A pilot study of fatigue on motorcycle day trips

August 2003

Prepared by

Therese Ma
Ann Williamson
Rena Friswell

NSW Injury Risk Management Research Centre

Contents

List of Figures

List of Tables

Acknowledgments

Many people provided their time, expertise and enthusiasm to the make this study happen.

We would like to thank the 21 riders who volunteered to take part in this study.

Guy Stanford and Brian Wood at the Motorcycle Council of NSW were pivotal in the behind-the-scenes organisation of the study. They recruited riders, arranged and tested the ride route, and provided technical advice, supervision and computing equipment.

We are indebted to Claire Campbell from Wollongong City Council and Jennifer Davies from Shellharbour City Council for their assistance in the organisation of the study.

Peter Davies and Peter Kelly each donated two Sundays to act as checkpoint supervisors and Paul Taffa and Guy Stanford manned the maintenance and recovery vehicle on the study days. Chris Coote and Brian Wood acted as supervising riders for the participants.

Alex Symonds assisted with the data collection.

The study was supported by the Wollongong City Council and the Motorcycle Council of NSW through IPWEA grants.

Summary

Despite recognition that driver fatigue is an important road safety risk factor, fatigue among motorcyclists has received virtually no attention. Twenty (20) motorcyclists took part in a pilot study of fatigue during a day ride. Participants were tested on two weekend days a week apart. On one of the days, participants rode from the Sydney testing centre to Robertson and back – a trip of approximately 279 km. The ride contained three mandatory stops totalling 1hr 10min, and the entire trip duration averaged 5hr 54min. The other day acted as a control condition and participants were asked to refrain from recreational riding. The order of the days was reversed for half the participants. Participants' reaction speed and concentration at the start and end of each day was tested. Subjective fatigue was also rated at these times and throughout the ride day. Greater subjective fatigue was reported at the end of both days than at the start. However, there was little evidence that the ride itself affected subjective fatigue more than control day activities. The findings on subjective fatigue are reflected in the performance data. No evidence of deteriorating concentration was observed across either the ride day or the control day. Reaction speeds were more variable at the end of each day than at the start but again, this was not related to the ride. Overall, the results suggest that the riding regime employed in the study did not produce fatigue at levels that would adversely affect riders' abilities to process information and initiate action. The impact of physical fatigue levels (observed at the end of the ride day), however may have impact on safe riding. In view of the fact that 10% of participants reported experiencing fatigue on at least half their rides about Sydney and almost half (40%) reported fatigue on at least half of their longer trips, further work in this area is indicated.

1 Background

This study was initiated by the Wollongong City Council and the Motorcycle Council of NSW through an IPWEA grant as a preliminary step toward understanding fatigue in motorcycle riders. Relatively little information is available about the incidence of fatigue or its development in motorcycle riders. This is despite the fact that, using current operational definitions of fatigue, 716 fatigued riders were involved in reportable traffic accidents in NSW between 1996 and 2001 and 94% of these accidents resulted in somebody, usually the motorcycle rider, being killed or injured (NSW RTA Traffic Accident Database). Fatigued riders made up 5.4% of all the riders involved in accidents during this period – a significantly higher percentage than for other types of road users who were involved in accidents and who were fatigued (4.5%; $\chi^2_{(1)}=23.52$, $p<0.001$). These crash data highlight the fact that fatigue is as important a safety threat to motorcycle riders as to other road users.

Although it may be tempting to rely upon the driver fatigue research to inform policy and interventions for rider fatigue, there are strong reasons to undertake fatigue research specifically focussed on the motorcycling population. In particular, the motorcycle riding task makes different demands of people than the car driving task. These differences may have important consequences for the way fatigue develops and affects drivers and riders, respectively. Consequently, the current pilot study was commissioned as an initial exploration of fatigue in motorcycle riders. In particular, the objectives of the study were to examine the effects of a recreational day ride on reported fatigue and performance and to gather some preliminary data on the usual occurrence and effects of fatigue among riders.

2 Introduction

2.1 The nature of fatigue

Driver fatigue is typically seen as a composite phenomenon which can be caused by both sleep need and task fatigue (Brown, 1994). It is characterised by the subjective experience of tiredness, reduced arousal and alertness, and by decreases in the ability to maintain attention and to respond quickly (Charlton & Baas, 2001; Lisper, Laurel, & van Loon, 1986; Nilsson, Nelson, & Carlson, 1997; Williamson, Feyer, & Friswell, 1996). There is also evidence that people become poorer at decision making and planning in novel and critical situations when they are fatigued (Harrison & Horne, 2000).

Although not generally included in definitions of the driver fatigue phenomenon, physical tiredness characterised by muscular fatigue (Brown, 1994; Grandjean, 1979) may be a relevant dimension of the fatigue experience for motorcyclists. In contrast, everyday driving typically requires more cognitive effort, such as sustained vigilance and complex decision making, compared to physical effort (Brown, 1994). Physical fatigue, has been reported to be important, however, for some professional drivers (e.g., long- distance and dump truck drivers, and bus drivers) with back and leg pain being the most dominant symptom after three to nine hours of driving (Milosevic, 1997).

2.2 Factors affecting fatigue

In general, fatigue is affected by acute and cumulative sleep loss and by circadian rhythms, with increased fatigue occurring during the biological low between midnight and dawn (Ferrara, & Gennaro, 2001; Horne & Reyner, 1995; Maycock, 1997). Further, fatigue increases with task workload and the time spent engaged on a task (Dinges & Kribbs, 1991; Hancock & Verwey, 1997; Matthews & Desmond, 2002).

The impact of fatigue can be modified by a number of other factors. For example, a person's motivation level can help to stave off the effects of fatigue temporarily (Brown, 1994; Matthews & Desmond, 2002; Wolf, Smith, & Birnbaum, 1995), and some types of task seem to be less susceptible to the effects of fatigue than others either because they are arousing or because they do not require high levels of alertness for adequate performance (Harrison & Horne, 2000; Wilkinson, 1992). For example, monotonous tasks, such as highway driving, appear to be more susceptible to fatigue than more arousing tasks such as urban driving (Horne & Reyner, 1995; Thiffault & Bergeron, 2003). Whether this same distinction applies to the task of motorcycle riding, however, is not clear. Riding enthusiasts often describe their open road riding experience as exhilarating or exciting and the extent to which this arousal reaction might offset the effects of fatigue and for how long deserves investigation.

Research on the impact of physical exertion on fatigue is mixed. There is some evidence to suggest that physical exertion may temporarily reduce fatigue effects (O'Neil, Kruegar, Van Hemel, & McGowan, 1999). In contrast, there is also evidence that physical fatigue may contribute to a decline in alertness, mental concentration, motivation, and driving performance (Åstrand & Rodahl, 1986; O'Neil et al., 1999). The degree of enhancement or impairment in performance appears to be dependent on the degree of physical exertion and the cumulative effect of fatigue (Fery, Ferry, vom Hofe, & Rieu, 1997; O'Neil et al., 1999). How the physical effort involved in motorcycle riding may affect the fatigue of riders is an open research question.

Not surprisingly, both naps and beverages containing high doses of caffeine have been shown to reduce fatigue due to sleep loss, particularly when used together (Horne & Reyner, 1995; Reyner & Horne, 1997). Break-taking without naps, with and without caffeine, also appears to postpone the effects of fatigue (Kopardekar & Mital, 1994; Neri, Oying, Colletti, Mallis, Tam, & Dinges, 2002) but simply taking a break is not as effective at offsetting fatigue as napping or caffeine consumption (Horne & Reyner, 1996). In addition, there is little evidence available about what is the best length and frequency of such breaks (Lisper & Eriksson, 1980; Neri et al., 2002). Preliminary findings seem to suggest that short and frequent breaks might be most effective.

2.3 The effects of fatigue

Driver fatigue has been shown to affect safe driving performance. For example, steering accuracy and lane tracking ability deteriorate when a driver is fatigued (Stein, 1995). Similarly, truck drivers report poorer gear changing, poorer steering, slowed reactions and failure to maintain vehicle speed as the primary effects of fatigue on their driving performance (Williamson, Feyer, Coumarelos & Jenkin, 1992; Williamson, Feyer, Friswell & Sadural, 2001). In simulated driving environments, fatigued drivers are more likely to crash the vehicle (Horne & Reyner, 1996). In contrast to driving, little is known about how fatigue affects the task of riding a motorcycle.

2.4 Indicators of fatigue

A range of fatigue measures has been used to assess driver fatigue. These include psychological, performance, perceptual, electrophysiological, and biochemical indicators. Cognitive and psychomotor performance measures of perception, reaction time, cognitive performance, and concentration have been amongst the most successful measures of fatigue (Williamson, Feyer, Mattick, Friswell, & Finlay-Brown, 2001).

Obviously, subjective experiences of fatigue are also an extremely important component of fatigue. Among the different techniques available for measuring subjective fatigue, bipolar scales that represent fatigue symptoms in analogue form are one of the more sophisticated (e.g., alert/drowsy dimension represented along a 10cm horizontal line; Brown, 1994). However, the impact of fatigue on subjective measures on the one hand and on performance and driving measures on the other has not always been consistent in the literature (e.g., Williamson, Feyer, Friswell and Finlay-Brown, 2000).

2.5 The current study

In view of the limited information available about rider fatigue, the current study was conducted to determine whether subjective fatigue and performance among motorcyclists were affected by a recreational day trip of approximately five hours in duration. The study also sought to gather preliminary information about the riders’ common experiences of fatigue.

3 Method

3.1 Study design

All riders participated in the study on two separate days, one week apart. On one of the days, they completed a scenic day ride on a set route south of Sydney (Ride day). On the other day (Control day), they were asked to engage in relaxing, light activities and to abstain from recreational riding. The order of the two conditions was counterbalanced to control for the possibility that participant responses may be systematically affected by familiarity with the study procedures. Riders' reaction speed and sustained attention performance were tested at the start and end of the ride and at comparable times on the control day. Riders' subjective experience of fatigue was also measured at these times. Any changes in performance or fatigue between the start and end of the ride that were not matched by changes across the control day could then be assumed to be due to the ride. In addition to these measures, participants rated their physical tiredness at the end of each day, made an assessment of their mental and physical workload during each day, and rated their subjective fatigue at the beginning and end of each of the three mandatory breaks on the ride day. These measures were used as a manipulation check, and to enhance understanding of the impact of motorcycle riding on fatigue. Riders completed a brief diary of their sleep, work and driving/riding in the days leading up to each study day. This information was used to ensure that riders were similarly rested prior to the two study days. Lastly, each rider provided background information about his/her lifestyle and sleep patterns, and provided information about his/her typical experiences of fatigue while riding.

