip*, average steering deviations tended to be larger for two-up drivers than single drivers (intercepts, $t_{(8)} = 2.35$, $p<0.05$) but the operations did not differ in terms of change over the hour (slopes). *Before Broome*, average steering

FIGURE 3.17: Slopes and intercepts for lines of best fit for Average Steering Deviation and Steering Variability at the beginning. the turnaround point, and at the end of the trip for type of operation.



deviations had not changed for either group since the beginning of the trip. Deviations for two-up drivers again tended to be larger than for single drivers (intercepts, $t_{(8)}$ = 3.19, p<0.02). However, the rate of change in steering over the hour compared with the hour at the beginning of the trip was not significantly different for two-up drivers, and tended towards decreased slopes among single drivers ($t_{(8)}$ = 2.7, p<0.05).

After Broome, at the beginning of the second leg of the trip, average deviations tended to decrease for single drivers (intercepts, $t_{(8)}$ = 2.32, p<0.05) and remained unchanged for two-up drivers compared with deviations before Broome, with no significant differences in the pattern of change over the hour (slopes). Average deviations again tended to be larger for two-up drivers than for single drivers (intercepts, $t_{(8)}$ = 2.93, p<0.025). At the *end of the trip*, average steering deviations increased significantly for both operations (intercepts for two-up drivers, $t_{(8)}$ = 5.47, p<0.001 and intercepts for single drivers, $t_{(8)}$ = 3.28, p<0.02) compared with the beginning of this leg of the trip, with no differences evident in change over the hour (slopes). Average deviations remained larger for two-up drivers at the end of trip ($t_{(8)}$ = 4.69, p<0.005).

Steering variability for each operation

Steering variability showed much the same pattern of results as average steering deviations (see Figure 3.17). At the *beginning of the trip*, there were no significant differences between the operations. *Before Broome*, average steering variability was significantly greater for two-up drivers than for single drivers (intercepts, $t_{(8)}$ = 2.44, p<0.05), although their level of variability had not changed significantly, either in terms of intercept or slope, compared with the hour at the beginning of the trip. No significant change was evident for single drivers either between the beginning of the trip and the end of the first leg.

After Broome, steering variability had not changed significantly for either operation compared with the hour before Broome, nor was there any significant difference between the operations. At the *end of the trip*, however, compared with the hour after Broome, average steering variability was significantly increased for two-up drivers (intercepts, $t_{(8)} = 3.9$, $p<0.005$) while the rate of change across the hour (slope) was not different. For single drivers, steering variability had not changed significantly at the end of the trip compared with the hour after Broome. Consequently, at the end of the trip average variability was greater for two-up drivers than for single drivers (intercepts, $t_{(8)} = 5.9$, $p<0.001$), although variability was increasing more rapidly over the hour for single drivers than for two-up drivers (slopes, $t_{(8)} = 3.00$, $p<0.02$).

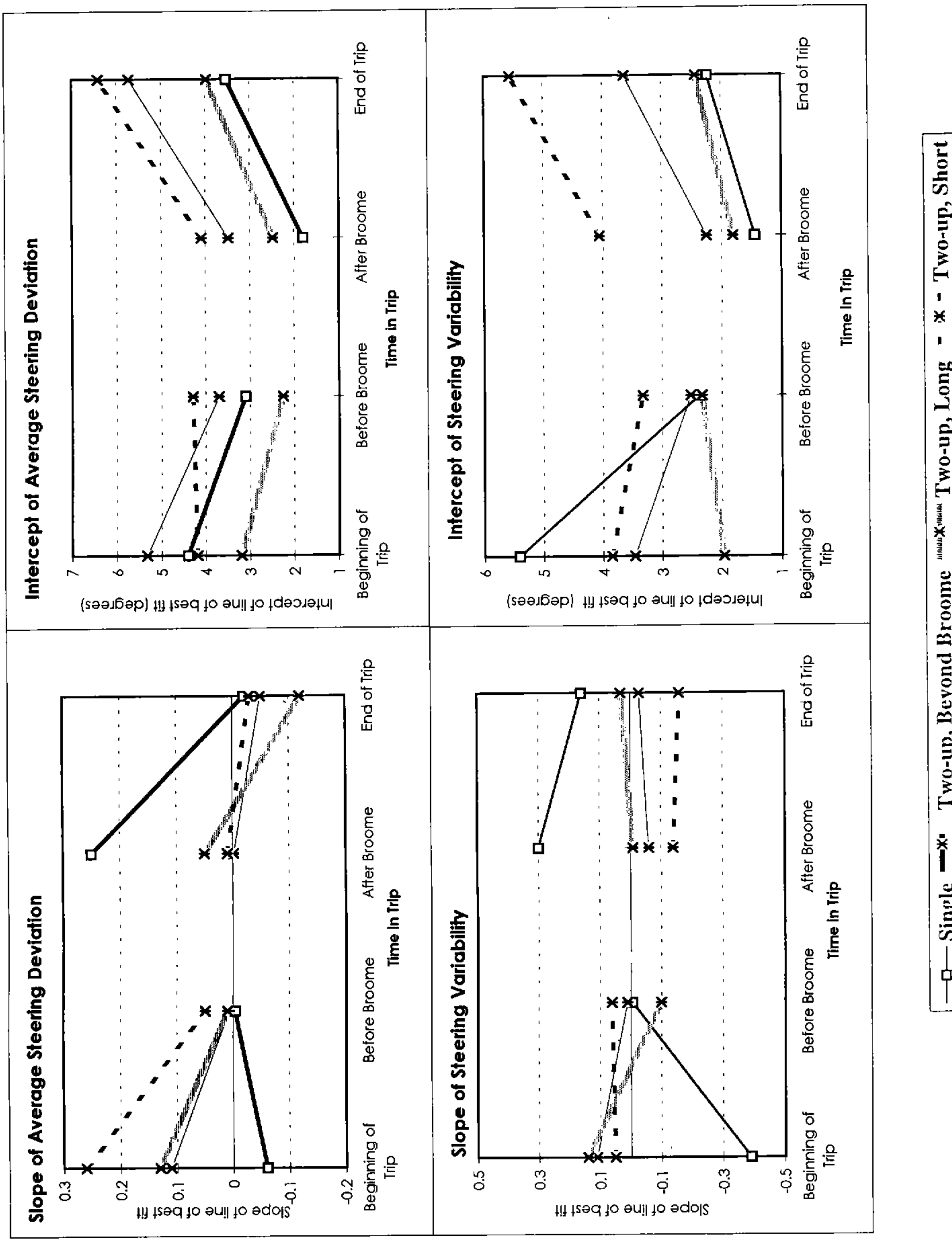
Average steering deviation for each trip type

Figure 3.18 shows the values for slopes and intercepts of lines of best fit for average steering deviation and steering variability for each trip type at milestones in the trip. Appendix 8 shows the actual values for the slopes and intercepts.

Within each two-up group, comparison of average steering deviation *before Broome* and *after Broome* revealed no significant differences for any of the groups. For each group, average steering deviation (intercepts) and change in deviations over the hour (slopes) remained unaffected. At the *end of the trip*, average steering deviation significantly increased for each two-up group compared with the hour after Broome (intercepts for drivers going beyond Broome, $t_{(8)} = 5.87$, $p<0.001$, drivers with long Broome stop, $t_{(8)} = 3.63$, $p<0.01$ and drivers with short Broome stop, $t_{(8)} = 4.69$, $p<0.001$). There were, however no significant differences in the rate at which steering deviation changed over the hour at the end of the trip, compared with the hour after Broome.

Compared with single drivers in the hour *after Broome*, average steering deviation tended to be greater for two-up drivers going beyond Broome (intercepts, $t_{(8)} = 2.82$, $p<0.025$) and for two-up drivers with a short Broome stop (intercepts, $t_{(8)} = 3.83$, $p<0.005$). There were no differences for slopes. Average steering deviation did not differ between single drivers and the two-up group with long Broome stop in the hour after Broome. At the *end of the trip*, average steering deviations were significantly

FIGURE 3.18: Slopes and intercepts for lines of best fit for Average Steering Deviation and Steering Variability at the beginning, the turnaround point, and at the end of the trip for each trip type.



greater for two-up drivers going beyond Broome (intercepts, $t_{(8)} = 6.64$, $p<0.05$) and for two-up drivers with a short Broome stop (intercepts, $t_{(8)} = 6.38$, $p<0.001$) than for single drivers, while two-up drivers with a long stop in Broome again did not differ from single drivers. There were no differences between any of the two-up groups and the single drivers in the pattern of steering deviation change over the hour at the end of the trip.

Steering variability for each trip type

Figure 3.18 also shows the values for slopes and intercepts of lines of best fit for steering variability for each trip type at milestones in the trip. Appendix 8 shows the actual values for the slopes and intercepts.

Within each two-up group, comparison of average variability in steering in the hour *before Broome* and the hour *after Broome*, revealed that there were no differences for any of the two-up groups, nor any differences in the rate at which steering deviation changed over each hour. At the *end of the trip*, average variability increased for each group compared with steering variability after Broome (intercepts for drivers going beyond Broome, $t_{(8)} = 6.0$, $p<0.001$, drivers with long Broome stop, $t_{(8)} = 3.94$, $p<0.01$ and drivers with short Broome stop, $t_{(8)} = 2.65$, $p<0.05$). There were no differences in the rate at which steering deviation changed over each hour.

Compared with single drivers, variability *after Broome* tended to be greater for two-up drivers with a short Broome stop (intercepts, $t_{(8)} = 2.33$, $p<0.05$), with no differences evident in average variability between single drivers and the other two-up groups. There were no significant differences between single drivers and any of the two-up groups in the rate at which steering deviation changed over the hour. At the *end of the trip*, steering variability remained significantly greater for two-up short Broome stop drivers (intercepts, $t_{(8)} = 8.76$, $p<0.001$) and two-up drivers going beyond Broome (intercepts, $t_{(8)} = 5.38$, $p<0.001$) than for single drivers, but tended to increase at a greater rate over the hour for the single drivers (slopes, single compared with two-up short stop, $t_{(8)} = 3.2$, $p<0.02$ and two-up beyond Broome, $t_{(8)} = 2.71$, $p<0.05$). Again, level of steering variability for two-up drivers with a long Broome stop did not differ to that for single drivers. However, as for the other two-up groups, there was a trend for steering variability to be increasing more markedly over the hour at the end of the trip for single drivers than two-up long Broome stop drivers (slopes, $t_{(8)} = 2.17$, $p<0.1$).

Summary of results for steering measures at milestones in the trip

The results for average steering deviation revealed that for single drivers, steering deviations remained unchanged over the first leg of the trip, but decreased in size significantly after Broome and then increased again at the end of the trip. These results suggest that alertness for these drivers had improved after Broome, and then deteriorated again at the end of the trip. For two-up drivers overall, steering deviations did not change until the end of the trip, at which time they increased in size. These results suggest that there were no alertness-related changes in steering control among two-up drivers until the end of the trip, when alertness decreased. Examination of the three two-up trip types revealed that this pattern was shown by each two-up trip type

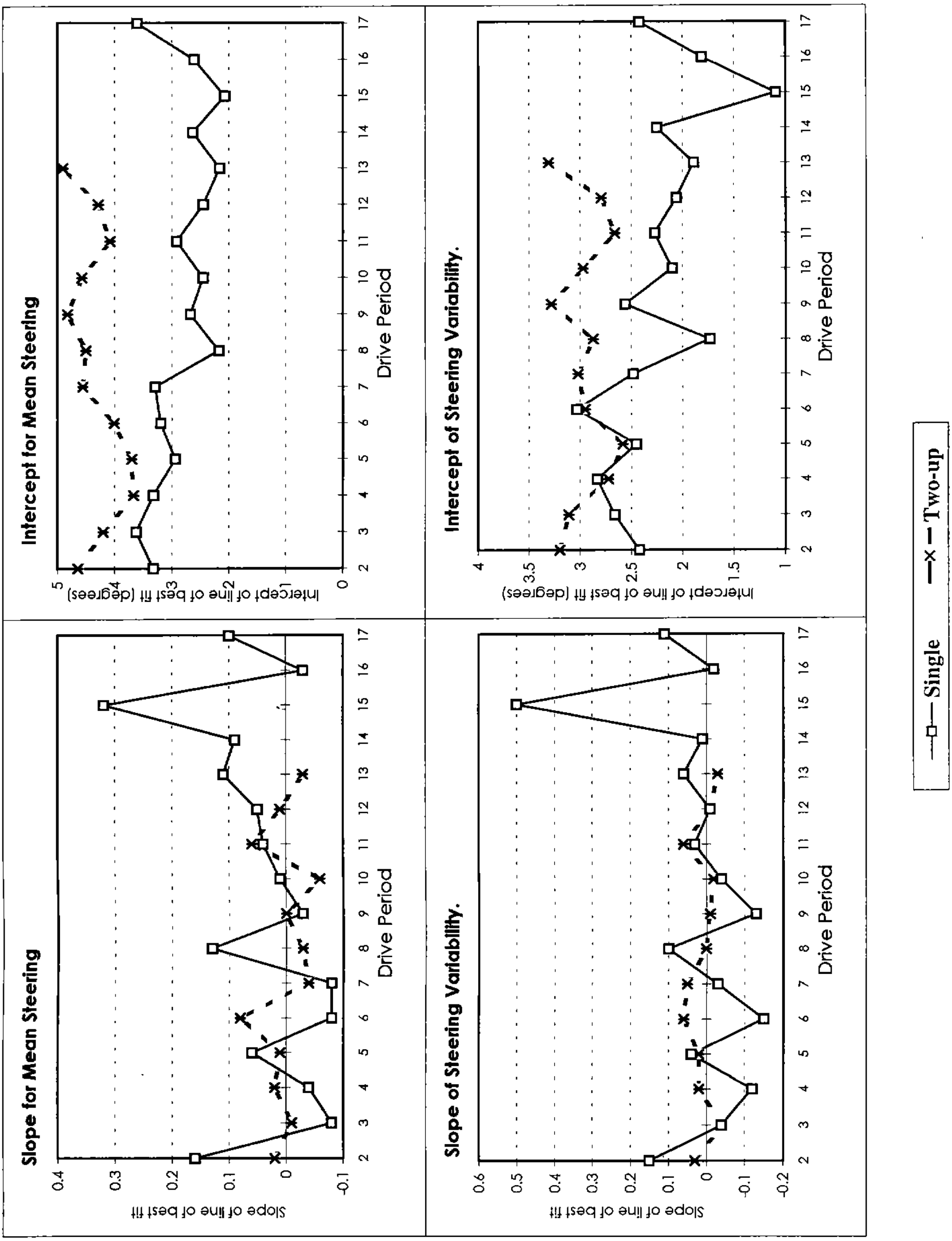
Throughout the trip, two-up drivers overall showed larger steering deviations than single drivers, suggesting, in general, lower alertness for two-up drivers throughout the trip. However, after Broome and at the end of the trip the analysis revealed that this was the case only for two-up short stop drivers and for drivers going beyond Broome. Those two-up drivers with a long stop in Broome were not significantly different to single drivers at either milestone over the homeward leg of the trip. Although no formal analysis was undertaken Figure 3.18 suggests that steering deviations were smaller for two-up long stop drivers than the other two-up groups throughout the trip, and largely paralleled levels shown by single drivers. In contrast, two-up short stop drivers and two-up drivers going beyond Broome appeared to show somewhat larger deviations than single drivers on the outward leg of the trip, but the difference between these groups and single drivers increased markedly on the return leg of the trip. These results suggest that alertness-related changes in steering movements were more marked for the two-up short stop drivers, and for two-up drivers going beyond Broome than single drivers on the homeward leg of the trip, while two-up long Broome stop drivers were more similar to single drivers.

