Fatigue in Motorcycle Crashes: Is There an Issue?

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ABSTRACT

Fatigue is acknowledged by road safety professionals as a substantial contributor to car and truck crashes. However, little is currently known about the contribution of fatigue to motorcycle crashes or if qualitative differences exist between rider fatigue and driver fatigue. This paper discusses how key factors such as temporal patterns of riding, trip purpose, environmental influences, the physical demands of riding, and the cognitive demands of riding differ from driving and their potential role as contributing factors for rider fatigue. A new conceptual Motorcycling Fatigue Model is presented as an adaptation of the Fatigue Expert Group model for fatigue in heavy vehicle drivers. The new model is an endeavour to integrate all motorcycle specific fatigue factors in addition to the known factors that contribute to fatigue in all road users (e.g. inadequate sleep) to synthesise our current understanding of fatigue in motorcycling and provide a framework for future research.

INTRODUCTION

Road deaths in Australia have decreased by an average 2.1% per year over the last five years, however, there has been a disturbing average annual increase of 4.1% in fatalities for motorcyclists over the same period (ATSB, 2006). Fatalities for motorcycle riders and pillions comprised 14% of the national road toll in Australia in 2005 (ATSB, 2006), though motorcycles comprise only 3% of all registered motor vehicles (ABS, 2005). The clear overrepresentation of motorcyclists in fatal road crashes and the alarming increasing trend warrant further investigation into the factors contributing to motorcycle crashes. Whilst fatigue is acknowledged by road safety professionals as a substantial contributor to car and truck crashes, little is currently known about the extent to which fatigue contributes to motorcycle crashes or if qualitative differences exist between rider fatigue and driver fatigue. Accordingly, this paper examines how fatigue may affect motorcycle riders based on the available literature and an examination of the temporal patterns of riding and crashes. The current knowledge is synthesised into a Motorcycling Fatigue Model based on the Fatigue Expert Group model for heavy vehicle driver fatigue (NTC, 2001) to provide a conceptual framework for further research

While there is no universally accepted definition of driver fatigue, it is commonly defined in terms of a subjective state (e.g. tiredness) and/or objective measurable performance decrement (e.g. increased reaction time). The Fatigue Expert Group (NTC, 2001) defined driver fatigue in terms of the following two dimensions:

> "Impaired performance (loss of attentiveness, slower reaction times, impaired judgement, poorer performance on skilled control tasks and increased probability of falling asleep) and subjective feelings of drowsiness or tiredness.
>
> Long periods awake, inadequate amount or quality of sleep over an extended period, sustained mental or physical effort, disruption of circadian rhythms……inadequate rest breaks and environmental stress (such as heat, noise and vibration)".

The impairment of driver performance by fatigue has been well documented in previous research (see Queensland Travelsafe Committee, 2005 for a review). The level of impairment has been compared to driving with a blood alcohol concentration (BAC) of between .05% and .10% in various studies (Falleti, Maruff, Collie, Darby, & McStephen, 2003; Marruff, Falleti, Collie, Darby, & McStephen, 2005; Williamson, Feyer, Mattick, Friswell, & Finlay-Brown, 2001). Similarly, contributing factors such as sleep deprivation, time on task, time of day, and trip characteristics (e.g. rest breaks and monotonous road environments) have received much attention in relation to driver fatigue research.

The Fatigue Expert Group (NTC, 2001) developed a model to highlight the contributing factors for heavy vehicle driver fatigue (see Figure 1). As professional drivers are subject to a range of work-related factors that may contribute to fatigue states, the model incorporated these in terms of "organisational factors" and "work demands". However, it was particularly emphasised that a range of factors external to the work environment also contribute to driver fatigue as summarised under the headings "biological factors" and "life away from work" factors. This model served as the point of departure for an exploration of the factors that may contribute to motorcycle rider fatigue and the following investigation of the literature.