3.2 Participants

Volunteer riders were recruited through advertisements in a popular motorcycle magazine and Internet newsgroups. Of the 21 volunteers, 20 completed both days of the study. Only data from volunteers who completed both days were included in the study. The group consisted of 15 men and 5 women, with a mean age of 37.2 years (SD=9.66) and an average of 13.54 years (SD=10.77) riding experience. Participants rode their own bikes on the ride day. The average engine capacity and weight of the motorcycles were 745cc (SD=257) and 206 kg (SD=38), respectively. There were no significant differences between females and males on these measures.

Table 3.2.1 shows how often the group rode locally and on longer trips. Eighty five percent of participants rode at least two to three times a week within Sydney, while 85% went on longer rides at least once or twice a month.

Table 3.2.1: Frequency of rides within and out of Sydney

	Everyday	2-3 times a week	Once a week	1-2 times a month	Rarely	Never
n=20 (%)						
Within Sydney	75	10	5	10	0	0
On longer trips	0	0	20	65	15	0

Alcohol, caffeine, and tobacco can affect physiological arousal and alertness (e.g., Gentry, Hammersley, Hale, Nuwer, & Meliska, 2000; Horne & Reyner, 1996; Liguori & Robinson, 2001). Thus, riders were asked to report their usual level of usage of these social drugs. One-fifth of participants were smokers, smoking on average 12.1 (SD=10.62) cigarettes a day. The majority of participants drank caffeine (95%), averaging 3.4 drinks per day. Similarly, most participants drank alcohol (90%); typically two or more times a week.

A summary of the typical experiences of sleepiness and sleep problems reported by riders is presented in Table 3.2.2. It was important to collate information regarding these issues as chronic sleep problems and sleepiness are likely to impact upon fatigue. Over half of the participants experienced loud snoring and at least sometimes moving around a lot in sleep. A large minority (40%) also reported sometimes experiencing difficulty staying awake during the day but none reported that this was a frequent occurrence.

The Epworth Sleepiness Scale (ESS) was used to measure the usual level of daytime sleepiness experienced by the participants. The scale asks how likely people are to doze in a number of everyday situations, including some where dozing may be appropriate and welcome (e.g., lying down to rest in the afternoon when circumstances permit). Scores of 10 or less on the ESS indicate that people are not normally excessively sleepy, whereas high scores (16 or more) suggest chronic sleepiness (Johns, 1991; Johns & Hocking, 1997). In the current study, 45% of the riders had somewhat elevated ESS scores (i.e., between 11 and 15), suggesting that their usual sleep was not sufficient to combat daytime tiredness. Interestingly, over half (56%) of those with an ESS over 10 reported that they rarely or never experienced problems staying awake during the day. This indicates that although some participants were tired enough that they could fall asleep quite easily during the day in appropriate settings, they were not so tired that they had difficulty preventing themselves from falling asleep at other times.

Table 3.2.2: Common experiences of sleepiness and sleep problems

		Always	Often	Sometimes	Rarely	Never
	n=20 (%)					
Loud snoring		15	35	10	20	20
Stopped breathing in sleep		0	0	10	5	85
Moving around a lot in sleep		5	25	40	20	10
Difficultly staying awake in day		0	0	40	50	10
		Yes	**No**			
Problems falling asleep		20	80			
Problems staying awake		30	70			
Epworth Sleepiness Scale	≤ 10	55				
	11 – 15	45				
	≥ 16	0				
Average (SD)		8.7 (3.13)				
Range		3 - 13				

All the riders had computing experience with 85% rating themselves as frequent users. This meant that participant responses on the computerised performance measures used in the present study would not be confounded by unfamiliarity with computer equipment.

3.3 Materials and Equipment

3.3.1 Paper and pencil measures

Participants completed a number of paper and pencil measures during the study.

3.3.1.1 Background Information Questionnaire

A Background Information Questionnaire was used for the first day of the study comprising of sections relating to: 1) general background information, 2) usual experiences of rider fatigue, 3) typical alcohol, caffeine, and tobacco use, 4) common experiences of sleepiness and sleep problems, 5) work, sleep, and driving/riding for the two days leading up to the study day, and 6) other activities prior to the study day (see Appendix 7.1). On the second day of the study only the last two sections were used.

3.3.1.2 Ride Diary

A small diary was provided to all participants on their allocated ride day (see Appendix 7.2). The Ride Diary asked riders to rate their subjective fatigue at the start and end of each of the mandatory breaks in the ride on three 10cm Visual Analogue Scales (VASs). The scales were anchored with the terms Fresh-Tired, Clear headed-Muzzy headed, and Very Alert-Very Drowsy. These scales have been used in other research on driver fatigue (Williamson et al., 2000) and were designed to capture different aspects of the fatigue experience. The time that each driver arrived and left each rest stop and the odometer reading on the bike on arrival were also recorded in each rider's diary by the checkpoint supervisor.

3.3.1.3 End-of-Day Questionnaire

The End-of-Day Questionnaire (see Appendix 7.3) was completed when participants returned to the testing centre at the end of the ride and control days. It consisted of two parts. The first part related to participants' activities during the day. For the ride day, participants noted the details of any additional breaks (other than the mandatory rest stops) that they had taken during the ride. For the control day, participants were asked to briefly record their activities during the day. The second part of the questionnaire asked participants to rate how physically tired they felt on 6 10cm VAS scales anchored with the terms Fresh-Tired. Ratings were obtained for the whole body as well as for the neck/head, back, eyes, arms/hands and legs/feet regions of the body separately.

3.3.1.4 Perceived workload

At the end of the ride and control days, participants rated the physical, mental, time and performance demand of their day's activities as well as the overall degree of effort and frustration involved with these activities using the NASA-TLX scale (Hart & Staveland, 1988; Hill, Iavecchia, Byers, Bittner, Zaklad, & Christ, 1992). The NASA-TLX also requires respondents to decide, for each pair of the 6 dimensions of workload, which was the most important contributor to their overall workload. Each of the 6 ratings can then be weighted (multiplied) by the number of times its dimension was chosen as the most important. The average weighted workload score across all 6 dimensions was also calculated.

3.3.2 Performance measures

At the start and end of each study day, participants completed two computerised performance tests sensitive to changes in fatigue (Williamson et al., 2000; Williamson, Feyer, Mattick, et al., 2001). Ten computers (laptop and desktop) were used to present the testing sessions. Before completing the performance tests, participants were presented with the 3 VAS rating scales of fatigue that were used in the ride diary. They made their ratings using the computer mouse. The performance tests then followed and participants responded to events on the computer screen using the keypad.

3.3.2.1 Simple Reaction Time task (RT)

The RT task presented a small circle moving slowly around the computer screen. Participants responded as quickly as they could whenever the circle changed colour. Forty colour changes occurred over the 2 minute task. Reaction speed, variability in reaction speed, and the number of missed responses were scored.

3.3.2.2 Mackworth Clock Vigilance task (MAK)

The MAK task tests the ability to maintain attention. Twenty-four dots were presented, arranged in a circle in the middle of the computer screen. For 15 minutes, each dot flashed in turn in a continuous circuit, one flash every half second. On 15 occasions during the task, a dot was skipped. Participants responded to the skipped dots as quickly as they could. As for the RT task, reaction speed, variability in reaction speed, and the numbers of missed responses were scored.

3.4 Procedure

All participants gave informed consent prior to taking part in the study. They were randomly allocated to complete either the ride or control day first, except where their personal commitments restricted the order.

Each participant was provided with a copy of the Background Information Questionnaire for week 1 at least three days prior to the first study day and was asked to complete sections 1 to 5 before arriving for the first testing session, at which time they completed the final section. At the end of the first study day, participants were given the Background Information Questionnaire for the following week and asked to complete the first section prior to the test day and the second section on arrival.

On each study day, participants were scheduled to arrive at the testing centre in three waves, at approximately 8:00am, 8:40am, and 9:20am. Each wave included both riders and control day participants. After completing their questionnaires on arrival, participants undertook brief practice versions of the performance tests and then completed the full length tests. Control day participants were then asked to return to the testing centre in the afternoon, approximately 6 hours later, and to refrain from strenuous activity and recreational riding during the day.

Ride day participants were instructed in the use of the ride diaries, and were briefed on the route and ride procedures by the ride supervisor prior to departing in small groups.

The ride itself took a scenic route through national park and rural country side, from the Sydney testing centre to Stanwell Tops south of Sydney, then further south to Robertson and then back to Sydney. The total distance was approximately 274 km, and took an average of 5hr 54min (SD=32min) to complete. Included in this time were three mandatory rest breaks of 20min at Stanwell Tops, 40min just outside Robertson for lunch, and 10min at Engadine on the outskirts of Sydney. Supervisors stationed at each rest stop ensured that riders took the mandated break and completed their diary entries and ratings. A recovery and repair team was stationed on the route in case any riders experienced mechanical difficulties.

Upon return to the Sydney testing centre, riders completed their diaries. Both ride and control participants then completed the End-of-day Questionnaire and the NASA-TLX and lastly, the end-of-day performance tests. The procedure for the second study day was identical to the first except that ride and control participants were reversed.

3.5 Statistical analysis

The main study question was whether subjective fatigue and performance responses would differ on ride days and rest or control days and whether they would differ on the time of measurement (i.e., pre- or post-study day, or across the ride day). Participant responses on the three VAS subjective fatigue scales were averaged to yield a single subjective fatigue measure, which was used in all subsequent analyses. Subjective fatigue across the two study days was compared using two-factor repeated measures MANOVAs: 2 (type of day) x 2 (pre-study day versus post-study day). Analysis of subjective fatigue across the ride day involved a single factor repeated measures MANOVA across all consecutive occasions (i.e., pre-ride, the start and end of each break, and post-ride). This was followed by t-tests comparing subjective fatigue at consecutive occasions throughout the ride day.