These results were largely confirmed by the results for variability of steering deviation. Initial variability of steering deviation did not change significantly for single drivers at any milestone in the trip. However, at the end of the trip, variability was increasing significantly over the hour, suggesting that alertness was waning. For two-up drivers overall, the same pattern emerged as for average deviation, with variability increased significantly at the end of the trip. This pattern was shown irrespective of type of two-up trip undertaken. At the end of the first leg of the trip (before Broome) and at the end of the trip, two-up drivers in general showed significantly greater variability than single drivers. Again, this reflected that only two-up short and two-up beyond Broome drivers differed from single drivers. After Broome, only two-up short stop drivers differed from single drivers, suggesting that alertness was greater for these drivers at this point in the trip. By the end of the trip two-up short stop and two-up beyond Broome drivers showed greater variability in steering deviations than single drivers. Two-up long stop drivers more closely paralleled the level of variability shown by single drivers. Again this would suggest that alertness alertness-related changes in steering movements were more marked for the two-up short stop drivers, and for two-up drivers going beyond Broome than single drivers on the homeward leg of the trip, while two-up long Broome stop drivers were more similar to single drivers.

3.2 Changes in steering with each period of driving during the trip

The pattern of steering deviation across each driving period in the trip was examined using the same method as for interbeat interval and interbeat variability. The slopes and intercepts of the lines of best fit for the first hour of each drive period were plotted for each operation (Figure 3.19 and Appendix 8). Again, trip type was not separately

FIGURE 3.19: Slopes and intercepts for lines of best fit for Average Steering Deviation and Steering Variability over the first hour of each drive period for each type of operation.



examined in this analysis because the later driver periods (beyond 8) essentially reflect the contribution of the two-up drivers doing the longer trips going beyond Broome. As previously, to determine if any linear relationship described the pattern of slopes and intercepts across drive periods in the trip, the data were subjected to a regression analysis using driving period, operation type and the interaction of the two factors as independent variables. The purpose of this analysis was to summarise general patterns across the data, rather than to examine changes at particular points in the trip.

Analysis of average steering deviation across the first hour of each driving period revealed a significant interaction between driving period and type of operation (test for parallelism, $F_{(1,24)} = 5.05$, $p=0.03$). Examination of the regression line ($F_{(3,24)} = 28.72$, $p<0.0001$, $r^2=0.78$) revealed that two-up drivers showed an increase in intercept values for steering deviation across the trip while single drivers showed a decrease in average steering deviation across the trip. This divergence appeared to become more marked later in the trip, after about the 6th or 7th driving period (Figure 3.19).

Analysis of the slopes for average steering deviations over the first hour of each drive period revealed no significant effect of type of operation, and no significant interaction between driving period and type of operation. When driving period was fitted alone, it also failed to reach significance. These results indicate that the pattern of change in average steering deviation within the first hour of each drive period did not vary systematically over the course of the trip. As Figure 3.19 shows, the size and direction of slopes varied around zero throughout the trip for two-up drivers. For single drivers, wider variation was evident, with a suggestion of an increase in the number of positive slopes of greater magnitude towards the end of the trip.

Steering variability showed much the same pattern as steering deviation. Regression of driving period and type of operation for average steering variability across the trip revealed a near significant interaction (test for parallelism, $F_{(1,24)} = 3.33$, $p=0.08$). Closer examination of the regression line showed that steering variability for two-up drivers did not change systematically over the course of the trip. In contrast, single drivers demonstrated decreasing steering variability at the beginning of each driving period as the trip progressed.

Analysis of slopes for steering variability across the trip revealed no effects of type of operation, or any interaction of this factors with driving period. When fitted alone, driving period also failed to approach significance. These results indicate that the pattern of change in steering variability within the first hour of each drive period did not vary systematically over the course of the trip. As Figure 3.19 shows, the direction and magnitude of slopes varied across the trip for both groups, with the variation appearing to be wider for single drivers.

4. Speed

Exactly the same analysis strategy was used to assess patterns of speed across the trip as was used for steering deviation and heart rate measures.

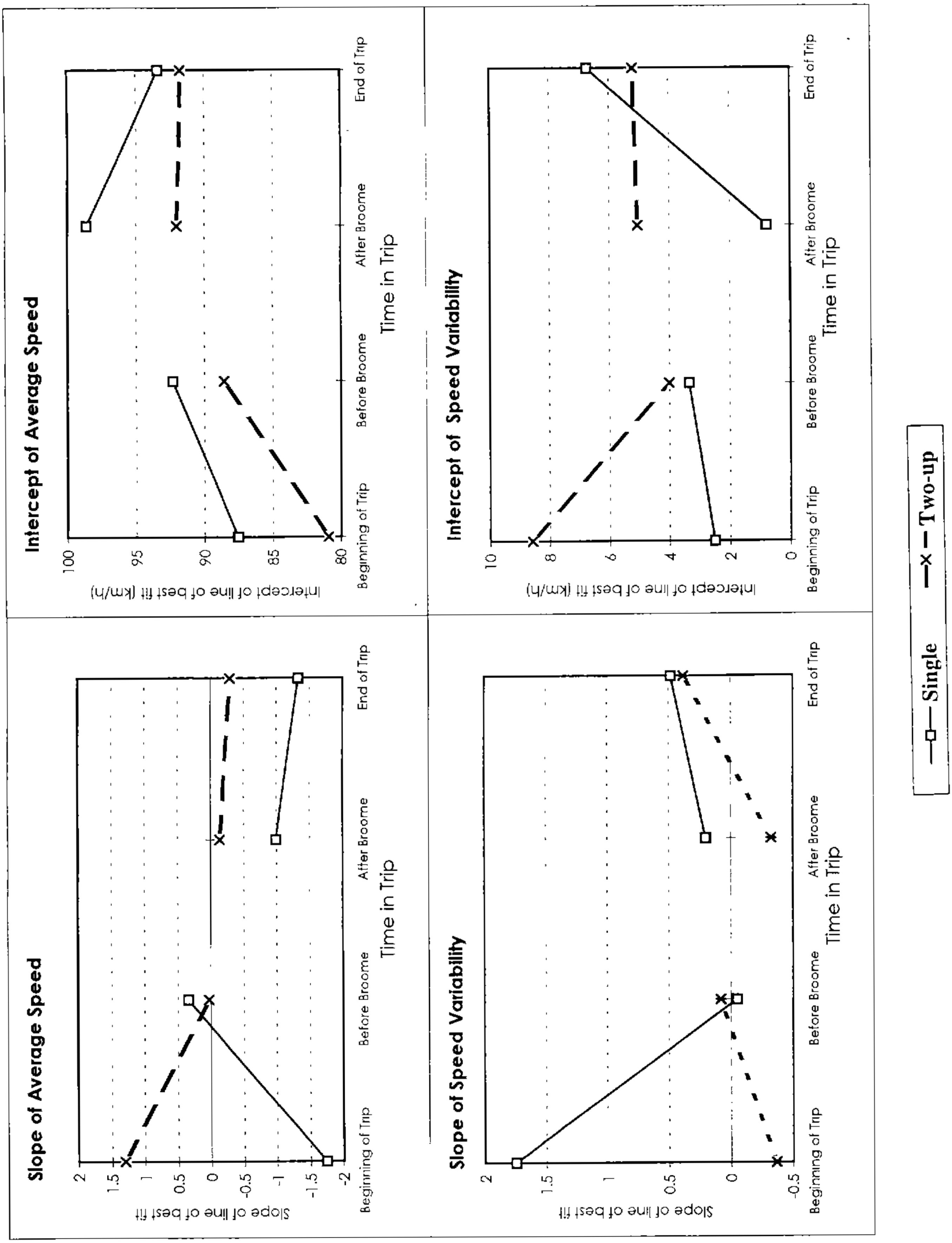
4.1 Comparison of speed at the beginning, turnaround point and end of trip milestones

Figure 3.20 shows the values for slopes and intercepts of lines of best fit for average speed and speed variability for each operation at milestones in the trip. Appendix 8 shows the actual values for the slopes and intercepts.

Average speed for each operation

The analysis of average speed revealed that there were few major differences between the two operations, with the same general pattern evident in the data. At the *beginning of the trip*, average speed (intercepts) and pattern of change across the hour (slopes) did not differ significantly between the two operations. Average speed increased over the first leg of the trip for both operations, with the increase

FIGURE 3.20: Slopes and intercepts for lines of best fit for Average Speed and Speed Variability at the beginning, the turnaround point, and at the end of the trip for each trip type.



approaching significance for two-up drivers (intercepts, $t_{(8)} = 2.8$, $p<.05$). ***Before Broome***, however, average speed was consistently slightly slower for two-up drivers than single drivers ($t_{(8)} = 4.4$, $p<0.005$), while the rate of change across the hour did not differ between the operations, being reasonably constant for both operations. Compared with their rate of change across the hour at the beginning of the trip, two-up drivers tended to change more slowly across the hour before Broome (slopes, $t_{(8)} = 2.26$, $p<0.1$), while the rate of change across the two hours was not significantly different for single drivers. Overall, then, speed over the first leg of the trip tended to converge for the two operations.

After Broome, average speed tended to be higher for both groups, with the increase approaching significance for single drivers, compared with the hour before Broome (intercepts, $t_{(8)} = 2.86$, $p<0.05$). Average speed over the hour was decreasing for both groups, with the difference in rate of change across the hour compared with the hour before Broome approaching significance for single drivers (slopes, $t_{(8)} = 2.38$, $p<0.05$). Similar to the pattern before Broome, average speed at the beginning of the second leg of the trip was consistently slightly slower for two-up drivers than for single drivers (intercepts, $t_{(8)} = 7.2$, $p<0.001$), with the speed decreasing more rapidly over the hour for single drivers than for two-up drivers (slopes, $t(8) = 3.7$, $p<0.01$). Again these results indicate that average speed at the beginning of the second leg of the trip converged for the two groups.

At the *end of the trip*, average speed was not significantly different for either operation, compared with the beginning of the second leg of the trip, nor did they differ from each other. Speed was decreasing over the hour for both groups. The rate of change across the hour at the end of the trip did not differ from the pattern for each operation after Broome, nor was there a difference between the slopes for the operations at this point in the trip.

Speed variability for each operation

Figure 3.20 shows the values for slopes and intercepts of lines of best fit for speed variability for each operation at milestones in the trip. Appendix 8 shows the actual values for the slopes and intercepts.

Analysis of speed variability only partly revealed the same pattern of convergence between the operations as had been shown for average speed. At the *beginning of the trip*, variability tended to be greater for two-up drivers than single drivers ($t_{(8)} = 3.12$, $p<0.02$), but increasing more rapidly for single drivers across the hour ($t_{(8)} = 4.24$, $p<0.01$). In the hour *before Broome*, at the end of the first leg of the trip, variability had converged for the two operations, so that average variability (intercepts) did not differ. Two-up drivers tended to have lower average variability in speed before Broome than they had at the beginning of the trip (intercepts, $t_{(8)} = 2.55$, $p<0.05$), whereas the intercepts did not differ for single subjects. Change in variability over the hour (slopes) did not differ between the operations, but single drivers were becoming significantly less variable over the hour than they had been over the hour at the beginning of the trip (slopes, $t(8) = 7.2$, $p<0.001$), while change over the hour was not significantly different from the beginning of the trip for two-up drivers.

After Broome, average speed variability was significantly lower for single drivers than two-up drivers (intercepts, $t_{(8)} = 3.79$, $p<0.01$), although the rate of change in variability across the hour (slopes) did not differ between the two operations. Average variability had not changed significantly for two-up drivers compared with the hour before Broome, but had decreased significantly for single drivers (intercepts, $t_{(8)} = 3.67$, $p<0.01$). Change in variability across the hour after Broome was not significantly different compared with the hour before Broome for either operation.

At the *end of the trip*, speed variability had increased for single drivers from levels shown after Broome (intercepts, $t_{(8)} = 4.7$, $p<0.01$) and remained unchanged for two-up drivers. The change over the hour was not significantly different for either group compared with the hour at the beginning of this leg of the trip. There were no differences in speed variability between the operations at the end of the trip.

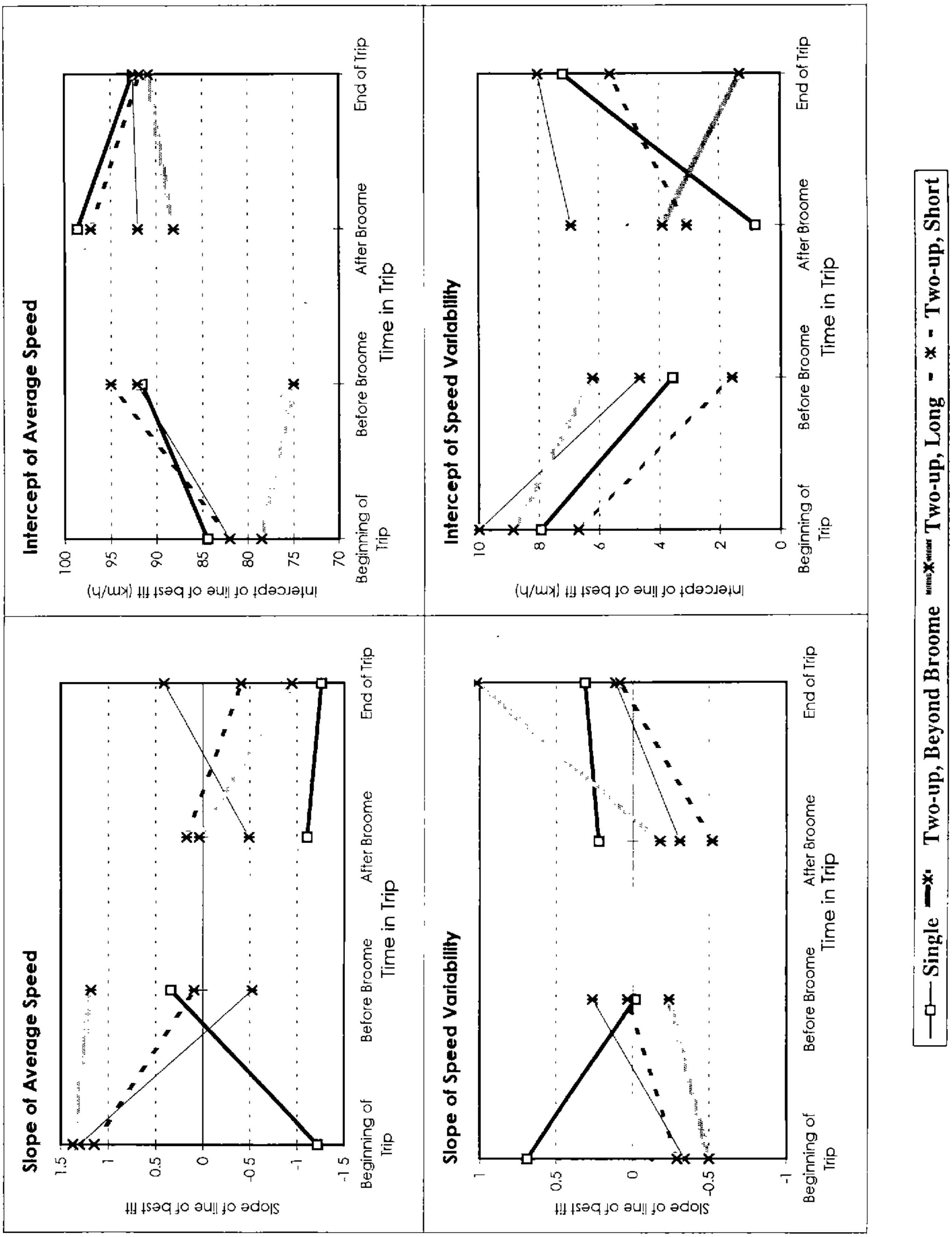
Average speed for each type of trip

Figure 3.21 shows the values for slopes and intercepts of lines of best fit for average speed and speed variability for each trip type at milestones in the trip. Appendix 8 shows the actual values for slopes and intercepts.