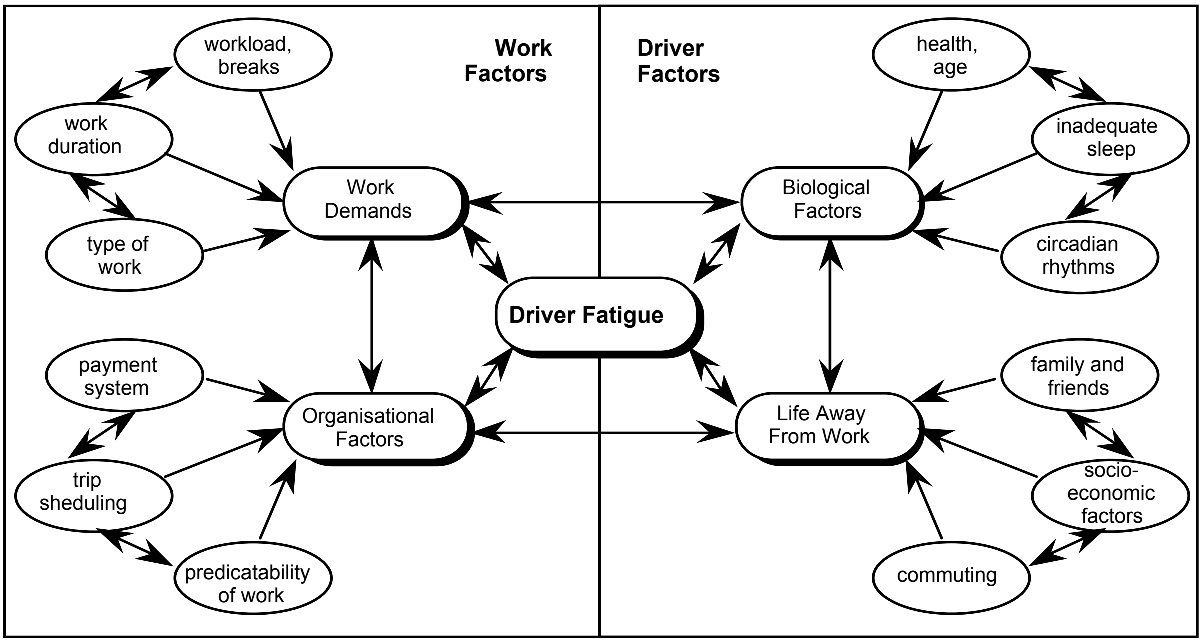

Figure 1. Factors contributing to heavy vehicle driver fatigue. Source National Transport Commission (2001).

HOW MIGHT RIDER FATIGUE DIFFER FROM DRIVER FATIGUE?

In an exploratory study by Ma, Williamson, and Friswell (2003) up to 40% of riders reported experiencing fatigue on at least half of their long journeys. This subjective measure was defined as feeling drowsy, sleepy, tired, lethargic, bored, unable to concentrate, unable to sustain attention, and/or being mentally slowed. These subjective symptoms of fatigue are consistent with measures of driver fatigue, however, potential qualitative differences between rider and driver fatigue may exist in terms of the physical demands that riders endure or the cognitive/perceptual demands associated with riding. To date, little is known about the specific contributing factors for rider fatigue.

Temporal Factors

Given the underlying physiological nature of circadian rhythms and the wide range of performance that they have been shown to affect (e.g. errors in manufacturing, failures of monitoring complex equipment) then it is likely that the performance of motorcyclists will be affected by circadian rhythms in the same way as car drivers. The importance of circadian rhythms for motorcycle crashes will depend on the extent to which motorcycle riding occurs in the circadian low periods of midnight to 6am and 2 to 4pm.

Few studies have collected information about the time of day patterns of motorcycle riding. Haworth, Smith, Brumen and Pronk (1997) counted the numbers of motorcyclists (and other vehicles) passing crash sites as part of the collection of control data for the Melbourne case-control study of motorcycle crashes. Unfortunately, when broken down into 2-hour periods, the exposure data is based on observations at a relatively small number of sites on a variety of road types and so may not be robust. Thus, the results which follow should be considered to be indicative of likely general patterns that would need to be confirmed by collection of more extensive exposure information. The time of day patterns were markedly different on weekdays and weekends, with the highest volumes in traditional peak traffic periods on weekdays. Overall, the average total number of motorcycles observed during the circadian low period of midnight to 6am was 5.2 on weekdays and 5.4 on weekends. During the circadian low period of 2 to 4pm, the average total number of motorcycles observed was 3.9 on weekdays and 3.0 on weekends.

An examination of Victorian motorcycle crash data for 2000-2004 was undertaken to detect temporal patterns for both weekday and weekend crashes. Figure 2 shows that the time of day pattern was different for weekday and weekend crashes. On weekdays there was a general increase from 6am through to 6pm followed by a sharp decline, with some evidence of a morning peak hour effect. The temporal distribution of weekend crashes was bell-shaped, with an increase from 10am through to 4pm, followed by a decline. On both weekdays and weekends there were relatively few crashes in the circadian low period of midnight to 6am but large numbers of crashes in the afternoon circadian low period of 2-4pm.