Performance across study days was analysed with three-factor repeated measures MANOVAs: 2 (type of day) x 2 (time of day) x 3 or 4 (blocks for MAK and RT, respectively). Each test session was partitioned into blocks of equal time. The blocks factor was included to determine whether performance within each test session deteriorated with time on task, the type of day and the time of day. An analysis was also conducted to assess the potential impact of "endspurt" within testing sessions and "practice effects" across testing sessions on RT and RT variability. Endspurt refers to the effect where subjects become more alert, responsive, and vigilant towards the end of a testing session presumably in anticipation of the task finishing. A practice effect occurs when subjects perform increasingly well as they become more familiar with the task. The extent that these effects influence the RT and MAK task impacts the validity of the results by obscuring the predicted vigilance or fatigue effect. Therefore, the presence of an endspurt or practice effect was evaluated by two-factor repeated measures MANOVAs: 4 (consecutive testing sessions) x 3 or 4 (blocks for MAK and RT, respectively).

Perceived workload across type of days was included to enhance understanding of how the motorcycle riding task affects riders and as a manipulation check. Both the raw NASA-TLX ratings and the weighted scores have been found to reflect objective experimental manipulations (Hart & Staveland, 1988). Because different participants in the current study engaged in different activities on the control day and because these activities may have varied in both the extent and type of demands they made, it was thought prudent to use the weighted NASA-TLX scales which allow the relative importance of different demands, as well as their extent, to be captured. However, it is also important to acknowledge some of the criticisms regarding the use of weighted NASA-TLX scores over the raw scores. Three criticisms raised by Nygren (1991) are relevant for the current study. Firstly, when an overall average weighted workload score is calculated from the six individual weighted subscale scores, the average weighting has a restricted and conservative range of 0.0 to 0.33, even though the original weights could vary between 0 and 5. Similarly, if individual dimensions are adjusted by their averaged weight (between 0 and 0.33) the differences between them will be artificially reduced. Secondly, if individual dimensions are given their averaged weights, raw and weighted scores may be almost perfectly correlated (e.g., r=0.96 to 0.98; Byers, Bittner, & Hill in Nygren, 1991), thus raising the question of the usefulness of the weighting scheme. In the current study, subscales were adjusted using the original weights (0 to 5) and not the averaged weights (0 to 0.33). Consequently, for both the ride and control day in the current study, only 25% of the raw and weighted NASA-TLX subscales were significantly correlated at the 0.05 level, thus indicating that weighting provided information not already captured in the raw ratings. Finally, subscale weights are based upon relative rankings of the six dimensions rather than absolute importance judgments of the dimensions so that they may artificially restrict the true extent of differences between the subscales. In the present study, the benefits of using the weighted dimensional scores to capture qualitative differences in the day's activities was judged to outweigh these criticisms that the weightings are conservative.

Differences in the nature of the perceived workload on the two days were analysed by two-factor repeated measures MANOVA analyses on the weighted NASA-TLX subscale scores; 2 (type of day) x 6 (perceived workload dimension). Follow-up t-tests were also carried out comparing responses on the different workload within and between the ride and control day. The same analysis strategy was used for the physical tiredness scores.

Information relating to events leading up to each study day was compared using repeated measures MANOVA. This was to ensure that performance on the two study days was not affected by events other than the experimental manipulation (i.e., ride or control condition).

4 Results

4.1 Typical experiences of rider fatigue

4.1.1 Frequency and onset

A summary of the frequency of fatigue experiences is presented in Table 4.1.1.1. Approximately 75% of riders had experienced fatigue while riding within Sydney, and 90% had experienced fatigue on longer rides. There was a trend for fatigue experiences to be more frequent while on longer rides ($\chi^2_{(2)}$=5.400, p=0.067). Only 1 in 10 riders reported fatigue on at least half their trips within Sydney whereas 4 in 10 riders reported fatigue on at least half their longer trips. On average, riders reported experiencing the onset of fatigue 3.75 (SD=2.02) hours into a ride.

Table 4.1.1.1: Fatigue during rides within Sydney and longer rides

	Every trip	**Most trips**	**Half of trips**	**Occasionally**	**Very rarely**	**Never**
n=20 (%)						
Within Sydney	0	5.0	5.0	25.0	40.0	25.0
On longer trips	10.0	15.0	15.0	25.0	25.0	10.0

	At least half of trips	**Occasionally**	**Very rarely or never**
Within Sydney	10.0	25.0	65.0
On longer trips	40.0	25.0	35.0

4.1.2 Causes of fatigue

The 18 riders who had experienced fatigue were asked to identify the factors that contributed to their fatigue and to highlight the factors they considered most important (see Table 4.1.2.1). The majority of riders highlighted the role of insufficient breaks, long riding hours, and a monotonous road as contributors to fatigue. These were also chosen by the most riders as "important" contributors. Motorcycle vibration and poor motorcycle design, factors that are relatively unique or particularly relevant to riders, were rated by a notable minority of riders, but not rated as important by many riders.

Table 4.1.2.1: Factors that contributor to rider fatigue

	Contributor	**Important contributor**
n=18 (%)		
Long riding hours	88.9	66.7
Insufficient breaks	94.4	50.0
Uninteresting/monotonous road	77.8	38.9
Poor road conditions	55.5	33.3
Inadequate sleep before trips	50.0	33.3
Not enough night time sleep	50.0	22.2
Poor weather conditions	38.9	16.7
Motorcycle vibration	33.3	11.1
Poor motorcycle design	27.8	11.1
Riding at night	27.8	11.1
Heavy highway traffic	22.3	5.6
Heavy city traffic	22.1	11.1
Use of alcohol	22.3	5.6
Riding during early afternoon	22.2	0.0
Poor diet/irregular eating	22.2	0.0
Riding at dawn	11.2	5.6
Other	11.2	5.6
Riding at dusk	5.6	0.0
After-effects of using drugs	0.0	0.0
Family problems	0.0	0.0

4.1.3 Effects of fatigue

All riders who had experienced fatigue while riding also reported that their riding was worse when they were fatigued. Riders were asked how fatigue affected their riding (see Table 4.1.3.1) and whether they had experienced dangerous events while riding in a fatigued state in the past four months (see Table 4.1.3.2). Reduced reaction speed, poorer steering, poorer braking, and poorer control on curves were the most frequently reported fatigue effects. Late braking was the most commonly reported dangerous event. Twenty two percent of riders had experienced this "sometimes" in the last 4 months and only 27.8% had not experienced it. In addition, only 44.4% of riders had not crossed lane lines, and only half had not over/under steered or had a near miss in the past four months.

Table 4.1.3.1: Impact of fatigue on riding

Impact of fatigue on riding	% of participants
	n=18
Slower to react	72.2
Poorer steering	55.6
Poorer braking	44.4
Poorer control on curves	44.4
Poorer gear changing	38.9
Poorer attention to traffic signs	38.9
Poorer awareness of other road users	33.3
Driving too slowly	22.2
Poorer signaling	16.7
Other	16.7
Speeding	11.1
Poorer overtaking	5.6

Table 4.1.3.2: Frequency of dangerous events in the past four months

Dangerous event (%)		Often	Sometimes	Rarely	Never
	n=18				
Late braking		0.0	22.2	50.0	27.8
Having a near miss		0.0	5.6	50.0	44.4
Over/under steering		0.0	16.7	33.3	50.0
Crossing lane lines		0.0	5.6	44.4	50.0
Nodding off/falling asleep		0.0	5.6	16.7	77.8
Running off the road		0.0	0.0	11.1	88.9
Colliding with something		0.0	0.0	5.6	94.4
Losing control of the bike		0.0	0.0	0.0	100.0

4.2 Comparability of events leading up to study

4.2.1 Work, rest, and riding/driving

Work, rest, and riding/driving activities leading up to the two study days are presented in Table 4.2.1.1. There were no significant differences in the total hours spent sleeping, in the number of sleeps, in total working hours, and total riding or driving hours prior to the ride and control days (p's>0.056). Similarly, there were no significant differences in the length or subjective ratings of the last sleep leading up to the ride or control day (p's>0.229), and no significant difference between the number of participants transporting themselves to the testing center or the length of this trip.

Table 4.2.1.1: Work, rest, and riding/driving in the two days prior to study day

From 00:00 two days prior to study day to the start of study (Mean, SD)	Ride day	Control day
	n=20	*n=20*
Total sleep hours	22.5 (1.7)	21.8 (1.6)
Total number of sleeps	3.3 (0.7)	3.1 (0.2)
Total work hours	8.3 (3.4)	7.9 (4.1)
Total ride/drive hours (not including ride to study venue)	3.8 (2.2)	4.6(2.3)
	n=19	*n=19*
Length of last sleep prior to study (hrs)	7.1 (1.7)	6.8 (1.5)
Quality rating of last sleep[a]	58.7 (27.9)	66.2 (25.6)
Refreshed rating of last sleep[b]	58.1 (29.7)	58.8 (24.5)
	n=20	*n=20*
Transporting self to study (%)	100	90
	n=18	*n=18*
Length of ride/drive to testing centre (hrs)	0.4 (0.3)	0.4 (0.2)

[a] 0 = very poor quality, 100 = very good quality
[b] 0 = not at all refreshed, 100 = very refreshed

4.2.2 Lifestyle and health

Table 4.2.2.1 details the lifestyle and health of riders immediately prior to the start of each study day. There was no significant difference in the time lag and amount of food, caffeine and alcohol consumed at the last occasion prior to the start of the ride day compared to the control day (p's>0.115). There was little or no difference in use of medication and current experiences of the cold/flu on the ride compared to the control day.