Within each two-up group, comparison of average speed *before Broome* and *after Broome* showed that speed was consistently slightly higher after Broome for the two-up long stop group (intercepts, $t_{(8)} = 5.78$, $p<0.001$) and tended to be higher for the two-up short stop group (intercepts, $t_{(8)} = 2.60$ $p<0.05$), although change across the hour (slopes) were not different for either group. For the group going beyond Broome both average speed and change across the hour remained unchanged. At the *end of the trip*, average speed was slightly higher for the two-up long Broome stop group compared with their speed after Broome (intercepts, $t_{(8)} = 4.91$, $p<0.01$) but was tending to decrease at a more rapid rate over the hour at the end of the trip (slopes, $t_{(8)} = 2.57$, $p<0.05$). Average speed and change in speed across the hour remained unaffected for the other two-up groups at the end of the trip, compared with the hour after Broome.

Compared with single drivers, few differences emerged for the three two-up groups at the beginning of the second leg of the trip. After Broome, the two-up long Broome stop showed consistently lower speed than the single group (intercepts, $t_{(8)} = 3.93$, $p<0.01$). There were no other differences at this point in the trip between the two-up groups and single drivers. Similarly, at the *end of the trip*, there were few differences in average speed between single drivers and two-up groups. Single drivers tended to decrease their speed at a more rapid rate than two-up drivers going beyond Broome (slopes, $t_{(8)} = 2.57$, $p<0.05$) but otherwise did not differ significantly from the two-up groups at the end of the trip.

FIGURE 3.21: Slopes and intercepts for lines of best fit for Average Speed and Speed Variability at the beginning, the turnaround point, and at the end of the trip for each trip type.



Speed variability for each trip type

Figure 3.21 shows the values for slopes and intercepts of lines of best fit for speed variability for each trip type at milestones in the trip. Appendix 8 shows the actual values for the slopes and intercepts.

Within each two-up group, there were few differences in the patterns of speed variability across the trip. Comparison of speed variability *before Broome* and *after Broome* revealed a tendency for two-up short Broome stop drivers to decrease their speed variability at a slightly greater rate over the hour after Broome than they had done in the hour before (slopes, $t_{(8)} = 2.62$, $p<0.05$) although their average initial variability (intercepts) was not significantly different. Both other two-up groups remained unchanged in the hour after Broome. At the *end of the trip* compared with the hour after Broome, two-up long Broome stop drivers tended to increase their variability at a greater rate over the hour (slopes, $t_{(8)} = 2.73$, $p<0.05$), but the average initial level of variability (intercepts) remained unchanged. Variability of speed also tended to be increasing more rapidly across the hour at the end of the trip for two-up short Broome stop drivers (slopes, $t_{(8)} = 3.16$, $p<0.02$), with their average level slightly higher at the end of the trip (intercepts, $t_{(8)} = 3.36$, $p<0.01$). Speed variability for the two-up group going beyond Broome remained unchanged at the end of the trip.

Compared with single drivers, the three two-up groups largely revealed the pattern of differences seen for the operations compared as a whole. *After Broome*, each two-up group tended to have slightly higher variability than single drivers (intercepts for two-up, beyond Broome, $t_{(8)} = 3.57$, $p<0.01$, two-up, long Broome stop, $t_{(8)} = 2.75$, $p<0.05$ and two-up, short Broome stop, $t_{(8)} = 2.62$, $p<0.05$). Across the hour after Broome, variability was decreasing at a slightly greater rate for two-up drivers with a short Broome stop, compared with single drivers (slopes, $t_{(8)} = 3.36$, $p<0.01$). There were no differences between single drivers and the other two-up groups at this point in the trip. At the *end of the trip*, variability of speed for single drivers had become greater than for two-up long Broome stop drivers (intercepts, $t_{(8)} = 3.4$, $p<0.01$) and was not different to that shown by the other two-up groups. There were no significant differences in the rate of change across the hour at the end of the trip between single drivers the two-groups.

Summary of speed measures at milestones in the trip

Overall, throughout the trip average speed was slightly slower for two-up drivers, but converged across the trip, however, so that the operations did not differ at the end of trip milestone. For both operations, average speed increased over the trip, before decreasing in the second last hour of the trip. In general, this pattern was seen irrespective of trip type for two-up drivers.

Speed variability only partly revealed the same pattern of convergence as seen for average speed. Two-up drivers overall tended to have more variable speed throughout the trip than single drivers. Over the first leg of the trip, variability was lower before Broome than at the beginning of the trip for two-up drivers and initial levels remained largely unchanged for single drivers with variability over the hour decreasing, so that the operations no longer differed before Broome. After Broome, variability decreased for single drivers and remained unchanged for two-up drivers, irrespective of trip type, resulting in lower variability of speed for single drivers at this point in the trip. At the end of the trip speed variability increased for single drivers, and again remained unchanged for two-up drivers, so that at this point in the trip the operations did not differ. Examination of trip type revealed that initial variability was unchanged only for the two-up long stop group and the two-up beyond Broome group. Variability in fact increased for the two-up short stop group, and was increasing more rapidly over the hour for the long stop group. At the end of the trip, variability was lower for two-up long stop drivers than for single drivers, while the other two-up drivers did not differ from single drivers.

These results suggest that after initially high variability at the beginning of the trip, speed variability for two-up drivers overall decreased and remained at the lower level for the remainder of the trip, impervious to changes in level of alertness. For single drivers, variability decreased after Broome, suggesting increased alertness and more robust control of speed. At the end of the trip, variability again increased for single drivers and for two-up short Broome stop drivers suggesting loss of alertness over the second leg of the trip.

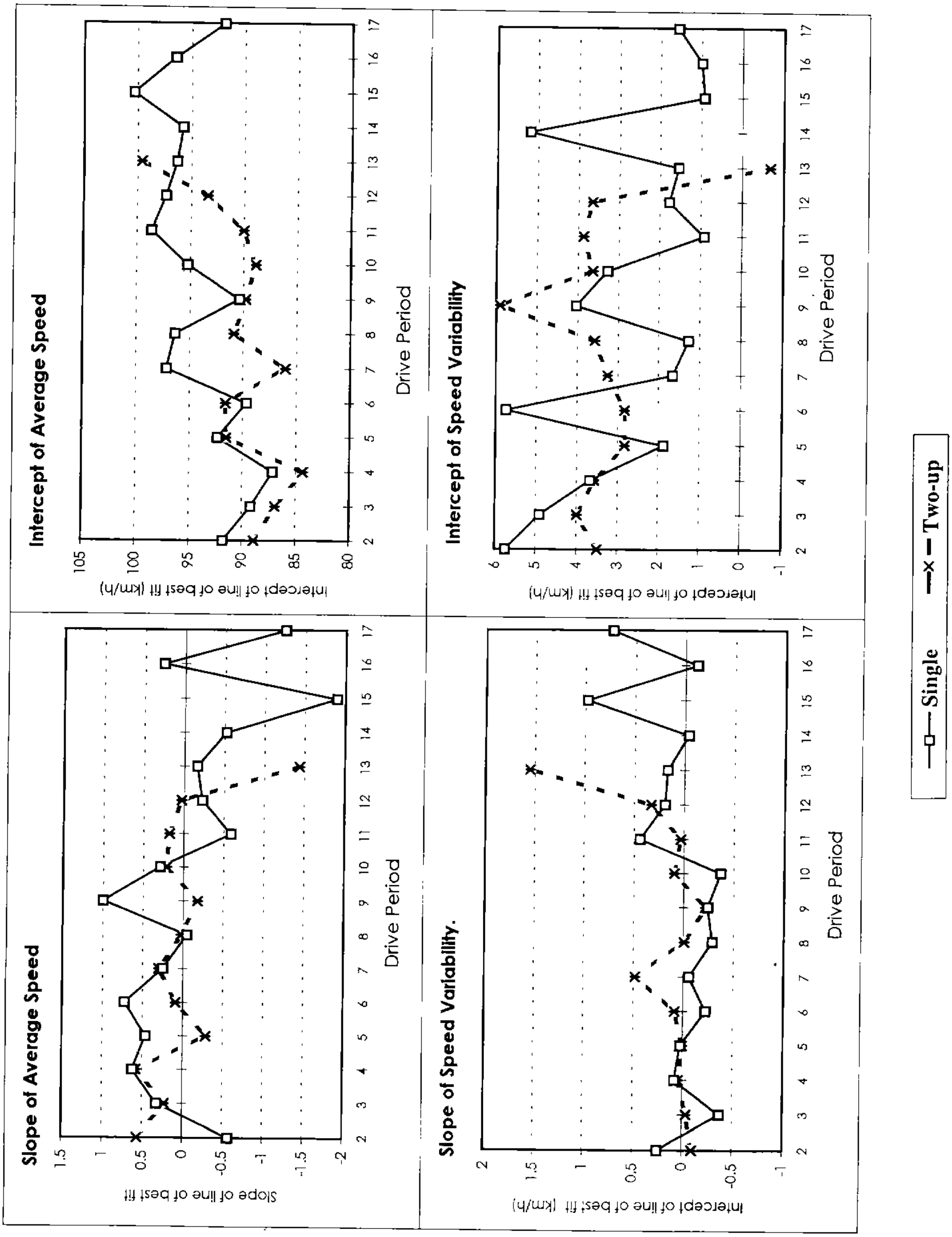
4.2. Changes in speed with each period of driving during the trip

Average speed and speed variability across each driving period in the trip were examined using the same method as for steering and heart rate measures. The slopes and initial intercepts of the lines of best fit for the hour at the beginning of each drive period were plotted for each operation (Figure 3.22 and Appendix 8). Again, trip type was not separately examined in this analysis because the later driver periods (beyond 8) essentially reflect the contribution of the two-up drivers doing the longer trips going beyond Broome. As previously, to determine if any linear relationship described the pattern of slopes and intercepts across drive periods in the trip, each measure was subjected to a regression analysis using driving period, operation type and the interaction of the two factors as independent variables. The purpose of this analysis was to summarise general patterns across the data, rather than to examine changes at particular points in the trip.

Analysis of average speed indicated that there was no significant interaction between type of operation and driving period for average speed across the trip. The regression model without interaction term produced significant partial F values for both driving period and type of operation. The line of best fit ($F_{(2,25)} = 13.34$, $p<0.0001$, $r^2=0.52$) indicated that speeds in the early part of the drive period increased across the trip for both groups, but that, overall, single drivers tended to start their drive periods somewhat faster.

The results of the analysis of slopes for average speed over the first hour of each driving period showed no significant effects of either type of operation or the interaction between operation and driving period. However, when drive period was

FIGURE 3.22: Slopes and intercepts for lines of best fit for Average Speed and Speed Variability over the first hour of each drive period for each type of operation.



fitted alone, the results revealed a significant decrease in slopes of average speed across the trip ($F_{(1,26)} = 11.92$, $p<0.02$, $r^2=0.31$). As Figure 3.22 shows, drivers appeared to be slowing more rapidly over the first hour of a driving period as the trip progressed.

Variability of speed showed much the same results. Regression across driving periods and type of operations for average variability revealed that there was no significant effect of operation type or interaction between operation and driving period. When driving period was fitted alone, a significant decrease in average variability across the trip emerged ($F_{(1,26)} = 8.18$, $p<0.008$, $r^2=.24$). As Figure 3.22 shows, speed at the start of the first hour of a driving period was becoming less variable across the trip.

Analysis of slopes for speec variability in the first hour of each driving period across the trip revealed no significant effects of type of operation or interaction of operation with driving period. When driving period was fitted alone, the results revealed increasing slopes for speed variability ($F_{(1,26)} = 6.23$, $p=0.02$, $r^2 = 0.19$). As Figure 3.22 shows, variability increased more rapidly over the first hour of a driving period as the trip progressed, with this tendency becoming more apparent after about the 11th or 12th driving period.

Overall, the analysis of speed showed that speed increased at the beginning of a period of driving as the trip progressed, but that drivers also slowed their speed more rapidly as the trip progressed. Initial speed in the first hour of each period of driving was less variable but variability increased more rapidly over the hour as the trip progressed. In general, these results seem to suggest less robust control of speed as the trip progressed and may reflect decreased alertness. The fact that this effect appeared to occur after the 11th driving period suggests that the data reflect findings for single drivers and two-up drivers going beyond Broome.

DISCUSSION

In this study, two-up and single drivers showed similar patterns of reported fatigue on a return trip between Perth to Broome. Fatigue increased for both two-up and single drivers on the first leg of the trip between Perth and Broome, regardless of the way the work was organised. No matter whether the trip was driven by one driver or shared between two, the level of subjective fatigue increased on both measures used to assess fatigue in this study. In addition, drivers doing both types of operations reported decreased fatigue at the start of the homeward leg, between Broome and Perth compared to their fatigue state when they arrived at Broome. For most of the trip, however, two-up drivers had higher reported fatigue overall than single drivers. On the homeward leg single drivers showed increased fatigue, just as they had over the same route on the first leg of the trip. The level of fatigue for two-up drivers, in contrast, did not change over the homeward leg. Drivers in both operations, however, ended the trip at about the same level of reported fatigue. For single drivers, however, this was the highest point for fatigue in the trip, but for two-up drivers peak fatigue occurred just before the end of the first leg.

Changes in heart rate and variability over the trip support these findings. The speed and patterning of heart activity is known to vary according to the individual's level of alertness or fatigue (Brookhuis and deWaard, 1993). Heart rate is known to slow and become more variable when the level of alertness decreases such as when the individual gets more tired. In this study, heart rate, as measured by interbeat interval, slowed and became more variable on the first leg of the trip for drivers doing both types of operations and on the second leg for single drivers. This pattern would be expected based on the driver's subjective ratings of higher fatigue. Heart rate increased for both groups following the Broome break, again as expected from their lower levels of fatigue at that time, although variability decreased only for the two-up drivers. Concordant with changes in fatigue ratings, single drivers showed decreased heart rate across the homeward leg of the trip, whereas two-up drivers tended to remain at the same level for both heart rate and variability. Finally, at the beginning of each leg of the trip, two-up drivers had slower heart rates compared to single drivers, which is consistent with two-up drivers ratings of greater fatigue at these times.

There were a few inconsistencies mostly between reported fatigue and heart activity for single drivers and mostly related to variability. Heart rate variability was higher at the beginning of the second leg for single drivers and decreased across it. The reason for this apparent anomaly is not clear, but it is possible that fatigue affects these measures at different rates and recovery at different rates. While single drivers felt less tired after Broome their physiological state may not have recovered to the same extent. Similarly, although the degree of variability decreased over the homeward leg for single drivers rather than increased as would be expected based on their ratings of increased fatigue, single drivers had higher variability at the end of the trip than at the beginning. This is consistent with their higher levels of reported fatigue.

For most of the trip the two-up driver group showed greater tiredness than single drivers. This is a surprising result since it might be expected that sharing the driving between drivers would have beneficial effects on fatigue level. It is notable, however , that two-up drivers reported and showed evidence of greater fatigue before the trip even started. Furthermore, two-up drivers did not get significantly more tired across the trip, unlike single drivers, suggesting that two-up driving itself may act to enable drivers to maintain alertness and stave off fatigue. The extent to which this is so may be understood better by looking at driver characteristics and factors in the driver's recent experience and on the study trip which might account for differences in fatigue.

The influence of driver characteristics and recent history

As the two-up and single driver groups started the trip with different levels of fatigue, differences between the characteristics of drivers in the two groups, recent work history and pretrip activity may result in different effects on their fatigue levels. The two groups of drivers were very similar in terms of home life, employment status, driving experience, and overall health status. Typically, drivers in both groups showed no health problems, and in particular no evidence of sleep disorders which might promote fatigue. They reported about the same level of use of social drugs like cigarettes and alcohol and a significant proportion reported exercising on a regular basis. Consequently, any differences in reported fatigue cannot be attributed to differences between the characteristics of drivers in the two groups.