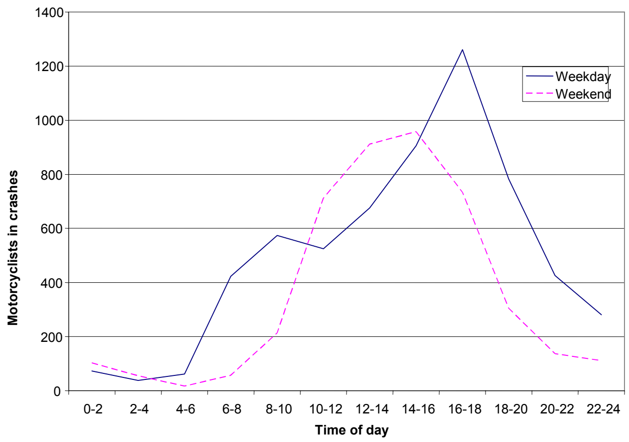

Figure 2. Number of motorcyclists in crashes in Victoria as a function of time of day on weekdays and weekends. Data for 2000-2004.

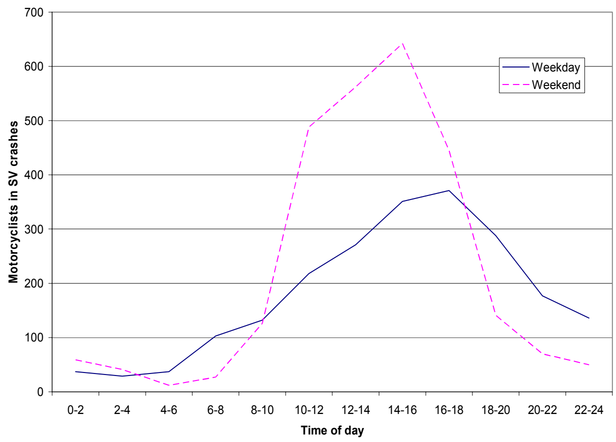

Figure 3. Number of motorcyclists in single-vehicle crashes in Victoria as a function of time of day on weekdays and weekends. Data for 2000-2004.

It is generally considered that fatigue is more common in single-vehicle crashes than multi-vehicle crashes. Figure 3 shows the time of day patterns for single vehicle motorcycle crashes in Victoria, which comprise 36% of weekday crashes and 62% of weekend crashes. The most striking feature of Figure 3 is the larger number of weekend crashes than weekday crashes from 10am to 6pm (despite there being 2.5 times as many weekdays as weekend days). On weekends, the temporal pattern of single-vehicle crashes is similar to that for all crashes, although with a more prominent peak between 2pm and 4pm. On weekdays, there is a gradual increase in crash numbers throughout the day, reaching a maximum between 4pm and 6pm. In terms of circadian low periods, there are still relatively few single vehicle crashes between midnight and 6am and much larger numbers between 2pm and 4pm, particularly on weekends.

To estimate the magnitude of possible circadian effects, the number of motorcyclists in crashes in each 2-hour period of the day calculated from the Victorian data for 2000-2004 (as shown in Figure 2) was divided by the mean number of motorcyclists (controls) observed by Haworth et al. (1997) in the same period of the day. While the absolute values of the crash index have little direct meaning, the pattern

across the day indicates the relative crash involvement of motorcyclists across the day, given the amount of riding that occurs at that time of day.
It should be remembered that the exposure data in 2-hour periods was based on small numbers of sites for some time periods and therefore the crash index may not be robust, given the constraints of the exposure data on which it relies. Bearing these caveats in mind, the crash indices for all crashes and single-vehicle crashes are presented in Figures 4 and 5.

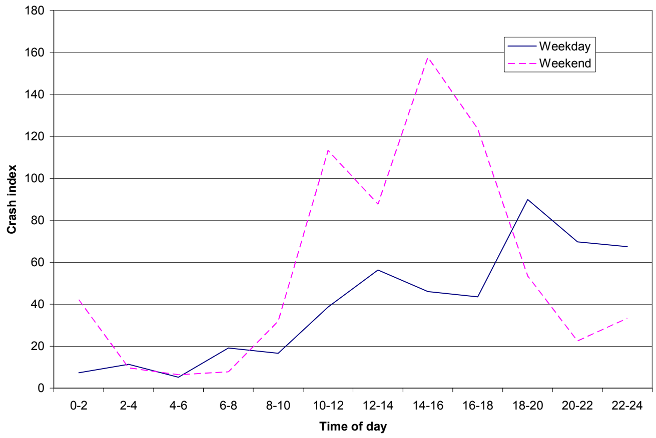

Figure 4. Crash index by time of day on weekdays and weekends (compiled from number of crashes during that period divided by exposure measure and corrected for more weekdays than weekends).