Table 4.2.2.1: Lifestyle and health information immediately prior to study day

Immediately prior to start of study			Ride day	Control day
			n=20	*n=20*
Food consumption	Lag (mean hrs, SD)		1.3 (0.8)	2.9 (4.0)
	Size (%)	*Light*	55	60
		Moderate	45	30
		Heavy	0	10
			n=19	*n=19*
Caffeine consumption	Lag (mean hrs, SD)		8.2 (9.0)	7.3 (9.4)
	Mean servings from 00:00 of study day (SD)		0.6 (0.5)	0.6 (0.5)
			n=13	*n=13*
Alcohol	Lag (mean hrs, SD)		17.8 (10.1)	17.3 (20.4)
	Mean standard drinks at last occasion		3.0 (2.2)	2.4 (1.5)
			n=20	*n=20*
Currently taking medication (%)			25	25
Current cold/flu (%)			20	10

4.3 Comparability of perceived workload during study days

The ride day involved a recreational day ride that included three mandatory breaks. The time spent riding and resting on the ride day is presented in Table 4.3.1. On the control day, participants were asked to engage in relaxing activities and to not ride. Activities reported for the control day included watching television, videos, and DVDs, reading, computing, working on motorcycles, and housework.

Table 4.3.1: Time spent riding and resting on the ride day

Time spent (hrs:min, SD)		
		n=20
Riding	*Testing centre to Checkpoint 1*	1:07 (0:09)
	Checkpoint 1 to 2	1:15 (0:11)
	Checkpoint 2 to 3	1:28 (0:22)
	Checkpoint 3 to testing centre	0:46 (0:05)
Break	*1*	0:21 (0:01)
	2	0:41 (0:05)
	3	0:12 (0:03)
		n=15
Extra breaks		0:14 (0:08)

A summary of the perceived workload measures for the activities on the ride and control days is presented in Table 4.3.2. Preliminary examination of the weighted NASA-TLX ratings suggested that mental demand was by far the most important contributor to workload on the ride day, although there was considerable variability in individual responses. The analysis showed that, on average, participants experienced significantly higher workload on the ride day compared to the control day ($F_{(1, 19)}$=25.456, p<0.001). There were also statistically significant differences between participant's responses on the NASA-TLX subscales ($F_{(5, 15)}$=7.158, p=0.001), and a significant interaction between type of day and the NASA-TLX dimensions ($F_{(5, 15)}$=9.196, p<0.001). Post-hoc t-tests confirmed that participants experienced significantly higher workload from mental demand ($t_{(1, 19)}$=3.140, p=0.005), physical demand ($t_{(1, 19)}$=4.668, p p<0.001), and effort ($t_{(1, 19)}$=7.997, p p<0.001) on the ride day than the control day. Comparison of the workload responses on the ride day indicated that: 1) mental demand was rated higher than temporal demand ($t_{(1, 19)}$=8.543, p<0.001), performance ($t_{(1, 19)}$=3.746, p=0.001), and frustration ($t_{(1, 19)}$=4.955, p<0.001), 2) physical demand was rated higher than temporal demand ($t_{(1, 19)}$=4.350, p<0.001), and 3) effort was rater higher than temporal demand ($t_{(1, 19)}$=7.037, p<0.001), performance ($t_{(1, 19)}$=3.605, p=0.002), and frustration ($t_{(1, 19)}$=4.639, p<0.001). In contrast, the only significant difference on the control day was that mental demand was rated higher than physical demand ($t_{(1, 19)}$=3.685, p=0.002).

Table 4.3.2: Perceived workload during study days

Workload measure (Mean, SD)	Ride day	Control day
	n=20	*n=20*
NASA-TLX[a] (weighted scores)		
Mental demand	272.25 (124.59)	155.50 (103.36)
Physical demand	181.50 (114.02)	44.25 (61.95)
Temporal demand	44.50 (63.60)	131.00 (129.44)
Performance	120.75 (103.38)	129.25 (124.08)
Effort	233.25 (95.85)	70.00 (61.58)
Frustration	69.50 (111.66)	62.75 (111.77)
Average	153.63 (37.09)	98.79 (37.56)
End-of-Day Physical Tiredness[b]		
Neck and head	50.40 (20.34)	32.65 (22.81)
Back	57.90 (20.59)	22.30 (19.00)
Arms and hands	55.30 (22.04)	22.25 (18.99)
Legs and feet	35.40 (20.65)	24.25 (20.89)
Eyes	49.20 (22.03)	35.10 (20.17)
Whole body	51.90 (16.18)	30.25 (21.82)

[a] 0 = low, 100 = high
[b] 0 = fresh, 100 = tired

The overall analysis of the End-of-Day Physical Tiredness scores yielded similar results (see Table 4.3.2 above). Participants reported greater physical tiredness on the ride day compared to the control day ($F_{(1, 19)}$=15.662, p=0.001) and there were significant differences between the responses on the six physical tiredness dimensions ($F_{(5, 15)}$=3.291, p=0.033). Post-hoc t-tests showed that participants experienced significantly greater physical back ($t_{(1, 19)}$=5.842, p<0.001), arms/hands ($t_{(1, 19)}$=5.697, p<0.001), and whole body ($t_{(1, 19)}$=3.282, p=0.004) tiredness on the ride day compared to the control day. Responses on the different physical tiredness dimensions were also significantly influenced by type of day ($F_{(5, 15)}$=11.317, p<0.001). Comparison of responses on the physical tiredness dimensions on the ride day showed that participants experienced greater tiredness in their back compared to their legs/feet ($t_{(1, 19)}$=3.857, p=0.001), arms/hands compared to their legs/feet ($t_{(1, 19)}$=4.061, p=0.001), and whole body compared to legs/feet ($t_{(1, 19)}$=3.880, p=0.001). In contrast, on the control day, participants reported significantly greater tiredness in their neck compared to their back ($t_{(1, 19)}$=3.750, p=0.001) and arms/hands ($t_{(1, 19)}$=3.620, p=0.002), their eyes compared to their back ($t_{(1, 19)}$=5.309, p<0.001), arms/hands ($t_{(1, 19)}$=5.223, p<0.001), and legs/feet ($t_{(1, 19)}$=5.126, p<0.001), and their whole body compared to their back ($t_{(1, 19)}$=4.248, p<0.001) and arms/hands ($t_{(1, 19)}$=4.204, p<0.001).

4.4 Changes in subjective fatigue across study days

4.4.1 Comparability of study days

Subjective fatigue rated at the time of the performance tests at the beginning and end of each study day is presented in Table 4.4.1.1. On average, participants reported significantly higher levels of fatigue on the ride day compared to the control day ($F_{(1, 19)}$=4.611, p=0.045). Similarly, on average, participants gave higher fatigue ratings at the end of the day compared to the beginning of the study day ($F_{(1, 19)}$=15.946, p=0.001). Importantly, there was no significant interaction between type of day and time of day. That is, despite appearances, subjective fatigue was not significantly higher after the ride day than after the control day.

Table 4.4.1.1: Subjective fatigue across study days

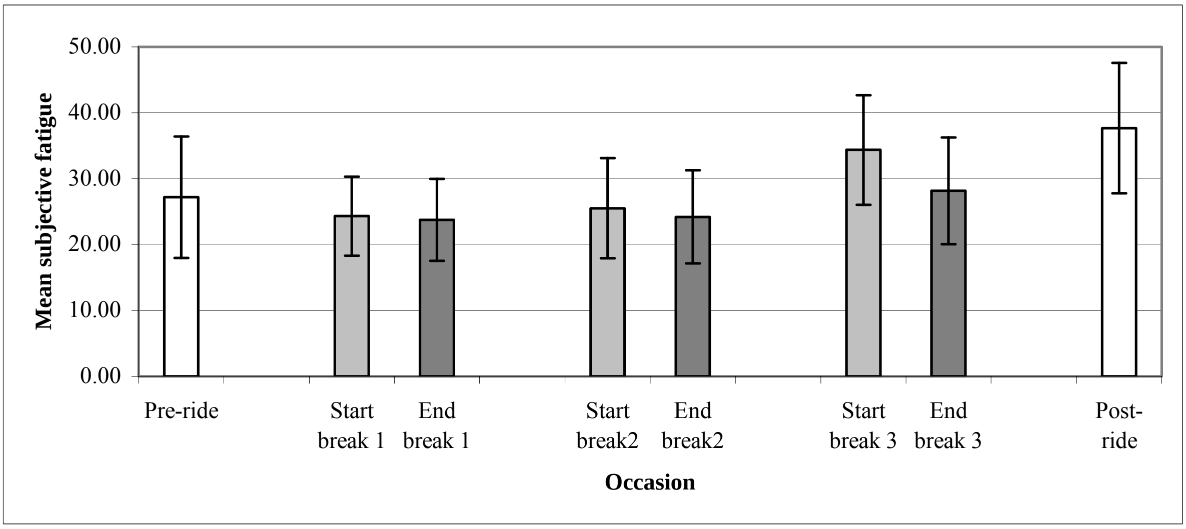
Occasion	Ride day	Control day
	n=20	*n=20*
Pre (M, SD)	29.33 (4.95)	23.83 (4.50)
Post (M, SD)	46.58 (3.92)	30.83 (5.34)

Correlations between subjective fatigue measures and the NASA-TLX and physical workload measures made at the end of each study day revealed that each of the end-of-day physical tiredness ratings were significantly and positively correlated with subjective fatigue on the control (r≥0.741) and ride day (r≥0.445). In contrast none of the weighted NASA-TLX subscales correlated significantly with subjective fatigue on either study day (p's>0.143). There was a trend, however, for the average weighted NASA-TLX to be positively correlated with subjective fatigue on the ride day (r=0.436, p=0.054). There was also little evidence that physical tiredness was correlated with weighted NASA-TLX responses during the control day, with only the NASA-TLX frustration subscale significantly and positively correlated to whole body physical tiredness (r=0.486, p=0.030) and back tiredness (r=0.554, p=0.011). There was a slightly higher number of significant associations on ride day ratings, with neck/head tiredness positively correlated with NASA-TLX mental demand (r=0.503, p=0.024), and back tiredness positively correlated with weighted NASA-TLX mental demand (r=0.496, p=0.026), temporal demand (r=0.462, p=0.041), and overall average rating (r=0.533, p=0.015).