Nor can the drivers' activities just before the trip be responsible for the fatigue differences. The two groups did not differ in their preparation for the trip. Similar proportions of the groups consumed a meal, alcohol and medication and they had slept for similar durations and had been awake for similar periods. These results suggest that the preparation for the trip was roughly the same for each group and in fact both groups of drivers were fairly well slept before the trip started.

There were a few important differences in the recent work experience of the two groups which were likely to influence fatigue levels. Over the past work week, two-up drivers worked less, and in particular, drove fewer hours than single drivers. In addition, two-up drivers did a much smaller proportion of driving at night and got much more rest overall compared to single drivers. Night driving and lack of rest are well-recognised as factors that increase fatigue (Hamelin, 1987; Prokop and Prokop, 1955). These findings would all suggest that single drivers should be the much more tired than two-up drivers at the beginning of the trip. The fatigue results, however, showed the opposite finding.

The higher fatigue for two-up drivers could be due to two other factors. In the last week two-up drivers did not get as much sleep in the most beneficial night hours compared to single drivers. Two-up drivers reported that they obtained about one-third of their sleep in the day time compared to only about five percent of sleep for single drivers. Two-up drivers tended to take their sleep in more frequent, shorter snatches. These factors are likely to have increased fatigue for two-up drivers due to lack of good quality sleep in the past week. If the amount of driving time is the main factor in producing fatigue, single drivers might be expected to be more tired than two-up drivers, but not if the quality of rest is the most important factor. Single drivers were distinguished by being able to keep to a strong day/night rhythm, with relatively little broken day sleep. In contrast, two-up drivers were exposed to a greater disruption of the rhythm which is well-known to increase fatigue because of an accumulating sleep debt (Waterhouse et al., 1992).

Involvement in yard-work and loading activities is the second factor likely to increase pretrip fatigue for two-up drivers. Almost all two-up drivers were involved in loading the truck in the hours before the trip actually started compared to only one-third of single drivers. Furthermore , two-up drivers were involved in yard-work, including loading, for twice as long as did single drivers. Typically, two-up drivers spent all day loading, starting their trips as soon as it was finished. This meant that two-up drivers tended to start their trips much later in the day, typically after 20:00 hours, compared to most single drivers whose trips started much earlier than that. This, in combination with poor sleep quality is likely to be the predominant reason why two-up drivers began the trip more tired than single drivers.

The continued reporting of higher fatigue levels by two-up drivers during the trip could be entirely a result of high levels at the start of the trip. Differences in the way each type of operation conducted their trip may also play an important role. As would be expected, single drivers spent a much longer time and a greater proportion of the trip driving than two-up drivers. Single trips were longer in overall duration, but a smaller proportion of it was spent in breaks and the average break length was shorter than for two-up drivers. Breaks on single trips were more likely to include work and much less likely to include sleep compared to two-up trips. This pattern of work and rest suggests that single drivers would develop more fatigue than two-up drivers due to these factors. As found for the pattern of work and rest in the past week, however, sleep for single drivers was almost always at night and for longer periods than two-up drivers. These differences in distribution of sleep across the trip reinforces the conclusion that single drivers would be counterbalancing their much greater actual work load with better quantity and quality of sleep. It appears that on the long leg between Perth and Broome fatigue was inevitable for single drivers, however the night sleep at Broome was very effective in bringing fatigue down to pretrip levels.

For two-up drivers the level of fatigue relief depended on the extent to which their shorter trips involving less driving and access to a relief driver trades-off against the restriction that they have to take sleep at all times of the day and night, mostly in a moving vehicle. Overall the trade-off seemed to work fairly well as the two-up drivers as a group ended the trip no more tired than when they had started it.

Operational differences within the two-up group

Analysis of the organisation of work on two-up trips, however, revealed that two-up drivers were not a homogenous group. They differed in the length of the trip and the distribution of rest obtained across the trip, both factors which might be expected to influence the experience of fatigue across the trip. Trips for around one-third of two-up drivers extended a significant distance beyond Broome. Of the remaining two-thirds, around half had a long stop involving a night's rest at Broome and the remainder only stayed in Broome for long enough to off-load and have a brief rest.

As the differences between the three types of two-up driving did not appear until after the Broome stop, it is not surprising that all groups showed the same increase in fatigue across the first leg of the trip. After Broome, operational differences produced different patterns of fatigue in the two-up groups. The differences in work practices provided the opportunity to make direct comparisons between them where only one major operational factor is varied at a time. For example, the effect of two-up driving itself can be evaluated by contrasting the short Broome stop group with single drivers. Both the two-up long Broome stop and short Broome stop groups only travelled as far as Broome. However, the short Broome stop group most closely reflects the principle motivating the use of two-up operations - to maximise the time a truck is on the road and to minimise the need for stationary rest time. The effect of trip length can be evaluated by the comparison between the beyond Broome group and all other groups and the effect of a long stationary rest at midtrip by the comparison between the long Broome stop group and the short Broome stop group.

With this in mind, the results showed that drivers with a short turnaround time and no significant rest time in Broome were just as tired when they left Broome as when they arrived unlike single drivers who were refreshed after Broome. Fatigue for the short

Broome stop two-up group then improved across the return leg so that their fatigue at the end of the trip was at pretrip levels, whereas it was significantly increased at the end of the trip for single drivers. Heart activity changes mirrored these patterns to a large extent. Short turnaround two-up drivers showed signs of reduced alertness, with decreasing heart rate and increasing variability on the first leg to Broome, and an overall increase in alertness across the trip to finish with similar heart rate and variability as shown at the beginning of the trip. These results suggest that, under certain conditions, two-up driving itself can reduce fatigue, in contrast to single driving which showed no such effect over the same trip. If drivers can reduce fatigue while working, in the absence of any significant breaks, two-up driving is clearly offering some benefits to the drivers.

When two-up drivers were allowed a significant break at Broome, a dramatic reduction in fatigue levels was seen after Broome, which had the effect of keeping fatigue low for the rest of the trip. These drivers actually finished the trip considerably less tired than they were at the beginning and less tired than any other driver group. Heart activity changes also supported this pattern. The addition of a long stationery break at night had a striking effect of reducing driver fatigue to very low levels. For two-up drivers whose trips took them beyond Broome, fatigue increased in a fairly linear fashion across the entire trip. These drivers ended their trips significantly more tired than any other group. Physiological changes in terms of heart rate and variability again provided support for the pattern of reported fatigue for this group.

It appears that experiences across the trip which might be expected to increase fatigue in drivers do so in a fairly predictable fashion. Long trips and few or short breaks lead to drivers becoming more tired. As two-up driving would be expected to reduce fatigue however, it is quite surprising that for most of the trip, two-up drivers reported greater fatigue than single drivers. The pretrip experiences of two-up drivers almost certainly contributed to their higher fatigue at the beginning of the trip. This finding reinforces the suggestion from the previous study of staged drivers (Williamson et al., 1994) that pretrip activity which results in fatigue is a potent influence on fatigue during a trip. This study shows however that the drivers' experiences during the trip can modify this fatigue state. Two-up driving itself appears to play some role in reducing fatigue as shown by the two-up drivers who only had a short stop in Broome. The biggest effect on fatigue though was seen in the two-up group who had an overnight stop in Broome. It seems that the combination of two-up driving coupled with a significant block of night sleep enabled the long-Broome stop two-up drivers to finish the trip with low levels of fatigue. Indeed fatigue levels at this point were as low as pretrip levels for almost all other groups. These results suggest that two-up driving in combination with a significant period during the trip of stationary rest probably at night, forms the most beneficial strategy for combating fatigue on very long distance trips.

The influence of breaks within the trip

The effectiveness of breaks within each leg of the trip varied for each type of operation and between each type of two-up trip. Across both types of operation, at least one-third of drivers reported reduced alertness level just before a break, with two-up drivers reporting the greatest fatigue prior to breaks, but also seeming, as a group, to gain less benefit from them for as long into the trip as did single drivers.

The influence of the different types of two-up trips could also be seen in the usefulness of breaks. Mostly the distribution of breaks between the three two-up groups was very similar, the major differences being due to the relative length of the trip or the existence of one very long break. The total proportion of trip time spent in breaks varied in predictable ways between the two-up groups, but showed a similar pattern overall, in contrast with single drivers who had a greatly lower proportion of break time. The results for two-up drivers showed that breaks were most effective for the group which had a long stop at Broome, with fatigue ratings being kept lower than any other group, including single drivers. The group which had a short stop at Broome also got considerable benefit from breaks, particularly towards the end of the trip. As fatigue levels for this group reduced on the last leg of the trip, this suggests that the short Broome stop group obtained more effective rest from their breaks. For the group going beyond Broome, breaks became increasingly ineffective as the trip progressed and totally lost their effectiveness towards the end of the trip. Presumably, the beyond Broome group simply got too tired for breaks to be of use. Work by Harris and Mackie (1977) supports this explanation. They found that the usefulness of breaks was inversely proportional to how tired a driver was. Paradoxically, drivers who were very tired did not recover as much after a break as drivers who were less tired. These authors suggested that breaks need to be taken preventively on long trips to gain the most benefit from them. Drivers' responses to breaks in this study are likely to be both a result of their fatigue and an additional cause of it depending on the type of trip and their experiences on it. Trips where the work-rest practices kept fatigue levels under control were likely to be helped by breaks. In contrast, trips where fatigue was allowed to build up, such as the single trips and the two-up trips which went beyond Broome, did not gain fatigue relief from breaks, once fatigue had accumulated.

The way drivers spaced their breaks within trips in this study casts some doubt about the usefulness of the current regulations relating to the scheduling of breaks. Drivers in this study were not bound to work to regulation, rather their work-rest schedules were governed more by operational constraints. For both two-up and single drivers, breaks which were initiated for their own reasons rather than work-related ones, tended to be taken after around four hours of driving. This is a somewhat shorter period between breaks than the five hour maximum advocated by regulation. In the previous study of staged and flexible driving (Williamson et al., 1994), drivers tended to take breaks after around four and a half hours driving and subsequent breaks were taken even earlier. It was likely, however that these drivers were taking breaks in response to operational or geographic factors rather than their body state. In the current study, there were fewer constraints on drivers so that when they stopped for non-work reasons, they were much more likely to be stopping because they actually needed a break. The discrepancy between the timing of driver-initiated breaks in this study and working hours regulations could constitute an additional pressure on drivers. Scheduling trips according to working hours regulations, may cause tired drivers to continue driving for too long. In fact in Williamson et al.'s (1992) driver survey, working to regulation was one of the reported causes of fatigue.

The effects of fatigue on performance

Given that fatigue was found to be a factor for all types of trips in this study, an important question is what effect it had on driver performance. Examination of the range of measures reflecting performance showed that fatigue and performance were related. In the main, when drivers reported fatigue, at least some aspects of their performance tended to be significantly poorer. For single drivers there was a clear relationship between fatigue levels and the ability to detect changes in a visual stimulus (CFF test), performance became poorer on the first leg of the trip and across the whole trip as single drivers reported increased tiredness. For the sustained attention or vigilance test, performance for single drivers got increasingly more variable as fatigue increased across the trip. Importantly, more direct measures of driving performance also showed a close relationship with fatigue for single drivers. On-board reaction time performance showed deterioration for single drivers as they became more tired over the first leg of the trip. Performance improved after Broome, just as did fatigue, but performance continued to improve to pretrip levels at the end of the trip, unlike fatigue which increased over that period. Changes in steering performance for single drivers largely paralleled changes in fatigue.

For two-up drivers as a group, CFF test performance deteriorated with increasing fatigue. Similarly, for two-up drivers higher fatigue was related to poorer performance on the Critical tracking task (CTT) on the first leg of two-up trips, with both CTT performance and fatigue improving across the second leg and on-board reaction time showed the same pattern of change as fatigue. For steering performance, the relationship was not as close. Steering deviations stayed at roughly the same level until the end of the trip when they became somewhat larger but not more variable which is suggestive of some loss in alertness.

Further understanding of the effects of fatigue on performance of two-up drivers can be seen from the results for the different types of two-up driving. For the short-Broome-stop group CFF and CTT performance mirrored fatigue. For on-road measures, on-board reaction time did not show the expected deterioration in performance on the first leg, with reaction time ending up at around pretrip levels at the end of the first leg. After Broome, however performance improved as would be expected. As would be expected from changes in subjective fatigue, at the end of the trip, performance had hardly changed, and the trip finished somewhat improved over pretrip levels. For long-Broome-stop two-up drivers, CFF and CTT performance also showed a close relationship with fatigue. The on-board reaction time test never showed a deterioration from pretrip levels but, contrary to expectations based on their increasing fatigue on the first leg, their reaction time improved over the first half of this leg although it decreased again to pretrip levels by the end of the first leg. As expected, this group showed a marked improvement in reaction time following the long break at Broome. Lastly for the two-up group which went beyond Broome, CFF performance again varied with changes in fatigue, with the biggest deterioration in performance occurring over the first leg of the trip when fatigue increased the most. Similarly, CTT performance showed a significant deterioration in performance on the first leg. On-board reaction time again showed the same pattern as reported fatigue.

The results from all groups demonstrate clearly that fatigue had negative effects on performance both on and off the road. The performance of drivers was much poorer when they were fatigued, just as drivers reported in the earlier survey of long distance truck drivers (Williamson et al., 1992). Particular types of performance functions seem to be most affected. Consistent deterioration in on-board reaction time, CFF and CTT tasks suggests that drivers' ability to respond to changes in visual stimuli and their capacity to respond to infrequent and unpredictable events, deteriorate when they become fatigued. These are obviously essential components of the driving task and cannot be ignored. The results from the earlier surveys show that many drivers are often fatigued on long trips and this study and the surveys suggest that driving performance is adversely affected when drivers are tired. Clearly to reduce driver fatigue will have positive effects on safety on the road.

It is notable that some tests failed to show changes due to fatigue across the trips. Performance on some tests actually improved from the beginning to the end of the trip. In particular, reaction speed improved across the trip for the reaction time and vigilance tests for all groups. For both of these tests, this reflected strong effects of performance benefiting from repeated exposure to the tests at intervals across the trip which was not overcome by providing drivers with practice before the study trip started. All the same, the results suggest that fatigue may have attenuated practice effects for some of the trips. For example, for the CTT, time on target reduced markedly for the first half of the test session at Broome before increasing in the second half to at least pretrip levels for drivers on most trips. If performance was being influenced by practice alone it would be expected that time on target would increase in a fairly linear fashion both within and across each test session. Similarly, for the simple reaction test two-up drivers showed a practice effect for the movement time measure between the Perth and Broome test sessions, but appeared to lose it on the last leg of the trip with movement time at the end of the trip slowing to around pretrip levels. Fatigue is the most likely reason for this change in simple reaction time performance. It is not possible therefore to conclude from this study that test functions which improved or showed little change across the trip, were not affected by fatigue without considering the role of practice effects on performance. This is especially so where the results from other tests might predict that these functions are affected by fatigue and there is a possibility that practice effects are camouflaging changes due to fatigue. In these circumstances, we may be underestimating the effects of fatigue on function. When this occurs, the practice effect or its lack can be an important indicator of fatigue.

It could be argued, however, that for some functions, the absence of effects of fatigue after practice implies that practiced tasks like driving and professional driving in particular, may not be as vulnerable to the effects of fatigue . To some extent this is probably true. The fact that drivers can still drive and do not always have accidents when they are tired is testimony to this contention. However not all driving is predictable. Things happen on the road that drivers cannot predict and cannot practice for. Drivers may know how to respond to unexpected events and circumstances, but our results suggest that when they are tired drivers may not be able to generate a timely response in such circumstances. Consequently, such clear performance effects with fatigue cannot be ignored, even for professional drivers.