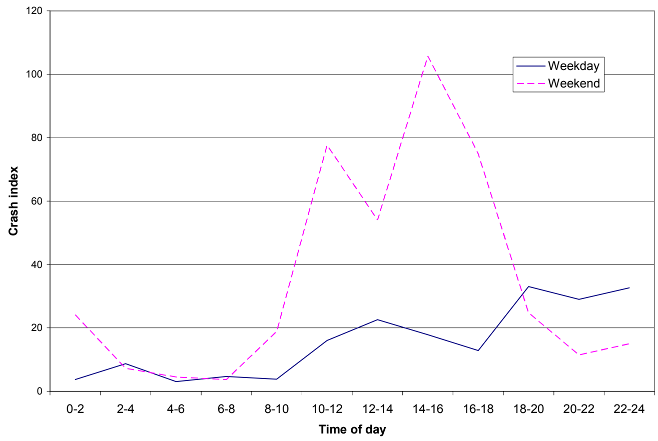

Figure 5. Single-vehicle crash index by time of day on weekdays and weekends (compiled from number of crashes during that period divided by exposure measure and corrected for more weekdays than weekends).

The shapes of the curves are similar for all crashes and single-vehicle crashes but differ noticeably between weekdays and weekends. On weekdays, the crash index generally increases throughout the day, being lowest in the midnight to 6am period and peaking between 6 and 8pm. It shows no clear evidence of peaks in circadian low periods. On weekends, the highest values of the crash index occur between 10am and 6pm, with the highest value being at the circadian low point of 2 to 4pm. Thus, this approach has not provided any clear evidence of an increased crash risk during the circadian low period of 12 midnight to 6am. While there is some evidence of an increased crash risk from 2pm to 4pm, this is only evident on weekends and may reflect other factors. We do not know what these factors might be, but they could potentially include such factors as increased alcohol/drug impairment, more riding by less experienced riders, or more riding by risk-taking riders.

Trip Purpose

The temporal patterns of motorcycle riding and crashes reflect differing trip purposes which may also differentially impact upon rider fatigue. It is generally accepted that weekday riding is predominantly for commuting and weekend riding is predominantly for recreation. This is also reflected in the routes ridden at these times. In support of the notion of differing trip purposes at these times the characteristics of these crashes also appear to differ. The RTA identified 10 routes with the highest number of motorcycle casualties in 1998-2002 (RTA, 2004). One group were key arterial routes within the Greater Sydney metropolitan area where crashes frequently involved multiple vehicles and occurred during afternoon peak hours. The second group were popular country and recreational routes where crashes were more likely to involve a single vehicle, occur on the weekend in the early afternoon, involve speeding and the motorcycle running off path on a curve. This is indicative of possible fatigue during the afternoon circadian low with riders potentially losing concentration during critical manoeuvres.

Many of the factors identified by the Fatigue Expert Group (NTC, 2001) as contributing to fatigue in professional heavy vehicle drivers were work-related (see Figure 1). While most motorcycles are used for recreation or commuting, there is some work-related use of motorcycles, particularly for mail deliveries, courier-type work and police enforcement.

Symmons and Haworth (2005) reported similar percentages of motorcycles and cars in New South Wales were fleet vehicles (14.4% of motorcycles and 15.5% of cars) and 9.0% of motorcycles in crashes were fleet vehicles. When motorcycles are used for work purposes, then some of the work-related contributing factors to fatigue that the Fatigue Expert Group report identified (trip scheduling, payment system, predictability of work) may be relevant.