4.4.2 Changes across ride

Subjective fatigue across the ride day is presented in Figure 4.4.2.1. Subjective fatigue at the start of the day was taken from the ratings made when doing the performance tasks at the start of the day. All subsequent ratings were obtained from the ride diary. Preliminary inspection of the data suggests that subjective fatigue was stable for the first 3.4hr into the ride day (i.e., up to the end of break 2). From there, subjective fatigue appeared to increase while riding to the checkpoints and to decrease across the third break. Repeated measures MANOVA analysis confirmed that subjective fatigue did differ significantly across the ride day ($F_{(1, 19)}=2.839$, $p=0.05$). Follow-up t-tests comparing consecutive occasions showed that there was a significant decrease in subjective fatigue across break 3 ($t_{(1, 18)}=3.226$, $p=0.005$), and a significant increase in subjective fatigue from the end of break 3 to the end of the ride ($t_{(1, 18)}=3.741$, $p=0.001$).

Figure 4.4.2.1: Subjective fatigue across ride day



Bars represent 95% confidence intervals

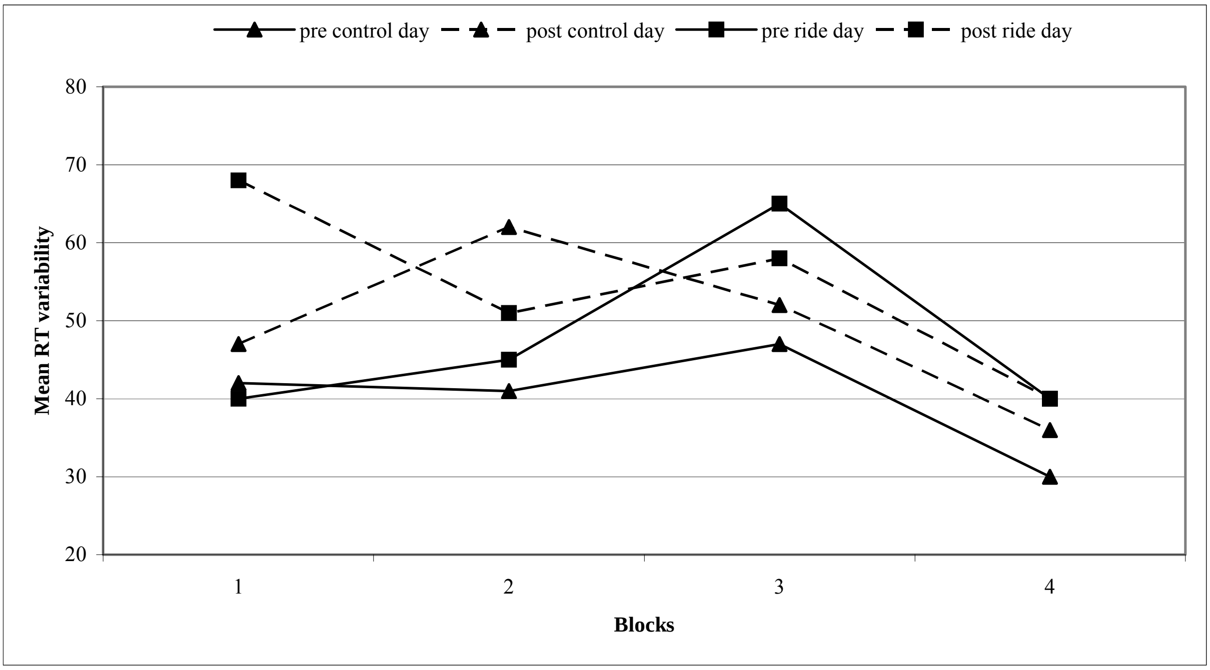
4.5 Changes in performance across study days

A summary of the reaction time (RT), variability of RT scores, and number of misses for the RT task are presented in Table 4.5.1. Repeated measures MANOVA analyses indicated no significant effects of type of day, time of day, or blocks of time within each test session on RT or the number of misses, and there were no interactions between these factors. There were, however, significant effects on the variability in RT (see Figure 4.5.1). Specifically, variability was greater on the ride day compared to the control day ($F_{(1, 19)}=4.938$, $p=0.039$), tended to be greater at the end of the day compared to the beginning ($F_{(1, 19)}=3.442$, $p=0.079$), and decreased at the last block within testing sessions ($F_{(1, 19)}=21.551$, $p<0.001$). There was also a trend for RT variability across blocks to differ as a function of time of day ($F_{(3, 17)}=2.833$, $p=0.069$), but this was also captured in the significant three-way interaction between type of day, time of day and blocks ($F_{(3, 17)}=5.302$, $p=0.009$). This interaction showed that RT variability at the beginning of both days appeared to be greatest in the third block. However, at the end of the days RT variability peaked earlier, especially for the ride day.

Table 4.5.1: Simple Reaction Time task performance across study

RT (M, SD)	Time of day	Blocks within sessions	Ride day	Control day
			n=20	*n=20*
RT (msec)	*Pre*	*Block 1*	445.4 (6.78)	450.20 (5.41)
		Block 2	440.50 (6.66)	443.50 (6.39)
		Block 3	446.60 (7.80)	441.45 (6.00)
		Block 4	446.50 (6.26)	455.75 (5.83)
		Average	444.75 (5.56)	447.73 (4.62)
	Post	*Block 1*	450.55 (9.93)	449.15 (7.83)
		Block 2	444.80 (9.70)	445.90 (8.79)
		Block 3	442.50 (8.31)	449.00 (8.80)
		Block 4	438.35 (6.27)	465.50 (12.17)
		Average	444.05 (6.99)	452.39 (8.66)
RT variability (msec)	*Pre*	*Block 1*	39.50 (2.60)	42.45 (2.79)
		Block 2	45.00 (3.96)	41.10 (3.47)
		Block 3	65.35 (6.74)	47.40 (4.35)
		Block 4	40.40 (5.36)	30.55 (4.07)
		Average	47.56 (2.43)	40.38 (2.37)
	Post	*Block 1*	67.55 (8.20)	47.65 (5.81)
		Block 2	51.05 (5.40)	62.80 (9.96)
		Block 3	57.70 (8.41)	51.85 (7.08)
		Block 4	39.80 (4.95)	35.85 (5.91)
		Average	54.03 (4.41)	49.54 (4.61)
Misses	*Pre*	*Block 1*	0.10 (0.10)	0.05 (0.05)
		Block 2	0.00 (0.00)	0.00 (0.00)
		Block 3	0.15 (0.11)	0.00 (0.00)
		Block 4	0.05 (0.05)	0.00 (0.00)
		Average	0.08 (0.04)	0.01 (0.01)
	Post	*Block 1*	0.05 (0.05)	0.20 (0.12)
		Block 2	0.05 (0.05)	0.05 (0.05)
		Block 3	0.00 (0.00)	0.10 (0.07)
		Block 4	0.05 (0.05)	0.00 (0.00)
		Average	0.04 (0.02)	0.09 (0.04)

Figure 4.5.1: Type of day, time of day, and blocks for RT variability on the RT task



A summary of the reaction time (RT), variability of RT, and number of misses for the MAK task are presented in Table 4.5.2. Repeated measures MANOVA analyses indicated that there were no overall differences on any measure between the ride and control day, or between the beginning and the end of the day. There were, however, significant linear increases in RT and the number of misses across blocks ($F_{(2, 18)}$=8.374, p=0.003 and $F_{(2, 18)}$=4.580, p=0.025, respectively). Reaction speed slowed and the number of missed signals increased as the test progressed for both ride and control days (see Figures 4.5.2 and 4.5.3). There were no significant interactions between type of day, time of day, or blocks for any of these measures.

Table 4.5.2: Mackworth Clock Vigilance task performance across study

MAK (M, SD)	Time of day	Blocks within sessions	Ride day	Control day
			n=20	*n=20*
RT (msec)	*Pre*	*Block 1*	759.15 (11.97)	753.25 (12.72)
		Block 2	801.25 (16.23)	860.65 (74.68)
		Block 3	823.60 (16.86)	788.35 (12.60)
		Average	794.67 (10.93)	800.75 (26.09)
	Post	*Block 1*	775.55 (10.79)	781.00 (15.41)
		Block 2	835.55 (22.61)	822.00 (20.21)
		Block 3	856.75 (41.93)	819.70 (20.66)
		Average	822.62 (18.04)	807.57 (16.75)
RT variability (msec)	*Pre*	*Block 1*	50.65 (6.93)	50.00 (6.14)
		Block 2	82.85 (14.86)	189.70 (140.95)
		Block 3	88.85 (12.27)	54.15 (8.18)
		Average	74.12 (7.62)	97.95 (46.09)
	Post	*Block 1*	66.00 (9.71)	68.05 (10.73)
		Block 2	116.10 (37.79)	80.75 (11.14)
		Block 3	129.55 (61.49)	87.35 (20.75)
		Average	103.88 (24.78)	78.72 (9.43)
Misses	*Pre*	*Block 1*	0.15 (0.11)	0.10 (0.10)
		Block 2	0.15 (0.08)	0.30 (0.22)
		Block 3	0.60 (0.21)	0.40 (0.21)
		Average	0.30 (0.11)	0.27 (0.16)
	Post	*Block 1*	0.15 (0.08)	0.15 (0.08)
		Block 2	0.20 (0.09)	0.25 (0.12)
		Block 3	0.45 (0.15)	0.30 (0.15)
		Average	0.27 (0.08)	0.23 (0.07)

Figure 4.5.2: Type of day, time of day, and blocks for reaction speed for the Mackworth Vigilance task