The finding of different operational groups within the two-up group changed the analysis of the data collected planned for this study. As a result the sample sizes for the two-up groups were considerably smaller than originally planned. The small sample sizes undoubtedly reduced the power of this study to detect changes across the trip which may have been due to fatigue. For this reason, all important trends were reported. However the finding of subgroups doing the two-up operation highlighted important operational differences which had critical implications for the experience of fatigue and for performance. These need to be examined in more detail.

Conclusions

The results of the current study confirm previous findings with staged drivers regarding the effects of activity prior to the trip on driver fatigue (Williamson et al., 1992). For two-up drivers, fatigue at the beginning of the trip was clearly influenced by the amount of work they did in the ten hours or so before the actual driving task began. Two-up drivers started the trip more tired and continued to be more tired for almost the entire trip. As found in the study of staged driving, pretrip fatigue had a marked effect on fatigue across the trip (Williamson et al., 1994). The results of this study reinforce the concept that a large component of driver fatigue occurs because of activities other than driving. This means that management of fatigue for long distance drivers must take into account all factors, like the amount of pretrip activity and the amount of rest time between trips. It is possible that these factors would play a more critical role in driver fatigue than factors in the driving task itself.

In interpreting the results of this study it is important to note that aside from the number of drivers available on the road, all drivers essentially used the same work practices on the Perth to Broome leg. With this in mind it is significant that all groups showed the greatest increase in fatigue over the first leg of the trip. It is likely that for all drivers there was greater time pressure to complete the trip in a certain time frame in order to make the Broome delivery. On the return journey this time pressure was less compelling. After Broome, the influence of different work practices could be seen in changes in fatigue level. Drivers who had the longest break at Broome showed the greatest relief from fatigue, in spite of the fact that they were also the most tired at the end of the first leg. The two groups which ended the trip with higher fatigue than when they started had both been exposed to work practices which were most likely to increase their fatigue. Single drivers and two-up drivers who went beyond Broome had by far the longest duration trips and spent the greatest proportion of the trip driving. The Broome turnaround two-up groups both showed no adverse effects of fatigue at the end of the trip, and were able to stave off the effects of fatigue on the final leg of the trip. Fatigue even reduced on the final leg for the short Broome stop group. The two-up group who were able to obtain a long rest at Broome gained an even greater benefit as their fatigue decreased to the lowest of all groups and to below their own pretrip levels. These results suggest that drivers can gain sufficient rest during two-up trips to maintain alertness, but only if the trips are short and even better if stationary rest is taken as well. This shows that judicious use of effective rest (that is, night rest), in combination with two-up driving, could overcome the fatigue that drivers experience on very long trips such as these.

The results also emphasise the importance of taking steps to reduce fatigue in long distance drivers. Fatigue had clear negative effects on performance which indicate that driver safety must be compromised when drivers are tired. The results also emphasise that reported fatigue is an effective indicator of the influence of fatigue on the body and on performance. This means that when drivers feel tired, their performance is much more likely to be poorer. Consequently work practices on long trips must be designed to keep fatigue as low as possible and to allow drivers the freedom to take timely action to reduce their fatigue.

Confirming the results of the previous study on staged driving, the present ones demonstrate the importance of taking into account overall work-rest patterns in designing work practices. Activities in the past week, activities before driving begins as well as the way the trip is structured all need to be considered if fatigue management is to be improved.

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Appendix 1

Excerpt from Trip Diary

DIARY FOR BREAKS FROM DRIVING

CODE NUMBER:

BREAKS DURING THE TRIP

The following questions ask about breaks during your trip.

We are interested in activities during your breaks, for example your sleep and food and drink intake, and also how you feel before and after the break.

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** and **FINISH** of **EACH** break

Questions for each break are on the same coloured paper

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.

If you have any problems with any of the questions
or with any of the equipment during the trip, please ring.
David Leslie on (015) 411 253,
or
Rena Friswell on (015) 411 254

THANK YOU FOR YOUR COOPERATION

BREAK NUMBER 1

1. **Time and date of the break** ? ______am/pm ___/___/___

2. **Where are you taking the break** ?

____

____

PLEASE COMPLETE THE SCALES ON THE FOLLOWING PAGES DESCRIBING HOW YOU FEEL AT THE BEGINNING OF THIS BREAK

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 ——X———————————— 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**

PLEASE TELL US WHAT YOU DID DURING THIS BREAK

1. **How long was the break** ? ______hours _____ mins

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

(Please tick any activites that apply to you. You may tick more than one)

Did you:

EAT ( ) **What did you eat** ? ________________________

____

DRINK ( ) **What did you drink** ?

____

____

SLEEP ( ) **For how long** ? _____hours ____mins

LOAD/UNLOAD ( ) **How long did it take** ? ____hours ____mins

OTHER (Please specify) _________________________________

For how long? _____hours _____mins

3. **Was the vehicle stationary for any part of the break?**

Yes ( )
No ( )

If YES For how long? _____hours ____mins

PLEASE COMPLETE THE SCALES ON THE FOLLOWING PAGES DESCRIBING HOW YOU FEEL AT THE END OF THIS BREAK

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	——X————————	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 NUMBER 2

1 **Time and date of the break** ? ______am/pm ___/___/___

2. **Where are you taking the break** ?

____

____

PLEASE COMPLETE THE SCALES ON THE FOLLOWING PAGES DESCRIBING HOW YOU FEEL AT THE BEGINNING OF THIS BREAK

Appendix 2

Background Information Questionnaire

CODE NUMBER:

TRUCK DRIVER

BACKGROUND INFORMATION

DRIVER FATIGUE STUDY

Worksafe Australia
National Occupational Health and Safety Commission
GPO BOX 58
SYDNEY NSW 2001

1994

Truck Driver Survey

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

All the information you give to us will be **CONFIDENTIAL** and **ANONYMOUS**. You will be assigned a code number so that we do not need to keep your name on file

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

THANK YOU FOR YOUR HELP

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

Work: _____________
Home: _____________

What is your: Age: __________

Height: __________

Weight: __________

		Please tick
Are you:	married ?	( )
	living in a defacto arrangement ?	( )
	single (never married, widowed divorced) ?	( )

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

Are you currently:
an employee driver ( )
an owner driver ( )
other (please specify) ( )
____

If you are an owner-driver: How many trucks do you own? __________

Do you drive mainly for one company ? Yes ( )
No ( )

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) ? ________________
____

Did you taking any medication for this condition ? Yes ( )
No ( )

How long did you take off work due to this condition ? ____________

Do you have any of the following medical problems ?

	Please circle
Diabetes	Yes No
Asthma/Hayfever	Yes No
Stomach or digestive problems	Yes No
Sleep problems	Yes No
Heart or circulation problems eg. angina or high blood pressure	Yes No
Headaches or migraine	Yes No

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

Do you have difficulty getting to sleep ?	Yes	( )
	No	( )
Do you have difficulty staying asleep once you are asleep ?	Yes	( )
	No	( )

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

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

Have you had your adenoids removed ?	Yes	( )
	No	( )

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 drink alcohol ? Yes ( )
No ( )

How much of the alcohol you usually drink, do you drink at one time ?

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	( )

Activities in Last Week

DAY 1

Work 0000 ______________________________ 2359

Drive 0000 ______________________________ 2359

Rest/sleep 0000 ______________________________ 2359

DAY 2

Work 0000 ______________________________ 2359

Drive 0000 ______________________________ 2359

Rest/sleep 0000 ______________________________ 2359

DAY 3

Work 0000 ______________________________ 2359

Drive 0000 ______________________________ 2359

Rest/sleep 0000 ______________________________ 2359

DAY 4

Work 0000 ______________________________ 2359

Drive 0000 ______________________________ 2359

Rest/sleep 0000 ______________________________ 2359

Activities in Last Week (cont)

DAY 5

Work 0000 ______________________________ 2359

Drive 0000 ______________________________ 2359

Rest/sleep 0000 ______________________________ 2359

DAY 6

Work 0000 ______________________________ 2359

Drive 0000 ______________________________ 2359

Rest/sleep 0000 ______________________________ 2359

DAY 7

Work 0000 ______________________________ 2359

Drive 0000 ______________________________ 2359

Rest/sleep 0000 ______________________________ 2359

Plan for the current trip

Where did you start this trip ? ________________
____

Where will you finish ? ________________
____

Do you have any stops planned along the way ?

Yes	( )
No	( )

Are you carrying freight?	Yes	( )
	No	( )

If YES, what freight are you carrying? ____________________

Did you load the freight or help load it yourself ?	Yes	( )
	No	( )
How long did it take ?	________	
Will you unload or help to unload it yourself?	Yes	( )
	No	( )

Pre-trip activities

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	( )
cider	( )

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

SUMMARY OF ACTIVITIES DURING CURRENT TRIP

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 ? ________________
____

CURRENT TRIP:

START TIME AND DATE:

FINISH TIME AND DATE:

Appendix 3

Recruitment & Consent Forms

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

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 have already studied drivers operating on the East Coast, between Melbourne and Sydney. However, as operating conditions are different for drivers working in the West, we would like to get a better understanding of the impact of these conditions on driver fatigue.

We would like to invite you to take part in this study.

What is involved?

We would like you to drive a regular trip to Broome and back, without any changes at all.

What we are interested in is how alert you are during the trip, and how this varies at different times in the trip. We have chosen Broome as a destination point from Perth for two reasons: because a number of companies operate to Broome from Perth, and because it seems to be reasonably typical of the sort of driving done in the West.

We will measure your alertness 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. Additionally, we will measure your reaction time at occasional intervals during the trip. A small microphone will be clipped to your clothes, to record your spoken response to a signal. 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.

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 9300

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 trip we are monitoring. We will ask you to fill out short questionnaires about these things.

All this measuring will involve about 45 minutes of your time at the beginning and end of the trip, and about 20 minutes in Broome.

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.

If you have any questions about the study,

please feel free to contact one of the study team.

Anne-Marie Feyer

(02) 565 9313

Ann Williamson

(02) 565 9311

David Leslie

Mobile: (015) 411 253

Rena Friswell

Mobile: (015) 411 254

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)

Appendix 4

Results of Subjective Fatigue Ratings

TABLE A4.1: Reported alertness of drivers in each operation type before and after each break in the trip - Stanford Sleepiness Scale.

Operation Type	Fatigue Rating	Break 1 Pre	Break 1 Post	Break 2 Pre	Break 2 Post	Break 3 Pre	Break 3 Post	Break 4 Pre	Break 4 Post	Break 5 Pre	Break 5 Post	Break 6 Pre	Break 6 Post	Break 7 Pre	Break 7 Post	Break 8 Pre	Break 8 Post	Break 9 Pre	Break 9 Post	Break 10 Pre	Break 10 Post
		(% drivers)																			
	1	13.3	40	50.0	64.3	33.3	53.3	23.1	42.9	33.3	57.1	46.7.	57.1	28.6	21.4	13.3	46.7	21.4	50.0	38.5	46.2
	2	33.3	26.7	0	14.3	33.3	20.0	7.7	28.6	33.3	28.6	20.0	37.7	35.7	64.3	53.3	40.0	21.4	21.4	30.8	38.5
	3	40.0	20.0	33.3	21.4	13.3	6.7	30.8	21.4	6.7	14.3	20.0	0	14.3	7.1	13.3	6.7	35.7	28.6	15.4	0
<u>SINGLE</u>	4	0	13.3	8.3	0	13.3	20.0	23.1	7.1	0	0	6.7	7.1	7.1	0	13.3	0	14.3	0	7.7	15.4
	5	0	0	8.3	0	6.7	0	7.7	0	6.7	0	0	0	7.1	7.1	6.7	6.7	0	0	0	0
	6	6.7	0	0	0	0	0	7.7	0	20.0	0	6.7	0	7.1	0	0	0	0	0	7.7	0
	7	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.1	0	0	0
	1	4.8	14.3	5.0	55.0	27.3	47.6	28.6	33.3	13.6	20.0	13.6	38.1	13.6	35.0	15.8	22.2	6.7	6.7	33.3	12.5
	2	52.4	52.4	25.0	15.0	22.7	38.1	14.3	33.3	27.3	50.0	45.5	42.9	36.4	40.0	36.8	38.9	40.0	46.7	22.2	25.0
	3	19.0	14.3	40.0	30.0	31.8	9.5	19.0	4.8	31.8	15.0	27.3	9.5	22.7	25.0	26.3	27.8	40.0	20.0	33.3	50.0
<u>TWO-UP</u>	4	14.3	9.5	25.0	0	18.2	4.8	33.3	19.0	13.6	15.0	4.5	4.8	22.7	0	21.1	5.6	13.3	20.0	0	12.5
	5	9.5	9.5	5.0	0	0	0	4.8	9.5	13.6	0	4.5	4.8	4.5	0	0	5.6	0	6.7	11.1	0
	6	0	0	0	0	0	0	0	0	0	0	4.5	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE A4.1: (Continued)

Operation Type	Fatigue Rating	Break 11 Pre	Break 11 Post	Break 12 Pre	Break 12 Post	Break 13 Pre	Break 13 Post	Break 14 Pre	Break 14 Post	Break 15 Pre	Break 15 Post	Break 16 Pre	Break 16 Post	Break 17 Pre	Break 17 Post	Break 18 Pre	Break 18 Post	Break 19 Pre	Break 19 Post	Break 20 Pre	Break 20 Post
		(% drivers)																			
SINGLE	1	36.4	30.0	16.7	30.0	0	16.7	0	40.0	25.0	25.0	0	25.0	50.0	0	0	100	100	100	100	100
	2	27.3	40.0	66.7	60.0	28.6	66.7	20.0	40.0	50.0	50.0	50.0	50.0	0	50.0	50.0	0	0	0	0	0
	3	9.1	20.0	0	10.0	57.1	16.7	40.0	20.0	25.0	25.0	50.0	25.0	0	50.0	0	0	0	0	0	0
	4	18.2	10.0	16.7	0	0	0	20.0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	20.0	0	0	0	0	0	50.0	0	50.0	0	0	0	0	0
	6	9.1	0	0	0	14.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TWO-UP	1	14.3	16.7	16.7	0	0	0	0	0	50.0	0	0	0	-	-	-	-	-	-	-	-
	2	42.9	16.7	66.7	50.0	50.0	100	50.0	50.0	50.0	0	100	100	-	-	-	-	-	-	-	-
	3	28.6	33.3	0	33.3	50.0	0	50.0	50.0	0	50.0	0	0	-	-	-	-	-	-	-	-
	4	14.3	16.7	16.7	0	0	0	0	0	0	50.0	0	0	-	-	-	-	-	-	-	-
	5	0	16.7	0	16.7	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-
	6	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-
	7	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-

TABLE A4.2: Ratings on the Visual Analogue Scales before and after each break for drivers in each operation type.