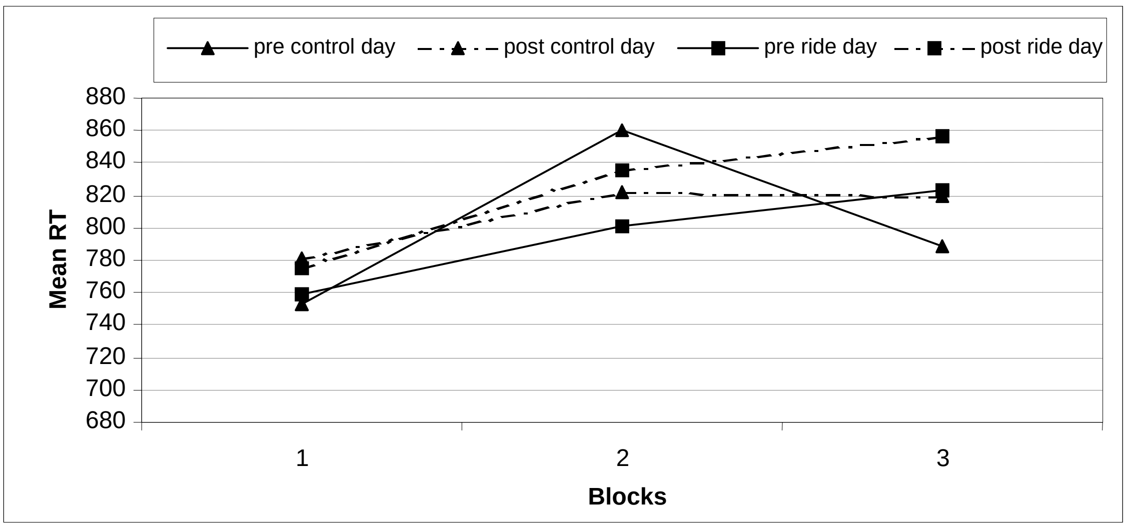
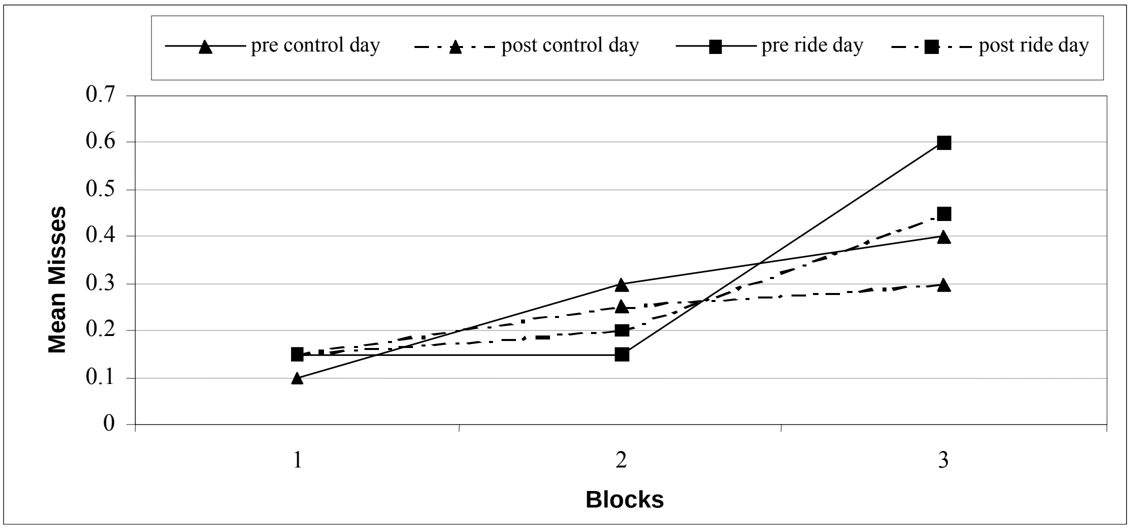


Figure 4.5.3: Type of day, time of day, and blocks for the number of missed signals for the Mackworth Vigilance task



4.5.1 Examination of confounding effects

To examine whether effects of fatigue on performance may have been obscured by performance improvements due to practice or by improvements motivated by the anticipation of the end of testing (the "endspurt" effect), the RT and MAK scores for reaction time and reaction time variability were reanalyzed for effects of test session order. There was no evidence of any effects due to the order of testing in terms of either practice effects or endspurt effects for either the Reaction time test or Mackworth Vigilance task.

5 Discussion

The results of this evaluation showed that motorcycle riders' ratings of fatigue increased significantly over a day involving a recreational ride, but this increase was not statistically significantly greater than that reported by the same people after they had spent a day resting at home. Riders however reported more physical tiredness at the end of the ride day than on the control day, especially for body regions that might be expected to be affected in motorcycle riders; the back, arms and hands. Despite this, the results also showed little difference in performance across a ride day compared to a rest or control day. There was no evidence of effects of the ride on speed or accuracy of performance on Simple Reaction time or Mackworth Vigilance tests. There was some evidence, however that on the ride day reaction speed was more variable than on the control day. Furthermore, changes in reaction speed variability differed between the test session at the beginning of each of the days and the end of the day. As might be expected for a monotonous task such as the Simple Reaction time test, in the test sessions at the beginnng of each of the days, reaction speed became more variable towards the middle of the test session as arousal levels dipped and attention began to wander, but reaction speed became more stable again as attention and arousal rose with the end of the task. In contrast, during the test sessions at the end of the day, reaction speed was most variable from the early part of the test, but this decreased towards the end of the test. This pattern was particularly marked on the ride day when reaction speed variability was high from the beginning of the second test session. This suggests that riders had greater difficulty in maintaining focus at the beginning of this task, possibly due to fatigue, but were able to increase attention so that reaction speed became more stable towards the end of the test session.

The patterns of subjective fatigue over the ride day showed that riders experienced more fatigue later in the ride since they reported a statistically significant increase in fatigue between the end of the last break and the end of the ride. In addition, at the end of the ride, there was evidence that fatigue levels were beginning to build up more rapidly than earlier in the ride since the last ride section of the day was the shortest, yet produced most fatigue. This interpretation is supported by the fact that the last break in the day ride was the shortest break, but produced the greatest benefit by being the only break that produced a statistically significant reduction in fatigue levels. This also suggests that fatigue levels were starting to build up by the end of the second ride sector and that a break was needed. The first two breaks made little difference to fatigue ratings, which is not surprising given that fatigue levels were not very high before the breaks were taken.

There are a number of potential explanations for the pattern of subjective fatigue changes in this study. Firstly, it is possible that the ride length was not long enough to produce a strong fatigue effect. Participants reported typically experiencing the onset of fatigue after approximately 3.75 hours of riding, which was consistent with the changes in subjective fatigue observed across the ride day; a significant increase in subjective fatigue was detected towards the end of the ride, after approximately 4.6 hours of riding separated by breaks.

Secondly, it is possible that the three mandatory breaks in the current study enabled riders to stave off the onset of fatigue during the ride day. The analyses of subjective fatigue ratings throughout the ride day clearly show that riders did not experience significant increases in subjective fatigue until the final leg of the route. Break taking as a counter measure to fatigue was also explicitly demonstrated during the last mandatory break. Thirdly, given that ratings of temporal demand did not differ between the ride and control day, it is feasible that the low time pressure of the recreational motorcycle ride was an important moderator of fatigue onset.

Finally, it is also possible that the length of the mandatory breaks in the current study may have influenced the onset of fatigue. For example, the significant increase in subjective fatigue in the last leg of the ride could have been associated with the fact that the last mandatory break was the shortest of the three breaks. A longer break may have adequately offset any significant changes in subjective fatigue.

In the current study, there was no evidence that a five hour recreational ride significantly affected performance. Whether a driving experience of the same duration, with the same mandatory breaks, would yield the same results is yet to be determined. Motorcycle riders reported similar influences on fatigue experiences to drivers. For riders, the time spent riding, the number of breaks taken, and road monotony were particularly important contributors of fatigue; these factors are also significant contributors to fatigue-related performance decrements in motorists (Brown, 1994; Horne & Reyner, 1995). Riders also reported that fatigue affected their reaction time, steering accuracy, and lane tracking ability. This is consistent with research findings on driver fatigue (Stein, 1995; Williamson, Feyer, Friswell, et al., 2001). Poor braking was also highlighted as an important consequence of fatigue, with late braking emerging as the most common dangerous event when riding in a fatigued state. Notably, factors more specific to riders (e.g., motorcycle vibration) also contributed to the fatigue experience in a sizeable minority of participants. The extent to which these extra factors affect the onset or effects of fatigue on riders is currently unknown. Further research is also needed to establish whether the effects of fatigue on driving/riding performance occur to the same extent or at the same rate in drivers and riders. The extent to which fatigue-related performance decrements contribute to accidents and near misses also warrants additional empirical investigation.

Examination of the effect of potential confounders on the results of this evaluation indicates that the results are not due to factors such as the lack of sensitivity of the performance tests. First there were small, but noticeable changes in performance, specifically the variability of reaction speed in the reaction time test, which could be attributed to the effects of the ride. Second, a vigilance decrement reflecting task fatigue was seen for the Mackworth Vigilance task within each test session as would be expected in this type of task. Overall, the fact that fatigue-related changes can be detected by these performance tests reinforces the conclusion that riders were able to cope with the demands of the four to five hour day ride evaluated in this study.

5.1 Conclusions and recommendations

Motorcyclists, like other road users, become more fatigued the longer they spend riding. However, the current study showed that although a recreational day ride substantially increases subjective fatigue towards the end of the ride, performance was not affected. Furthermore, the rate that fatigue was experienced during the ride was not high. A number of explanations have been proposed for these results, focusing on trip length, the benefits of the three mandatory breaks, and the temporal demand of the ride. Further research needs to be carried out to enhance our understanding of fatigue development in riders. For example, the impact of a longer trip (e.g., 7+ hrs) with equal morning and afternoon breaks (e.g., three breaks of 10, 30, and 10 mins) on fatigue would clarify the findings of the current study. On the basis of the current study, it can be concluded that a day ride of almost six hours with three spaced breaks should not impair reaction time and attention in riders provided they have had approximately seven hours of night sleep prior to the ride.

Preliminary information regarding the typical fatigue experience of motorcyclists was collected in this study, specifically highlighting the factors that contribute to rider fatigue, how fatigue affects riding, and the frequency of specific dangerous events as a result of fatigue. Furthermore, a better understanding of how motorcycling impacts physical fatigue and perceived workload was achieved. However, it is important to note that a large proportion of this information was derived from self-report. It is essential to complement this source with objective empirical data for a more comprehensive understanding of rider fatigue.

Finally, although the current study suggests that there are many similarities in the fatigue experiences of drivers and riders, further research needs to be carried out directly comparing these two types of road users.

6 References

Åstrand, P. O., & Rodahl, K. (1986). *Textbook of work physiology: Physiological bases of exercise*. New York: McGraw Hill.

Brown, I. D. (1994). Driver fatigue. *Human Factors, 36:2*, 298-314.

Charlton, S. G., & Baas, P. H. (2001). Fatigue, work-rest cycles, and psychomotor performance of New Zealand truck drivers. *New Zealand Journal of Psychology, 30:1,* 32-39.

Dinges, D. F. & Kribbs, N. B. (1991). Performing while sleepy: Effects of experimentally-induced sleepiness. In T. H. Monk (Ed.), *Sleep, sleepiness and performance*. Chichester: John Wiley & Sons. (pp. 97-128).

Ferrara, M. & Gennaro, L. D. (2001). How much sleep do we need?. *Sleep Medicine Reviews, 5:2*, 155-179.

Fery, Y. A., Ferry, A., vom Hofe, A., & Rieu, M. (1997). Effect of physical exhaustion on cognitive functioning. *Perceptual & Motor Skills, 84:1*, 291-298.

Gentry, M. V., Hammersley, J. J., Hale, C. R., Nuwer, P. K., & Meliska, C. J. (2000). Nicotine patches improve mood and response speed in a lexical decision task. *Addictive Behaviors, 25:4*, 549-557.

Grandjean, E. (1979). Fatigue in industry. *British Journal of Industrial Medicine*, *36:3*, 175-86.

Hancock, P. A. & Verwey, W. B. (1997). Fatigue, workload and adaptive driver systems. *Accident Analysis & Prevention, 29:4*, 495-506.

Harrison, Y. & Horne, J. A. (2000). The impact of sleep deprivation on decision making: a review. *Journal of Experimental Psychology: Applied, 6:3*, 236-249.

Hart, S.G., & Staveland, L.E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P.A. Hancock & N. Meshkati (Eds.), *Human mental workload*. BV North Holland: Elsevier Science Publishers. (pp.139-183).

Hill, S.G., Iavecchia, H.P., Byers, J.C., Bittner, A.C., Zaklad, A.L., & Christ, R.E. (1992). Comparison of four subjective workload rating scales. *Human factors*, *34:4*, 429-439.

Horne, J. A. & Reyner, L. A. (1995). Sleep-related vehicle accidents. *British Medical Journal, 310*, 565-567.

Horne, J. A. & Reyner, L. A. (1996). Counteracting driver sleepiness: Effects of napping, caffeine, and placebo. *Psychophysiology, 33*, 306-309.

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

Johns, M. & Hocking, B. (1997). Excessive daytime sleepiness: Daytime sleepiness and sleep habits of Australian workers. *Sleep, 20:10*, 844-849.

Kopardekar, P. & Mital, A. (1994). The effect of different work-rest schedules on fatigue and performance of a simulated directory assistance operator's task. *Ergonomics, 37:10*, 1697-707.

Liguori, A., Robinson, J. H. (2001). Caffeine antagonism of alcohol-induced driving impairment. *Drug & Alcohol Dependence, 63:2*, 123-129.

Lisper, H-O & Eriksson, B. (1980). Effects of the length of a rest break and food intake on subsidiary reaction-time performance in an 8-hour driving task. *Journal of Applied Psychology, 65:1*, 117-122.

Lisper, H-O., Laurel, H., & van Loon, J. (1986). Relation between time to falling asleep behind the wheel on a closed track and changes in subsidiary reaction time during prolonged driving on a motorway. *Ergonomics, 29:3*, 445-453.

Matthews, G. & Desmond, P. A. (2002). Task-induced fatigue states and simulated driving performance. *Quarterly Journal of Experimental Psychology A. 55A:2*, 659-686.

Maycock, G. (1997). Sleepiness and driving: The experience of U.K. car drivers. *Accident Analysis and Prevention, 29:4*, 453-462.

Milosevic, S. (1997). Drivers' fatigue studies. *Ergonomics, 40:3*, 381-389.

Neri, D. F., Oying, R. L., Colletti, L. M., Mallis, M. M., Tam, P. Y., & Dinges, D. F. (2002). Controlled breaks as a fatigue countermeasure on the flight deck. *Aviation, Space, and Environmental Medicine, 73:7*, 654-664.

Nilsson, T., Nelson, T. M., & Carlson, D. (1997). Development of fatigue symptoms during simulated driving. *Accident Analysis and Prevention, 29:4*, 479-488.

Nygren, T. E. (1991). Psychometric properties of subjective workload measurement techniques: Implications for their use in the assessment of perceived mental workload. *Human Factors, 33:1*, 17-33.

O'Neil, T. R., Kruegar, G. P., Van Hemel, S. B., & McGowan, A. L. (1999). *Effects of operating practices on commercial driver alertness*. Office of Motor Carrier and Highway Safety, FHWA-MC-99-140.

Reyner, L. A. & Horne, J. A. (1997). Suppression of sleepiness in drivers: Combination of caffeine with a short nap. *Psychophysiology, 34*, 721-725.

Stein, A. C. (1995). Detecting fatigued drivers with vehicle simulators. In L. R. Hartley (Ed.), *Fatigue and driving: Driver impairment, driver fatigue and driving simulation*. London: Taylor & Francis. (pp. 133-148).

Thiffault, P. & Bergeron, J. (2003). Monotony of road environment and driver fatigue: A simulator study. *Accident Analysis and Prevention, 35*, 381-391.

Wilkinson, R. T. (1992). The measurement of sleepiness. In R. J. Broughton and R. D. Ogilvie (Eds*.), Sleep, arousal, and performance: a tribute to Bob Wilkinson*. Boston: Birkhäuser. (pp. 254-265).

Williamson, A. M., Feyer, A.-M., Coumarelos, C., & Jenkins, T. (1992). *Strategies to combat fatigue in the long distance road transport industry. Stage 1: The industry perspective*. CR 108. Canberra: Federal Office of Road Safety.

Williamson, A., Feyer, A-M., & Friswell, R. (1996). The impact of work practices on fatigue in long distance truck drivers. *Accident Analysis and Prevention, 28:6*, 709-719.

Williamson, A., Feyer, A.-M., Friswell, R., & Finlay-Brown, S. (2000). *Development of measures of fatigue: Using an alcohol comparison to validate the effects of fatigue on performance*. CR 189. Canberra: Australian Transport Safety Bureau.

Williamson, A., Feyer, A.-M., Friswell, R., & Sadural, S. (2001). *Driver fatigue: A survey of long distance heavy vehicle drivers in Australia*. CR 198. Canberra: Australian Transport Safety Bureau.

Williamson, A., Feyer, A.-M., Mattick, R. P., Friswell, R., & Finlay-Brown, S. (2001). Developing measures of fatigue using an alcohol comparison to validate the effects of fatigue on performance. *Accident Analysis and Prevention, 33*, 313-326.

Wolf, L. F., Smith, J. K., & Birnbaum, M. E. (1995). Consequence of performance, test motivation, and mentally taxing items. *Applied Measurement in Education, 8:4,* 341-351.

7 Appendices

7.1 Background Information Questionnaire for week 1
7.2 Excerpts from the Ride Diary
7.3 End-of-day Questionnaire

7.1 Background Information Questionnaire for week 1

Code Number:

PARTICIPANT

BACKGROUND INFORMATION

QUESTIONNAIRE

Week 1

FATIGUE IN MOTORCYCLE DAY RIDES

2003

INSTRUCTIONS

As part of our research on fatigue in motorcycle riders, we need to find out about the people participating in the study. In particular we need to collect some general information about your lifestyle, sleep and riding history and about your experiences of fatigue.

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

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

Please fill in ***SECTIONS 1 to 5 before*** going to the study test session.

SECTION 5 asks you to record your work, sleep and driving times for the two days before the first study session (Friday, Saturday, and Sunday morning). Please fill this in during each of these days.

The final ***SECTION 6*** should be completed ***when you arrive at the study*** session.

Please bring this questionnaire with you to the study session.

THANK YOU FOR YOUR HELP

If you have any questions about this questionnaire please phone Dr Ann Williamson (9385 4599), Rena Friswell (9385 5353) or Therese Ma (9385 5361) at the NSW Injury Risk Management Research Centre.

SECTION 1: GENERAL BACKGROUND

1. What is your: Age: __________ years

Sex: *(Please circle)* M F

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

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

3. How long have you been riding a motorcyle? __________ years

4. How often do you ride a motorcycle:

	Within Sydney? *(Please tick one)*	**On longer trips?** *(Please tick one)*
Every day	( )	( )
2-3 times a week	( )	( )
Once a week	( )	( )
1-2 times a month	( )	( )
Rarely	( )	( )
Never	( )	( )

SECTION 2: EXPERIENCES OF FATIGUE

The following questions are about fatigue you may experience when riding.

By FATIGUE we don't ONLY mean feeling DROWSY or SLEEPY.

We ALSO mean being TIRED, LETHARGIC, BORED, UNABLE TO CONCENTRATE, UNABLE TO SUSTAIN ATTENTION and being MENTALLY SLOWED.

5. How often do you become fatigued while riding?

	Within Sydney? *(Please tick one)*	**On longer trips?** *(Please tick one)*
On every trip	( )	( )
On most trips	( )	( )
On about half your trips	( )	( )
Occasionally	( )	( )
Very rarely	( )	( )
Never	( )	( )

If you have never experienced fatigue on a ride, please go to SECTION 3, otherwise continue to Question 6 below.

6. How long into a ride do you usually BEGIN to feel fatigue?

_________ hours

7. In general is your riding WORSE when you are fatigued?

Yes ( ) No ( )

If YES, HOW is your driving worse?