Operation Type	Fatigue Rating	Break 1 Pre	Break 1 Post	Break 2 Pre	Break 2 Post	Break 3 Pre	Break 3 Post	Break 4 Pre	Break 4 Post	Break 5 Pre	Break 5 Post	Break 6 Pre	Break 6 Post	Break 7 Pre	Break 7 Post	Break 8 Pre	Break 8 Post	Break 9 Pre	Break 9 Post	Break 10 Pre	Break 10 Post
		Mean *(sd)*																			
SINGLE	Tired	42.5 *(25.8)*	25.7 *(15.5)*	27.9 *(29.1)*	18.9 *(23.1)*	31.6 *(24.6)*	25.7 *(26.6)*	41.2 *(29.7)*	24.5 *(22.3)*	44.2 *(32.0)*	16.6 *(18.7)*	40.1 *(36.3)*	19.6 *(19.8)*	42.3 *(28.5)*	28.9 *(22.3)*	43.9 *(25.8)*	23.7 *(22.9)*	44.2 *(29.4)*	20.9 *(19.5)*	34.8 *(26.5)*	22.9 *(20.8)*
	Muzzy	35.8 *(22.8)*	24.6 *(19.1)*	24.9 *(22.5)*	18.3 *(18.6)*	23.9 *(18.1)*	22.6 *(22.8)*	32.9 *(24.2)*	27.3 *(27.5)*	34.0 *(29.2)*	16.2 *(17.1)*	26.3 *(28.2)*	19.2 *(17.7)*	36.4 *(22.2)*	27.9 *(18.5)*	30.4 *(19.4)*	21.0 *(24.7)*	42.0 *(29.6)*	21.5 *(15.2)*	27.1 *(19.4)*	23.9 *(25.1)*
	Drowsy	32.6 *(20.2)*	22.7 *(12.5)*	28.3 *(28.8)*	15.9 *(14.8)*	29.4 *(21)*	21.9 *(20.8)*	39.7 *(24.9)*	24.1 *(18.6)*	38.1 *(32.1)*	15.5 *(16.5)*	26.1 *(27.8)*	18.3 *(17.2)*	38.1 *(22.7)*	29.7 *(22.1)*	32.9 *(22.3)*	19.4 *(18.4)*	38.2 *(25.6)*	20.2 *(14.8)*	28.9 *(19.3)*	19.6 *(16.0)*
TWO-UP	Tired	47.6 *(21.4)*	37.0 *(22.8)*	53.5 *(25.6)*	26.8 *(26.0)*	37.7 *(26.1)*	24.1 *(23.0)*	40.1 *(25.3)*	34.2 *(31.4)*	50.7 *(28.7)*	30.2 *(21.2)*	39.8 *(22.9)*	22.1 *(16.0)*	38.6 *(24.1)*	27.7 *(20.3)*	34.8 *(21)*	30.6 *(23.5)*	40.6 *(23.6)*	36.5 *(28.0)*	37.0 *(31.6)*	34.4 *(21.5)*
	Muzzy	36.0 *(21.8)*	30.6 *(18.1)*	39.4 *(23.2)*	22.9 *(18.7)*	28.8 *(19.4)*	24.0 *(18.9)*	33.3 *(21.4)*	29.0 *(24.7)*	37.9 *(24.0)*	27.9 *(19.2)*	36.1 *(22.4)*	20.7 *(16.4)*	34.5 *(22.7)*	25.9 *(18.7)*	29.7 *(18.8)*	25.9 *(13.6)*	36.8 *(20.0)*	32.1 *(21.1)*	35.6 *(27.7)*	35.8 *(22.2)*
	Drowsy	40.9 *(21.9)*	38.1 *(21.9)*	46.0 *(20.3)*	23.5 *(20.8)*	32.0 *(21.1)*	20.9 *(16.6)*	34.4 *(20.9)*	32.3 *(26.6)*	40.9 *(22.5)*	28.1 *(21.0)*	34.6 *(23.4)*	21.8 *(17.1)*	37.0 *(23.1)*	26.3 *(18.2)*	31.6 *(20.9)*	30.7 *(22.1)*	37.9 *(20.8)*	35.3 *(28.1)*	35.4 *(28.1)*	34.9 *(26.1)*

TABLE A4.2: (Continued)

Operation Type	Fatigue Rating	Break 11		Break 12		Break 13		Break 14		Break 15		Break 16		Break 17		Break 18		Break 19		Break 20	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
		Mean *(sd)*																			
SINGLE	Tired	36.1 *(27.5)*	31.5 *(20.6)*	31.0 *(20.7)*	26 0 *(15 9)*	45.1 *(23 3)*	21.7 *(12.9)*	50.4 *(25 8)*	26.0 *(21 9)*	27.0 *(12.6)*	27.3 *(13.9)*	37.0 *(8 2)*	32.3 *(20.4)*	34.5 *(36 1)*	30.5 *(23.3)*	50.0 *(41 0*	5.0 *(1.4)*	4.5 *(0.7)*	4.0 *(1.4)*	3.0 *(4 2)*	3.0 *(0 0)*
	Muzzy	28.1 *(21 3)*	26.1 *(18.5)*	24.7 *(14 2)*	20.3 *(10 3)*	36 0 *(15 1)*	26.7 *(17 4)*	52.2 *(17.2)*	25.6 *(21.2)*	28.8 *(10 2)*	26.8 *(13 1)*	37.8 *(7 7)*	33.8 *(22 0)*	35.5 *(34.7)*	28.5 *(24.8)*	45.0 *(38.2*	5.0 *(1.4)*	8.5 *(0 7)*	4.0 *(0.0*	6.0 *(2 8)*	2.5 *(0.7)*
	Drowsy	32.0 *(27.6)*	26.0 *(18.3)*	25.1 *(15.9)*	19.4 *(12.1)*	41.3 *(15 4)*	22.8 *(8.5)*	49.2 *(22 6)*	24.2 *(19 4)*	25.5 *(11 0)*	26.8 *(11.7)*	37.0 *(5 2)*	31.8 *(21.7)*	36.5 *(36.1)*	35.0 *(11 3)*	49.5 *(47 4)*	3.5 *(0 7)*	5.0 *(0.0)*	3.5 *(0.7)*	6.0 *(2.8)*	2.5 *(0 7)*
TWO-UP	Tired	39.4 *(27.4)*	34.1 *(25.6)*	37.3 *(22 4)*	45.8 *(31 9)*	55.5 *(5 3)*	29.0 *(9 8)*	56.0 *(35 4)*	45.5 *(14 9)*	29.5 *(17.7)*	50.0 *(1 4)*	54.0 -	30.0 -	-	-	-	-	-	-	-	-
	Muzzy	38.4 *(26.5)*	32.1 *(21 0)*	27.5 *(18.9)*	48.3 *(19 9)*	48.0 *(7 0)*	31.0 *(8 6)*	34.5 *(5 0)*	51.0 *(11 3)*	39.5 *(2.1)*	56.0 *(4.2)*	56.0 --	30.0 --	-	-	-	-	-	-	-	-
	Drowsy	35.3 *(25.5)*	33.1 *(29.6)*	32.5 *(19 1)*	47.0 *(28 4)*	49.0 *(6.8)*	29.0 *(7.1)*	48.0 *(12 7)*	62.0 *(9.9)*	38.0 *(4.2)*	55.5 *(7.8)*	54.0 --	29.0 --	-	-	-	-	-	-	-	-

TABLE A4.3: Ratings on the Visual Analogue Scales before and after each break for drivers doing each trip type.

Operation Type	Fatigue Rating	Break 1 Pre	Break 1 Post	Break 2 Pre	Break 2 Post	Break 3 Pre	Break 3 Post	Break 4 Pre	Break 4 Post	Break 5 Pre	Break 5 Post	Break 6 Pre	Break 6 Post	Break 7 Pre	Break 7 Post	Break 8 Pre	Break 8 Post	Break 9 Pre	Break 9 Post	Break 10 Pre	Break 10 Post
		Mean *(sd)*																			
SINGLE	**Tired**	39.6 *(22.3)*	27.8 *(15.7)*	30.7 *(30.5)*	21.4 *(24.1)*	31.1 *(25.2)*	23.2 *(25.7)*	37.5 *(26.3)*	25.8 *(23.1)*	36.7 *(28.5)*	14.1 *(17.6)*	43.4 *(37.7)*	21.3 *(20.8)*	39.3 *(26.6)*	30.8 *(23.6)*	47.9 *(25 4)*	24.6 *(24.5)*	40.3 *(28 6)*	19.9 *(21 0)*	34.4 *(28.9)*	25.6 *(21.4)*
	Muzzy	33.7 *(22.6)*	25.8 *(20.5)*	27.5 *(23 3)*	20.9 *(19 2)*	24.3 *(19.4)*	21.3 *(23.6)*	35.6 *(25 7)*	28.8 *(29.0)*	27.3 *(24 7)*	12.8 *(15 0)*	27.3 *(30.2)*	20.8 *(18.7)*	35.3 *(23.5)*	29.3 *(19.7)*	31.4 *(20.9)*	21.5 *(26.7)*	39.4 *(28 1)*	19.9 *(16.0)*	23.9 *(18.9)*	26.8 *(26.7)*
	Drowsy	27 5 *(11 5)*	22.8 *(13.5)*	31.1 *(30.1)*	17.8 *(15 4)*	27.8 *(21.7)*	18.1 *(17.8)*	35.2 *(20.6)*	25.9 *(19 2)*	29.5 *(25.4)*	11.6 *(13.6)*	26.5 *(29.4)*	19.8 *(18.3)*	34.0 *(17.0)*	31.6 *(23.2)*	35.5 *(23.1)*	20.9 *(19.6)*	35.2 *(26 9)*	18.3 *(15.3)*	26.8 *(15.2)*	21.6 *(16.8)*
TWO-UP, BEYOND BROOME	**Tired**	50.7 *(24.2)*	40.8 *(27 8)*	38.7 *(28.1)*	28.5 *(27.7)*	32.4 *(27.2)*	18.7 *(15.3)*	40.0 *(26.2)*	39.9 *(35.2)*	40.0 *(27 9)*	30.3 *(24 0)*	31.9 *(16.6)*	20.0 *(14.8)*	32.9 *(26.0)*	29.8 *(21.1)*	34.6 *(23.0)*	40.7 *(26.6)*	51.6 *(21.4)*	47.9 *(31.7)*	38.4 *(32 6)*	42.0 *(17.6)*
	Muzzy	38.4 *(30)*	30.4 *(18.8)*	30.0 *(22.5)*	26.0 *(22.6)*	26.4 *(17 5)*	23 4 *(18 8)*	35.1 *(23 6)*	35.6 *(28.9)*	34.4 *(26 0)*	27.8 *(18 3)*	31.3 *(16.4)*	19.0 *(11.0)*	32.3 *(25 6)*	29.4 *(14 0)*	27.4 *(17 3)*	34.6 *(10.9)*	45.5 *(18.1)*	39.6 *(24.0)*	38.1 *(28 9)*	44.6 *(15 9)*
	Drowsy	47.1 *(27.4)*	49.4 *(25.8)*	37.7 *(23 6)*	26.3 *(26.5)*	29.9 *(22.4)*	20.4 *(16 3)*	34.4 *(22.2)*	38.9 *(32.4)*	33.1 *(25.1)*	30.8 *(23 4)*	29.3 *(23 7)*	19.1 *(12.5)*	30.5 *(24.4)*	30.8 *(16 3)*	30.1 *(17 1)*	44.7 *(19.4)*	42.4 *(20 6)*	45.1 *(30.8)*	38.9 *(29 7)*	43.3 *(23.1)*
TWO-UP, LONG	**Tired**	60.7 *(21 3)*	28.4(*12 9)*	58.7 *(27.5)*	16.2 *(18 6)*	38.2 *(34 4)*	9.8 *(7.4)*	39.5 *(34.4)*	25.0 *(35.1)*	58.2 *(32.2)*	11.0 *(9.8)*	30.3 *(24 5)*	17.5 *(17 7)*	41.7 *(23 0*	25.2 *(25 5)*	27.6 *(15 1)*	26.8 *(26.9)*	27.3 *(25 6)*	22.3 *(16 3)*	32.0 *(39.6)*	8.0 *(5.7)*
	Muzzy	28.8 *(22.0)*	23.6 *(17.4)*	36.2 *(18 8)*	13.7 *(14.9)*	23.0 *(23 6)*	9.2 *(5 5)*	20.0 *(15 7)*	11 8 *(8 4)*	34.3 *(26 6)*	8.0 *(6 9)*	24.7 *(22).0*	11.7 *(13 2)*	27.7 *(21 0)*	18.5 *(26.1)*	22.6 *(10 8)*	14.4 *(9 2)*	22.3 *(19.4)*	20.5 *(13.4)*	26.5 *(30.4)*	5.0 *(0 0)*
	Drowsy	34.7 *(21.0)*	22.8 *(17 7)*	40.7 *(17 3)*	15.5 *(18 1)*	30 7 *(26 8)*	10.0 *(8.2)*	24.8 *(20.2)*	18.8 *(19.5)*	44.3 *(22 1)*	7.0 *(6 8)*	23.0 *(21 7)*	16.8 *(19.8)*	38.8 *(23.1)*	23.3 *(25 1)*	20.2 *(17)*	20.6 *(28)*	27.8 *(25.6)*	23.5 *(25.3)*	23.5 *(26.2)*	5.5 *(2.1)*
TWO-UP, SHORT	**Tired**	35.1 *(12 3)*	38.5 *(23 3)*	60.6 *(20.3)*	33.5 *(29 9)*	42.6 *(21.2)*	39.5 *(28 2)*	40.8 *(20.0)*	36.1 *(27 8)*	55.8 *(27 3)*	39.8 *(16 9)*	54.9 *(21 6)*	27.3 *(16 3)*	41.9 *(25.2)*	27.6 *(17 2)*	41.2 *(23 6)*	21.8 *(14 4)*	29.0 *(16 5)*	25 0 *(21 4)*	-	-
	Muzzy	39 3 *(13 6)*	35 3 *(18 8)*	48.8 *(25 6)*	27.4 *(17 8)*	35.6 *(18.2)*	35.5 *(18.8)*	41.6 *(20 5)*	36.1 *(24.9)*	44.0 *(21 9)*	37.9 *(17.4)*	49 4 *(23 4)*	28.9 *(19.7)*	41.9 *(21 5)*	28.1 *(17.1)*	38.7 *(24.5)*	25.5 *(13.3)*	33.0 *(18.4)*	27.7 *(17 2)*	-	-
	Drowsy	40.0 *(18.3)*	36.4 *(14.4)*	56 1 *(17 5)*	27.3 *(18.9)*	35.1 *(17.3)*	29.4 *(18.2)*	41.6 *(19.9)*	36.6 *(25.2)*	46.0 *(20 7)*	35.9 *(17 1)*	48.6 *(19 2)*	27 8 *(18 7)*	42.0 *(23.4)*	23 7 *(14 9)*	43.0 *(25 2)*	22.8 *(11.3)*	39.3 *(16.5)*	24.7 *(20 6)*	-	-

TABLE A4.3: (Continued).

Operation Type	Fatigue Rating	Break 11 Pre	Break 11 Post	Break 12 Pre	Break 12 Post	Break 13 Pre	Break 13 Post	Break 14 Pre	Break 14 Post	Break 15 Pre	Break 15 Post	Break 16 Pre	Break 16 Post	Break 17 Pre	Break 17 Post	Break 18 Pre	Break 18 Post	Break 19 Pre	Break 19 Post	Break 20 Pre	Break 20 Post
		Mean *(sd)*																			
SINGLE	**Tired**	33.3 *(24.8)*	33.3 *(22.4)*	28.5 *(22.7)*	28.0 *(17.1)*	46.8 *(13.8)*	25.8 *(11.7)*	59.5 *(18.4)*	31.0 *(21.8)*	32.7 *(6.8)*	33.3 *(8.1)*	39.7 *(7.6)*	42.0 *(7.2)*	60.0 -	47.0 -	21 -	4 -	4 -	5 -	0 -	3 -
	Muzzy	26.3 *(19.8)*	25.4 *(20.5)*	20.9 *(13.6)*	20.7 *(11.2)*	38.2 *(12.2)*	24.8 *(11.1)*	58.8 *(10.4)*	29.8 *(22.0)*	33.3 *(5.5)*	32.0 *(9.5)*	40.7 *(6.1)*	43.7 *(11.6)*	60.0 -	46.0 -	18 -	4 -	8 -	4 -	4 -	2 -
	Drowsy	27.5 *(20.2)*	24.1 *(19.4)*	21.0 *(15.6)*	21.6 *(12.9)*	36.6 *(6.3)*	21.5 *(10.5)*	58.0 *(12.9)*	29.0 *(18.6)*	30.7 *(4.5)*	31.7 *(7.8)*	37.7 *(6.1)*	41.7 *(10.7)*	62.0 -	43.0 -	16 -	4 -	5 -	3 -	4 -	3 -
TWO-UP, BEYOND BROOME	**Tired**	39.4 *(27.4)*	34.1 *(25.6)*	37.3 *(22.4)*	45.8 *(31.9)*	55.5 *(5.3)*	29.0 *(9.8)*	56.0 *(35.4)*	45.5 *(14.9)*	29.5 *(17.7)*	50.0 *(1.4)*	54.0 -	-	-	-	-	-	-	-	-	-
	Muzzy	38.4 *(26.5)*	32.1 *(21.0)*	27.5 *(18.9)*	48.3 *(19.9)*	48.0 *(7.0)*	31.0 *(8.6)*	34.5 *(5.0)*	51.0 *(11.3)*	39.5 *(2.1)*	56.0 *(4.2)*	56.0 - 0	30.0 -	-	-	-	-	-	-	-	-
	Drowsy	35.3 *(25.5)*	33.1 *(29.6)*	32.5 *(19.1)*	47.0 *(28.4)*	49.0 *(6.8)*	29.0 *(7.1)*	48.0 *(12.7)*	62.0 *(9.9)*	38.0 *(4.2)*	55.5 *(7.8)*	54.0 -	29.0 -	-	-	-	-	-	-	-	-
TWO-UP, LONG	**Tired**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muzzy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Drowsy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TWO-UP, SHORT	**Tired**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Muzzy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Drowsy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix 5

Off-Road Cognitive Performance Results

TABLE A5.1: Speed of Correct Responses for the Vigilance test, summarised in blocks of 60 trials, for drivers in each operation before and after the trip.