	You may tick <u>more than one option</u>
Slower to react	( )
Poorer steering (eg, crossing lane lines, under/over steering)	( )
Poorer braking	( )
Poorer gear changing	( )
Poorer overtaking	( )
Poorer control on curves	( )
Speeding	( )
Driving too slowly	( )
Poorer signalling	( )
Poorer attention to traffic signs	( )
Poorer awareness of other road users	( )
Other (please describe):	( )

____

____

8. Which of the following a) contribute to your fatigue while riding, and b) are the most important contributors?

a) Contributors **b) Most**

	to your fatigue while riding	**important contributors**
	You may tick more <u>than one option in each column</u>	
Long riding hours	( )	( )
Poor road conditions	( )	( )
Insufficient rest breaks	( )	( )
Uninteresting/monotonous route	( )	( )
Heavy highway traffic	( )	( )
Heavy city traffic	( )	( )
Poor weather conditions (eg, rain)	( )	( )
Poor motorcycle design	( )	( )
Motorcycle vibration	( )	( )
Inadequate sleep before trips	( )	( )
Not enough night time sleep	( )	( )
Family problems	( )	( )
Riding at night	( )	( )
Riding at dawn	( )	( )
Riding during early afternoon	( )	( )
Riding at dusk	( )	( )
Poor diet/ irregular eating	( )	( )
After-effects of using drugs	( )	( )
Use of alcohol	( )	( )
Other (please describe):	( )	( )

____

____

9. All riders may encounter potentially dangerous events due to fatigue. How often have you experienced the following things due to fatigue THIS YEAR (ie from January on)?

	Often	**Some times**	**Rarely**	**Never**
Nodding off/falling asleep	( )	( )	( )	( )
Having a near miss	( )	( )	( )	( )
Running off the road	( )	( )	( )	( )
Crossing lane lines	( )	( )	( )	( )
Over/under steering	( )	( )	( )	( )
Late braking	( )	( )	( )	( )
Colliding with something	( )	( )	( )	( )
Losing control of bike	( )	( )	( )	( )
Other (please describe):	( )	( )	( )	( )

____

____

SECTION 3: LIFESTYLE INFORMATION

10. Do you smoke cigarettes?

Please tick one

Yes ( ) How many do you smoke on average per day?

__________ cigarettes

Given up ( ) How long ago did you give up?

______________ years/months

No ( )

11. Do you drink caffeinated drinks? (e.g., tea, coffee, coke, red bull)

Yes ( ) No ( )

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

____

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

____

12. How often do you usually drink alcohol?

	Please tick one
Every day	( )
2-3 times a week	( )
Once a week	( )
1-2 times a month	( )
Rarely	( )
Never	( )

If you do drink alcohol, how many ***standard*** drinks do you usually have on one occasion?

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

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

SECTION 4: SLEEP PROBLEMS AND SLEEPINESS

13. When you are sleeping, how frequently:

	Always	**Often**	**Some times**	**Rarely**	**Never**
has someone told you that you snore loudly? *(please tick one)*	( )	( )	( )	( )	( )
do you stop breathing? *(please tick one)*	( )	( )	( )	( )	( )
do you move around a lot? *(please tick one)*	( )	( )	( )	( )	( )

14. Do you have difficulty getting to sleep ?

Yes ( ) No ( )

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

Yes ( ) No ( )

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

Please tick one

Always	( )
Often	( )
Sometimes	( )
Rarely	( )
Never	( )

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

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

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

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

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

SECTION 5: WORK, SLEEP AND RIDING/DRIVING IN THE 2 DAYS BEFORE THE STUDY

This section asks you to keep a ***diary record of your work, sleep and riding/driving*** in the two days leading up to the first study session.

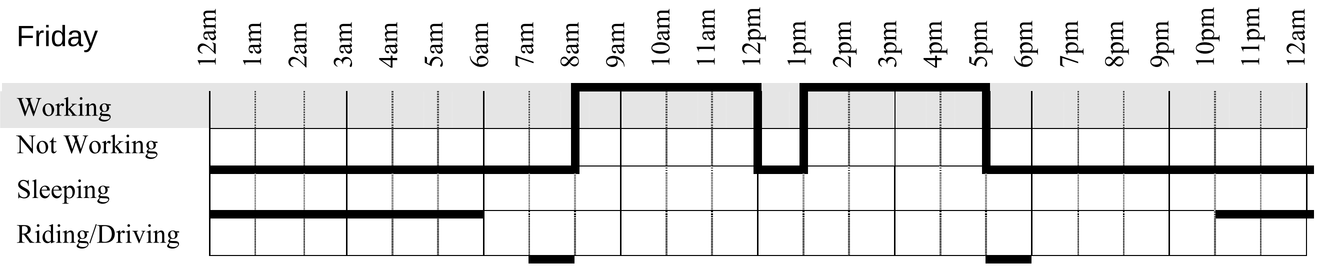
We would also like you to ***rate the quality of each sleep*** that you take during this period and to rate how refreshed you feel upon waking.

To record your work, riding/driving and sleep times, we have provided three timelines on the next page – one each for Friday, Saturday, and Sunday (the study day).

Fill these in using lines to indicate when you were working or not working and also when you were sleeping or riding/driving. Please draw the lines ***to the nearest half hour***.

It is important to fill the timelines in each day rather than doing them later from memory.

The following example for Friday *shows a person who was working from 8am to 5pm with a 1 hour lunch break from 12noon to 1pm. This person spent an hour riding to and from work (from 7am to 8am and from 5pm to 6pm). He/she slept until 6am in the morning and went to sleep at 10pm at the end of the day.*



18. Please fill in the following timelines for the days leading up to the first study session.

Friday	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm	12am
Working																									
Not Working																									
Sleeping																									
Riding/Driving																									

Saturday	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm	12am
Working																									
Not Working																									
Sleeping																									
Riding/Driving																									

Please fill in Sunday up to the time you leave home to go to the study session

Sunday	12am	1am	2am	3am	4am	5am	6am	7am	8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm	12am
Working																									
Not Working																									
Sleeping																									
Riding/Driving																									

For each sleep that you record in the timelines, please rate on the following pages, the quality of the sleep and how you felt when you awoke. ***It is important to make these ratings soon after you wake,*** rather than doing them later from memory.

To make your rating, simply put a cross on each line. ***For example,*** on a scale of happy-sad, if you were feeling bit sad your rating might look like this:

Sleep 1: Day: ________________ Time: ____________

How would you rate the quality of this sleep?

Very poor quality — *Very good quality*

|——————————————————|

How did you feel when you awoke from this sleep?

Not at all refreshed — *Very refreshed*

|——————————————————|

Sleep 2: Day: ________________ Time: ____________

How would you rate the quality of this sleep?

Very poor quality — *Very good quality*

|——————————————————|

How did you feel when you awoke from this sleep?

Not at all refreshed — *Very refreshed*

|——————————————————|

Sleep 3: Day: ________________ Time: ____________

How would you rate the quality of this sleep?

Very poor quality — *Very good quality*

|——————————————————|

How did you feel when you awoke from this sleep?

Not at all refreshed — *Very refreshed*

|——————————————————|

Sleep 4: Day: ________________ Time: ____________

How would you rate the quality of this sleep?

Very poor quality *Very good quality*

How did you feel when you awoke from this sleep?

Not at all refreshed *Very refreshed*

Sleep 5: **Day:** ________________ **Time:** ____________

How would you rate the quality of this sleep?

Very poor quality *Very good quality*

How did you feel when you awoke from this sleep?

Not at all refreshed *Very refreshed*

SECTION 6: ACTIVITIES JUST BEFORE THE STUDY

The questions in this section should be completed when you arrive at the first study session.

19. Study session 1 commenced:

Time: ___________ am/pm Date: ___________

20. When did you last eat a meal?

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

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

Moderate ( )

Large ( )

Have you snacked since then?

Yes ( ) No ( )

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

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

How many caffeinated drinks have you had today? ___________ drinks

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

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

How many alcoholic drinks did you have on that occasion?

__________ drinks

23. Are you currently taking any medication?

Yes ( ) No ( )

If YES, what? ____

24. Do you currently have a cold/flu or are you recovering from one?

Yes ( ) No ( )

25. Did you ride or drive yourself to the study session?

Yes ( ) No ( )

If YES, which suburb did you travel from? _______________________

How long did this trip take you? ______________ minutes

7.2 Excerpts from the Ride Diary (Break 2 and 3 identical to Break 1)

Depart time:

Odometer:

CODE:

WEEK:

STUDY OF FATIGUE IN MOTORCYCLE DAY RIDES 2003

- Remember to get check point signatures
- Fill in ratings at the start and end of each break
- In case of emergency, ring 9385 4837

Check Point 1 – Stanwell Park (20 minute break)

START OF BREAK 1

Time: am/pm	Odometer:	Check point signature:

Please rate how you feel now on the following scales

Fresh ———————————————— *Tired*

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

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

END OF BREAK 1

Please rate how you feel now on the following scales

Fresh ———————————————— *Tired*

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

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

Time pulled out of check point: _______________ am or pm

End of Study – University of New South Wales

Time: am/pm	Odometer:	Check point signature:

Please rate how you feel now on the following scales

Fresh ———————————————— *Tired*

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

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

7.3 End-of-day Questionnaire

Code Number: _______

Week: _______

End-of-day questionnaire

FATIGUE IN MOTORCYCLE DAY RIDES

2003

Riding day only:

1. Did you take any breaks during the ride in addition to the 3 at the checkpoints?

Yes ( ) No ( )

If YES, what time did these additional breaks occur, and why did break?:

Start time 1: _____________ End time 1: _____________

Reason for break: _____________________________________

Start time 2: _____________ End time 2: _____________

Reason for break: _____________________________________

Please go to question 3

Non-riding day only:

2. Please briefly describe your activities today since leaving the testing session this morning:

____

____

____

____

____

Please go to question 3

3. Please rate how ***physically*** tired you feel now on the scales below.
Make separate ratings for the different parts of your body listed below and for your body overall.

NECK AND HEAD

Fresh ———————————————— Tired

BACK

Fresh ———————————————— Tired

ARMS AND HANDS

Fresh ———————————————— Tired

LEGS AND FEET

Fresh ———————————————— Tired

EYES

Fresh ———————————————— Tired

WHOLE BODY

Fresh ———————————————— Tired