BLOCK NUMBER	TWO-UP Before	TWO-UP After	SINGLE Before	SINGLE After
	[Mean msecs, *(sd)*]			
1	589.67 *(99.06)*	546.01 *(74.26)*	579.63 *(77.06)*	536.22 *(79.50)*
2	576.25 *(84.30)*	530.12 *(83.79)*	582.69 *(85.41)*	536.92 *(74.67)*
3	568.79 *(92.49)*	541.35 *(86.74)*	568.20 *(80.89)*	530.03 *(70.32)*
4	567.52 *(82.95)*	530.16 *(73.92)*	570.31 *(86.54)*	544.81 *(82.68)*
5	556.46 *(83.00)*	522.74 *(58.66)*	562.55 *(72.71)*	551.50 *(75.66)*
6	561.25 *(83.07)*	520.57 *(70.72)*	564.09 *(71.15)*	540.03 *(71.94)*
7	553.08 *(95.75)*	525.63 *(73.09)*	548.79 *(64.79)*	527.50 *(65.75)*
8	559.45 *(90.58)*	523.3 *(81.12)*	550.63 *(63.54)*	531.00 *(63.67)*
9	547.42 *(78.92)*	522.75 *(72.63)*	543.06 *(56.26)*	528.97 *(59.60)*
10	547.94 *(88.64)*	515.03 *(73.00)*	531.91 *(52.35)*	540.91 *(79.56)*

TABLE A5.2: Mean (*SD*) correct vigilance RT (ms) as a function of trip type, milestone and trial block

	Two-up - Beyond Broome (N=8)		**Two-up - Long Broome Stop** (N=6)		**Two-up - Short Broome Stop** (N=8)		**Single** (N=11)	
	Pre trip	**Post trip**	**Pre trip**	**Post trip**	**Pre trip**	**Post trip**	**Pre trip**	**Post trip**
Trial block								
1	642.4	560.6	600.1	573.4	529.1	510.9	571.7	512.1
	(74.3)	*(90.3)*	*(108.9)*	*(48.8)*	*(89.4)*	*(66.2)*	*(80.8)*	*(54.3)*
2	621.8	553.3	599.1	572.9	513.6	474.9	561.0	522.0
	(69.6)	*(79.8)*	*(82.1)*	*(84.4)*	*(66.1)*	*(62.7)*	*(72.8)*	*(69.0)*
3	590.9	577.6	616.2	565.6	511.1	487.0	549.8	519.4
	(95.4)	*(106.8)*	*(101.3)*	*(64.5)*	*(54.3)*	*(53.1)*	*(70.4)*	*(68.9)*
4	587.0	551.0	621.7	560.7	507.4	486.4	550.3	537.2
	(47.2)	*(60.7)*	*(83.8)*	*(75.3)*	*(79.5)*	*(71.9)*	*(77.8)*	*(85.1)*
5	583.1	555.1	598.6	542.2	498.2	475.8	544.5	547.9
	(65.9)	*(52.7)*	*(105.9)*	*(47.1)*	*(45.8)*	*(43.8)*	*(62.1)*	*(80.0)*
6	580.7	540.6	592.3	552.9	518.5	476.2	546.9	531.5
	(90.0)	*(85.8)*	*(90.7)*	*(50.7)*	*(58.1)*	*(47.0)*	*(62.7)*	*(66.9)*
7	580.5	541.1	585.5	573.3	501.4	474.4	539.5	514.8
	(121.2)	*(62.4)*	*(83.7)*	*(72.5)*	*(54.8)*	*(56.3)*	*(66.2)*	*(57.7)*
8	585.2	541.7	588.1	571.1	512.2	469.1	537.4	521.3
	(103.8)	*(88.0)*	*(96.4)*	*(67.3)*	*(56.5)*	*(55.3)*	*(59.7)*	*(57.1)*
9	563.4	542.4	584.6	559.5	503.5	475.5	532.2	520.5
	(62.3)	*(80.4)*	*(83.0)*	*(62.6)*	*(78.8)*	*(49.2)*	*(53.5)*	*(59.0)*
10	577.9	537.6	586.9	551.6	488.8	465.0	523.3	533.6
	(73.6)	*(84.4)*	*(103.0)*	*(55.3)*	*(65.2)*	*(45.7)*	*(52.5)*	*(76.2)*

Appendix 6

On-Board Vocal Reaction Time Results

TABLE A6.1: Mean *(SD)* on-board reaction time (ms) by type of driving operation and point in trip.

TRIP LEG	Outward leg (Perth to Broome)			Homeward leg (Broome to Perth)		
POINT IN TRIP	**Beginning**	**Middle**	**End**	**Beginning**	**Middle**	**End**
TYPE OF OPERATION						
Two-up	655.23 *(416.59)*	511.48 *(293.19)*	736.94 *(323.89)*	517.55 *(287.38)*	612.23 *(386.06)*	650.72 *(638.01)*
Single	710.07 *(536.33)*	846.94 *(561.83)*	1115.48 *(528.07)*	880.56 *(496.22)*	725.30 *(509.03)*	374.13 *(420.96)*

TABLE A6.2: Mean *(SD)* on-board reaction time (ms) by trip type and point in trip.

TRIP LEG	**Outward leg (Perth to Broome)**			**Homeward leg (Broome to Perth)**		
POINT IN TRIP	**Beginning**	**Middle**	**End**	**Beginning**	**Middle**	**End**
TRIP TYPE						
Two-up - Beyond Broome	538.21 *(320.72)*	571.41 *(394.28)*	752.55 *(380.97)*	597.18 *(393.34)*	625.48 *(365.72)*	701.53 *(517.99)*
Two-up - long turnabout	786.88 *(387.81)*	507.67 *(163.48)*	802.61 *(241.73)*	475.45 *(223.93)*	786.29 *(502.20)*	681.03 *(241.24)*
Two-up - short turnabout	682.06 *(555.83)*	444.73 *(271.92)*	664.00 *(353.16)*	430.82 *(94.17)*	371.46 *(114.96)*	523.92 *(237.93)*
Single	606.08 *(400.55)*	822.97 *(579.83)*	1066.68 *(520.03)*	894.47 *(515.63)*	717.84 *(530.92)*	551.70 *(296.08)*

TABLE A6.3: Mean *(SD)* number of timeout trials in on-board reaction time task by type of driving operation and point in trip.

TRIP LEG	**Outward leg (Perth to Broome)**			**Homeward leg (Broome to Perth)**		
POINT IN TRIP	**Beginning**	**Middle**	**End**	**Beginning**	**Middle**	**End**
TYPE OF OPERATION						
Two-up	1.44 *(4.06)*	0.50 *(1.47)*	1.17 *(2.43)*	0.56 *(1.75)*	0.38 *(0.89)*	0.81 *(1.87)*
Single	3.23 *(5.10)*	3.23 *(4.85)*	6.00 *(6.44)*	2.92 *(3.80)*	1.69 *(3.38)*	2.39 *(4.48)*

TABLE A6.4: Mean *(SD)* number of timeout trials in on-board reaction time task by trip type and point in trip.

TRIP LEG	Outward leg (Perth to Broome)			Homeward leg (Broome to Perth)		
POINT IN TRIP	**Beginning**	**Middle**	**End**	**Beginning**	**Middle**	**End**
TRIP TYPE						
Two-up - Beyond Broome	0.00 *(0.00)*	0.71 *(1.89)*	1.14 *(3.02)*	1.14 *(2.61)*	0.57 *(1.13)*	1.57 *(2.64)*
Two-up - long turnabout	0.20 *(0.45)*	0.00 *(0.00)*	0.80 *(1.10)*	0.20 *(0.45)*	0.40 *(0.89)*	0.00 *(0.00)*
Two-up - short turnabout	4.17 *(6.52)*	0.67 *(1.63)*	1.50 *(2.81)*	0.00 *(0.00)*	0.00 *(0.00)*	0.50 *(1.00)*
Single	2.50 *(4.56)*	3.17 *(5.06)*	5.25 *(6.12)*	3.17 *(3.86)*	1.83 *(3.49)*	1.33 *(2.50)*

Appendix 7

Heart Rate Results

TABLE A7.1: Slopes and intercepts (ms) for lines of best fit for average interbeat interval and interbeat variability at each milestone in the trip for each operation.

	Average Interbeat Interval		**Interbeat Variability**	
	Slope *(St. Error)*	**Intercept** *(St. Error)*	**Slope** *(St. Error)*	**Intercept** *(St. Error)*
Beginning of Trip				
Single	16.27 *(4.30)*	638.93 *(20.04)*	6.17 *(11.51)*	64.11 *(53.39,*
Two-up	5.78 *(0.99)*	694.46 *(3.90)*	1.62 *(1.75)*	95.03 *(6.81)*
Before Broome				
Single	2.03 *(2.14)*	735.71 *(2.34)*	0.43 *(3.45)*	95.59 *(13.43,*
Two-up	2.10 *(1.62)*	734.15 *(6.29)*	-5.78 *(1.61)*	132.53 *(6.26,*
After Broome				
Single	0.63 *(3.54)*	631.88 *(13.77)*	-11.02 *(4.28)*	122.96 *(16.67*
Two-up	8.04 *(2.88)*	691.67 *(11.21)*	3.43 *(3.27)*	92.50 *(12.72,*
End of Trip				
Single	-5.93 *(1.85)*	707.82 *(7.20)*	1.35 *(6.80)*	87.12 *(26.49,*
Two-up	-2.16 *(4.03)*	707.14 *(15.70)*	3.52 *(1.35)*	80.87 *(5.23)*

TABLE A7.2: Slopes and intercepts (ms) for lines of best fit for average interbeat interval and interbeat variability at each milestone in the trip for each trip type.

	Average Interbeat Interval		Interbeat Variability	
	Slope *(St. Error)*	**Intercept** *(St. Error)*	**Slope** *(St. Error)*	**Intercept** *(St. Error)*
Beginning of Trip				
Single	16.27 *(4.30)*	638.93 *(20.04)*	6.17 *(11.51)*	64.11 *(53.39)*
Two-up, beyond	1.47 *(2.71)*	726.22 *(10.60)*	3.33 *(3.73)*	72.55 *(14.51)*
Two-up, long	9.31 *(2.46)*	624.03 *(9.59)*	-0.99 *(2.46)*	127.73 *(9.57)*
Two-up, short	10.71 *(1.94)*	719.42 *(7.54)*	1.39 *(5.98)*	88.03 *(23.28)*
Before Broome				
Single	2.03 *(2.14)*	735.71 *(8.34)*	0.43 *(3.45)*	95.59 *(13.34)*
Two-up,beyond	15.47 *(4.39)*	673.75 *(17.11)*	-2.51 *(6.14)*	110.24 *(23.92)*
Two-up, long	-9.56 *(2.92)*	777.35 *(11.39)*	-9.36 *(5.24)*	127.82 *(20.42)*
Two-up, short	-0.41 *(4.72)*	752.39 *(18.37)*	-5.74 *(3.36)*	152.50 *(13.09)*
After Broome				
Single	0.63 *(3.54)*	631.88 *(13.77)*	-11.02 *(4.28)*	122.96 *(16.67)*
Two-up, beyond	4.05 *(2.30)*	808.66 *(8.99)*	4.11 *(2.38)*	52.40 *(9.28)*
Two-up, long	9.30 *(4.95)*	623.79 *(19.29)*	2.82 *(3.68)*	77.20 *(14.35)*
Two-up, short	5.16 *(3.74)*	674.33 *(14.26)*	2.38 *(7.85)*	150.37 *(30.56)*
End of Trip				
Single	-5.93 *(1.85)*	707.82 *(7.20)*	1.35 *(6.80)*	87.12 *(26.49)*
Two-up, beyond	-2.92 *(17.17)*	795.42 *(66.85)*	6.26 *(4.75)*	83.44 *(18.50)*
Two-up, long	-6.68 *(2.60)*	694.80 *(9.98)*	2.24 *(3.05)*	83.24 *(11.87)*
Two-up, short	4.91 *(1.98)*	660.81 *(7.70)*	3.97 *(7.36)*	75.20 *(28.67)*

TABLE A7.3: Intercepts and slopes (SE) of lines of best fit for mean interbeat interval (ms) over the first hour of each drive period for two-up and single drivers.

Drive	Intercepts		Slopes	
Period	**Two-up**	**Single**	**Two-up**	**Single**
2	697.03 (7.60)	752.82 (9.64)	-2.13 (1.95)	-4.50 (2.48)
3	698.45 (9.59)	720.04 (5.02)	0.44 (2.46)	-2.14 (1.29)
4	714.26 (6.50)	686.03 (17.93)	1.10 (1.67)	1.64 (4.60)
5	715.32 (8.06)	725.24 (13.79)	-2.24 (2.07)	-0.70 (3.54)
6	701.91 (6.56)	684.33 (7.96)	1.74 (1.68)	-5.00 (2.04)
7	708.87 (12.90)	710.08 (11.04)	5.78 (3.31)	-2.85 (2.83)
8	696.46 (4.55)	780.92 (28.07)	-1.88 (1.17)	-9.18 (7.21)
9	757.83 (10.07)	680.07 (19.78)	-2.45 (2.59)	1.09 (5.08)
10	710.49 (19.94)	696.10 (8.69)	3.53 (5.12)	4.13 (2.23)
11	748.82 (35.59)	729.07 (17.19)	3.54 (8.37)	1.11 (4.41)
12	813.76 (29.80)	685.50 (7.19)	-3.63 (7.65)	3.25 (1.85)
13		730.56 (19.25)		1.15 (4.94)
14		879.18 (10.85)		-10.56 (2.79)

TABLE A7.4: Intercepts and slopes (SE) of lines of best fit for variability in interbeat interval (ms) over the first hour of each drive period for two-up and single drivers.

Drive Period	Intercepts Two-up	Intercepts Single	Slopes Two-up	Slopes Single
2	83.63 (7.17)	91.51 (11.51)	-0.26 (1.84)	1.82 (2.95)
3	96.68 (10.43)	59.54 (8.05)	1.76 (2.68)	3.37 (2.07)
4	108.01 (5.45)	131.63 (17.17)	-6.42 (1.40)	-3.95 (4.41)
5	86.95 (6.91)	70.57 (16.16)	3.62 (1.77)	6.63 (4.15)
6	76.97 (4.86)	100.87 (8.23)	5.13 (1.25)	-2.26 (2.11)
7	117.36 (15.65)	62.40 (11.18)	0.10 (4.02)	7.70 (2.87)
8	63.97 (5.67)	110.75 (29.14)	1.61 (1.46)	-8.05 (7.48)
9	79.55 (5.00)	94.18 (20.07)	-3.71 (1.28)	3.12 (5.15)
10	77.61 (5.61)	93.71 (7.92)	0.92 (1.44)	-1.01 (2.03)
11	105.34 (13.91)	143.15 (14.98)	-9.49 (3.57)	-13.20 (3.85)
12	79.25 (21.96)	142.83 (2.35)	3.68 (5.64)	-9.61 (0.60)
13		114.23 (22.61)		-6.41 (5.81)
14		107.87 (15.61)		-2.21 (4.01)

Appendix 8

Driving Performance Results

TABLE A8.1: Slopes and intercepts (°) for lines of best fit for average steering deviation and steering variability at each milestone in the trip for each operation.

	Average Steering Deviation		Steering Variability	
	Slope *(St. Error)*	**Intercept** *(St. Error)*	**Slope** *(St. Error)*	**Intercept** *(St. Error)*
Beginning of Trip				
Single	0.20 *(0.09)*	3.28 *(0.36)*	0.15 *(0.20)*	2.82 *(0.85)*
Two-up	0.18 *(0.07)*	4.15 *(0.28)*	0.10 *(0.07)*	3.14 *(0.29)*
Before Broome				
Single	0.01 *(0.03)*	3.13 *(0.10)*	-0.001 *(0.02)*	2.41 *(0.10)*
Two-up	0.02 *(0.03)*	3.64 *(0.13)*	0.01 *(0.03)*	2.80 *(0.13)*
After Broome				
Single	0.23 *(0.13)*	1.90 *(0.52)*	0.27 *(0.24)*	1.54 *(0.95)*
Two-up	0.02 *(0.03)*	3.45 *(0.10)*	-0.03 *(0.05)*	2.80 *(0.20)*
End of Trip				
Single	-0.04 *(0.03)*	3.67 *(0.12)*	0.14 *(0.05)*	2.30 *(0.18)*
Two-up	-0.05 *(0.08)*	5.31 *(0.33)*	-0.10 *(0.06)*	4.01 *(0.23)*

TABLE A8.2: Slopes and intercepts (°) for lines of best fit for average steering deviation and steering variability at each milestone in the trip for each trip type.

	Average Steering Deviation		Steering Variability	
	Slope *(St. Error)*	**Intercept** *(St. Error)*	**Slope** *(St. Error)*	**Intercept** *(St. Error)*
Beginning of Trip				
Single	-0.06 *(0.14)*	4.40 *(0.55)*	-0.39 *(0.35)*	5.41 *(1.37)*
Two-up, beyond	0.11 *(0.10)*	5.32 *(0.40)*	0.11 *(0.09)*	3.46 *(0.34)*
Two-up, long	0.13 *(0.07)*	3.20 *(0.26)*	0.14 *(0.01)*	1.97 *(0.04)*
Two-up, short	0.26 *(0.12)*	4.19 *(0.46)*	0.05 *(0.12)*	3.85 *(0.47)*
Before Broome				
Single	-0.004 *(0.03)*	3.10 *(0.12)*	-0.007 *(0.02)*	2.37 *(0.09)*
Two-up,beyond	0.007 *(0.02)*	3.70 *(0.09)*	0.009 *(0.02)*	2.52 *(0.11)*
Two-up, long	0.01 *(0.07)*	2.25 *(0.27)*	-0.10 *(0.13)*	2.33 *(0.51)*
Two-up, short	0.05 *(0.07)*	4.29 *(0.28)*	0.06 *(0.06)*	3.33 *(0.25)*
After Broome				
Single	0.25 *(0.14)*	1.80 *(0.56)*	0.30 *(0.26)*	1.44 *(1.02)*
Two-up, beyond	-0.002 *(0.05)*	3.49 *(0.20)*	-0.06 *(0.04)*	2.25 *(0.17)*
Two-up, long	0.05 *(0.06)*	2.48 *(0.23)*	-0.01 *(0.02)*	1.8 *(0.09)*
Two-up, short	0.009 *(0.05)*	4.10 *(0.20)*	-0.14 *(0.12)*	4.05 *(0.46)*
End of Trip				
Single	-0.02 *(0.02)*	3.53 *(0.09)*	0.16 *(0.05)*	2.23 *(0.20)*
Two-up, beyond	-0.05 *(0.08)*	5.72 *(0.32)*	-0.03 *(0.04)*	3.63 *(0.16)*
Two-up, long	-0.12 *(0.09)*	3.97 *(0. 34)*	0.03 *(0.03)*	2.43 *(0.12)*
Two-up, short	-0.03 *(0.11)*	6.40 *(0.45)*	-0.16 *(0.08)*	5.56 *(0.32)*

TABLE A8.3: Intercepts and slopes (SE) of lines of best fit for mean steering movements (°) over the first hour of each drive period for two-up and single drivers.

Drive Period	Intercepts		Slopes	
	Two-up	Single	Two-up	Single
2	4.64 (0.21)	3.32 (0.10)	0.02 (0.06)	0.16 (0.03)
3	4.20 (0.07)	3.62 (0.15)	-0.01 (0.02)	-0.08 (0.04)
4	3.67 (0.13)	3.32 (0.07)	0.02 (0.03)	-0.04 (0.02)
5	3.70 (0.15)	2.94 (0.07)	0.01 (0.04)	0.06 (0.02)
6	4.01 (0.18)	3.20 (0.11)	0.08 (0.05)	-0.08 (0.03)
7	4.55 (0.15)	3.29 (0.20)	-0.04 (0.04)	-0.08 (0.05)
8	4.50 (0.38)	2.17 (0.12)	-0.03 (0.10)	0.13 (0.03)
9	4.82 (0.22)	2.67 (0.13)	-0.001 (0.06)	-0.03 (0.03)
10	4.57 (0.27)	2.45 (0.09)	-0.06 (0.07)	0.01 (0.02)
11	4.08 (0.30)	2.91 (0.14)	0.06 (0.08)	0.04 (0.04)
12	4.28 (0.15)	2.45 (0.17)	0.01 (0.04)	0.05 (0.04)
13	4.90 (0.22)	2.16 (0.28)	-0.03 (0.06)	0.11 (0.07)
14		2.63 (0.28)		0.09 (0.07)
15*		2.07 (0.16)		0.32 (0.04)
16*		2.61 (0.36)		-0.03 (0.09)
17		3.61 (0.36)		0.10 (0.09)

* N=2 Points included for continuity with drive period 17.

TABLE A8.4: Intercepts and slopes (SE) of lines of best fit for variability in steering movements (°) over the first hour of each drive period for two-up and single drivers.

Drive Period	Intercepts Two-up	Intercepts Single	Slopes Two-up	Slopes Single
2	3.20 (0.14)	2.42 (0.12)	0.03 (0.04)	0.15 (0.03)
3	3.11 (0.10)	2.66 (0.13)	-0.04 (0.03)	-0.04 (0.03)
4	2.72 (0.31)	2.83 (0.26)	0.02 (0.08)	-0.12 (0.07)
5	2.58 (0.18)	2.45 (0.12)	0.02 (0.05)	0.04 (0.04)
6	2.95 (0.10)	3.03 (0.22)	0.06 (0.03)	-0.15 (0.06)
7	3.02 (0.30)	2.48 (0.28)	0.05 (0.08)	-0.03 (0.07)
8	2.87 (0.22)	1.73 (0.12)	0.001 (0.06)	0.10 (0.03)
9	3.28 (0.09)	2.56 (0.28)	-0.01 (0.02)	-0.13 (0.07)
10	2.97 (0.16)	2.10 (0.15)	-0.02 (0.04)	-0.04 (0.04)
11	2.66 (0.17)	2.27 (0.10)	0.06 (0.04)	0.03 (0.02)
12	2.79 (0.21)	2.06 (0.13)	-0.01 (0.05)	-0.01 (0.03)
13	3.31 (0.19)	1.89 (0.28)	-0.03 (0.05)	0.06 (0.07)
14		2.25 (0.28)		0.01 (0.07)
15*		1.09 (0.57)		0.50 (0.15)
16*		1.81 (0.23)		-0.02 (0.06)
17		2.42 (0.24)		0.11 (0.06)

* N=2 Points included for continuity with drive period 17.

TABLE A8.5: *Slopes and intercepts (km/h) for lines of best fit for average speed and speed variability at each milestone in the trip for each operation.*

	Average Speed		Speed Variability	
	Slope *(St. Error)*	**Intercept** *(St. Error)*	**Slope** *(St. Error)*	**Intercept** *(St. Error)*
Beginning of Trip				
Single	-1.75 *(3.33)*	87.53 *(15.43)*	1.75 *(3.33)*	2.5 *(2.03)*
Two-up	1.30 *(0.53)*	80.90 *(2.06)*	-0.37 *(0.44)*	8.59 *(1.72)*
Before Broome				
Single	0.34 *(0.13)*	92.30 *(0.50)*	-0.05 *(0.08)*	3.34 *(0.32)*
Two-up	0.03 *(0.18)*	88.55 *(0.69)*	0.08 *(0.19)*	4.00 *(0.75)*
After Broome				
Single	-0.99 *(0.55)*	98.62 *(2.15)*	0.20 *(0.16)*	0.77 *(0.63)*
Two-up	-0.14 *(0.41)*	92.00 *(1.59)*	-0.33 *(0.24)*	5.05 *(0.94)*
End of Trip				
Single	-1.33 *(0.45)*	93.35 *(1.75)*	0.48 *(0.28)*	6.73 *(1.10)*
Two-up	-0.30 *(0.42)*	91.71 *(1.65)*	0.38 *(0.30)*	5.20 *(1.15)*

TABLE A8.6: Slopes and intercepts (km/h) for lines of best fit for average speed and speed variability at each milestone in the trip for each trip type.

	Average Speed		Speed Variability	
	Slope *(St. Error)*	**Intercept** *(St. Error)*	**Slope** *(St. Error)*	**Intercept** *(St. Error)*
Beginning of Trip				
Single	-1.22 *(1.31)*	84.42 *(5.10)*	0.69 *(0.52)*	7.94 *(2.01)*
Two-up, beyond	1.30 *(0.75)*	81.96 *(2.90)*	-0.34 *(0.74)*	9.98 *(2.87)*
Two-up, long	1.37 *(0.70)*	78.49 *(2.72)*	-0.50 *(0.29)*	8.86 *(1.13)*
Two-up, short	1.15 *(0.80)*	81.98 *(3.11)*	-0.29 *(0.53)*	6.69 *(2.08)*
Before Broome				
Single	0.34 *(0.15)*	91.59 *(0.60)*	-0.02 *(0.10)*	3.56 *(0.40)*
Two-up,beyond	-0.53 *(0.44)*	92.12 *(1.71)*	0.26 *(0.28)*	4.65 *(1.08)*
Two-up, long	1.18 *(0.49)*	74.93 *(1.92)*	-0.24 *(0.46)*	6.21 *(1.78)*
Two-up, short	0.09 *(0.19)*	94.98 *(0.75)*	0.03 *(0.16)*	1.60 *(0.63)*
After Broome				
Single	-1.11 *(0.61)*	98.60 *(2.37)*	0.22 *(0.18)*	0.81 *(0.71)*
Two-up, beyond	-0.49 *(0.67)*	92.04 *(2.59)*	-0.31 *(0.4)*	6.92 *(1.56)*
Two-up, long	0.04 *(0.32)*	88.11 *(1.23)*	-0.18 *(0.22)*	3.89 *(0.86)*
Two-up, short	0.17 *(0.10)*	97.14 *(0.37)*	-0.52 *(0.13)*	3.09 *(0.50)*
End of Trip				
Single	-1.26 *(0.32)*	92.57 *(1.25)*	0.31 *(0.23)*	7.18 *(0.91)*
Two-up, beyond	0.41 *(0.57)*	92.51 *(2.21)*	0.11 *(0.51)*	8.02 *(1.97)*
Two-up, long	-0.95 *(0.67)*	90.89 *(2.62)*	1.02 *(0.38)*	1.34 *(1.47)*
Two-up, short	-0.41 *(0.74)*	91.18 *(2.89)*	0.08 *(0.14)*	5.61 *(0.56)*

TABLE A8.7: Intercepts and slopes (SE) of lines of best fit for mean speed (km/h) over the first hour of each drive period for two-up and single drivers.

Drive	Intercepts		Slopes	
Period	Two-up	Single	Two-up	Single
2	88.86 (0.57)	91.77 (2.77)	0.56 (0.15)	-0.57 (0.71)
3	86.90 (0.46)	89.19 (1.58)	0.22 (0.12)	0.32 (0.41)
4	84.30 (0.76)	87.16 (2.47)	0.58 (0.20)	0.62 (0.64)
5	91.51 (0.61)	92.34 (1.63)	-0.29 (0.16)	0.46 (0.42)
6	91.57 (0.84)	89.63 (1.80)	0.09 (0.22)	0.72 (0.46)
7	86.03 (1.92)	97.17 (1.51)	0.30 (0.49)	0.25 (0.39)
8	90.83 (3.01)	96.35 (1.40)	0.02 (0.77)	-0.05 (0.36)
9	89.75 (1.31)	90.40 (2.43)	-0.18 (0.34)	1.00 (0.62)
10	88.84 (1.69)	95.24 (1.31)	0.21 (0.43)	0.29 (0.34)
11	90.01 (0.85)	98.63 (1.12)	0.18 (0.22)	-0.59 (0.29)
12	93.43 (2.90)	97.31 (1.17)	0.03 (0.75)	-0.23 (0.30)
13	99.62 (1.60)	96.33 (1.45)	-1.44 (0.41)	-0.16 (0.37)
14		95.78 (2.64)		-0.52 (0.68)
15*		100.33 (4.28)		-1.90 (1.10)
16*		96.44 (0.35)		0.26 (0.09)
17		91.89 (1.93)		-1.25 (0.50)

* N=2 Points included for continuity with drive period 17.

TABLE A8.8: Intercepts and slopes (SE) of lines of best fit for variability in speed (km/h) over the first hour of each drive period for two-up and single drivers.

Drive Period	Intercepts Two-up	Intercepts Single	Slopes Two-up	Slopes Single
2	3.49 (0.25)	5.74 (1.15)	-0.10 (0.06)	0.25 (0.30)
3	3.99 (0.39)	4.90 (0.82)	-0.04 (0.10)	-0.37 (0.21)
4	3.56 (0.74)	3.67 (0.95)	0.04 (0.19)	0.08 (0.24)
5	2.82 (0.53)	1.87 (0.38)	0.003 (0.14)	0.02 (0.10)
6	2.82 (0.36)	5.74 (1.58)	0.08 (0.09)	-0.23 (0.41)
7	3.25 (0.43)	1.66 (1.17)	0.48 (0.11)	-0.06 (0.30)
8	3.57 (0.80)	1.28 (1.21)	-0.01 (0.21)	-0.29 (0.31)
9	5.90 (0.87)	4.03 (0.80)	-0.22 (0.22)	-0.24 (0.21)
10	3.63 (0.81)	3.27 (1.25)	0.09 (0.21)	-0.37 (0.32)
11	3.87 (1.02)	0.92 (1.22)	0.03 (0.26)	0.44 (0.31)
12	3.65 (1.26)	1.78 (1.00)	0.33 (0.32)	0.19 (0.26)
13	-0.68 (2.36)	1.55 (1.03)	1.55 (0.60)	0.17 (0.26)
14			5.19 (1.06)	-0.04 (0.27)
15*			0.93 (3.68)	0.98 (0.95)
16*			0.99 (0.23)	-0.12 (0.06)
17			1.57 (0.97)	0.73 (0.25)

* N=2 Points included for continuity with drive period 17.