Physical Aspects of Riding

It is recognised that fatigue for car and truck drivers can be associated with the level of comfort provided by the vehicle. Paradoxically, fatigue may ensue from the driver being too comfortable (e.g. if the heater is on and driver is too relaxed) or from a lack of comfort (e.g. seat vibration for truck drivers). However, for motorcyclists a range of physical demands may potentially impact upon rider fatigue. Brown (1994) highlighted the different aspects of physical fatigue in terms of static and dynamic muscle fatigue. Dynamic muscle fatigue is the result of exhausting the muscle beyond its capacity to recover and perform as normal (Brown, 1994). Such fatigue is experienced with exercise that places demands on the muscles to contract and relax. During typical on-road riding a motorcyclist would not normally experience this level of physical activity. However, if performing acts (mostly illegal) such as racing through tight curves or stunts such as wheel-stands, a rider may possibly experience this type of physical fatigue if these activities were prolonged without rest.

Static muscle fatigue results from the body assuming a fixed position for an extended period and is the type of physical fatigue that would be associated with riding an on-road motorcycle where the rider is ostensibly restricted to the same position throughout the course of a journey in order to safely operate the vehicle. Furthermore, certain categories of motorcycles may be more subject to these ergonomic constraints than others (Robertson & Porter, 1987). For example, the rider of a sports bike adopts a racing posture of leaning forward whilst the rider of a cruiser style motorcycle (e.g. a Harley Davidson) is typically more upright. Some motorcycles require the rider to tuck their legs up, whereas others offer a more extended leg position. Accordingly, tight/stiff muscles are commonly reported by riders from assuming a fixed position on long rides (Gillen, 1998; Motorcycle Council of NSW, 2006). Brown (1994) asserted that static muscle fatigue in particular may distract operators from the cognitive demands of the required task. However, in their on-road examination of rider fatigue, Ma et al. (2003) found that whilst riders reported significant levels of physical fatigue, performance on vigilance and reaction time tasks was not diminished. In contrast, Travers and Jennings (1980) found that whilst riders did not feel fatigued their reaction times were slower after an extended ride than after a nights rest. Furthermore, some riders have reported increased alertness during riding. Tunnicliff (2005) investigated qualitative aspects of riders' experiences for a range of factors including fatigue. She found that some riders mentioned how exhilarating and refreshing it was to get on their motorcycles after a tiring days work and that their alertness levels were restored during the ride. Similarly, other riders reported getting a 'buzz' out of riding. This aspect of riding may possibly be linked to personal satisfaction and enjoyment that many riders experience which may serve as a short-term remedy for fatigue. As such, more research is required to ascertain the true nature of this phenomenon.

Environmental factors

Motorcycle riders are exposed to a range of environmental factors that may impact upon fatigue states including wind, rain, heat and cold, vibration, noise, and road conditions. Exposure to some of these factors may vary between categories of motorcycles. For instance, sports tourer style motorcycles commonly have fairings and screens to deflect the wind, while cruiser style motorcycles may expose the rider more in this regard and some models have historically been considerably noisier than other types. Ma et al. (2003) found that monotonous road environments, vibration, and poor weather conditions were all factors that riders reported as causes of fatigue. Similarly, Robertson and Porter

(1987) found thermal problems, noise, and vibrations to be major influences on rider comfort. Furthermore, the Motorcycle Council of NSW (2006) warns that riders are particularly prone to dehydration due to exposure to environmental elements. Issues such as environmental conditions and the need to hydrate adequately are commonly discussed by rider groups and some government agencies, suggesting that the physical demands of riding certainly impact upon rider fatigue.

For example, the impact of cold weather on rider fatigue is mentioned by several independent authors, rider associations, and government agencies (Californian Department of Motor Vehicles, 2006; Gillen, 1998; Gloucestershire County Council, 2006; Park, 2006; Womens International Motorcycle Association, 2006).

Heat and cold also affect the likelihood of riding at particular times. In Victoria, many older riders report that they only ride during summer (Haworth, Mulvihill, & Symmons, 2002). The motorcycle case-control study (Haworth et al., 1997) found that the mean number of motorcycles passing control sites per hour was somewhat higher in February than in the other months but that there was no clear seasonal effect on motorcycle volumes. However, motorcycle volumes on the weekend showed a more marked seasonal effect than those on weekdays. In general, weekend volumes were higher than weekday volumes during January to March but lower during the cooler months. This suggests that recreational riding is much more seasonal than commuter riding. Thus, the contribution of cold to motorcycle fatigue is mitigated by many recreational riders being less likely to ride at colder times of the year.

Cognitive Demands

The level of mental effort required when in control of a motorcycle is arguably higher than that required for driving a car (Motorcycle Council of NSW, 2006; RTA, 2004). This is possibly the case due to the substantial ramifications of loss of attention/concentration for riders. When in control of a motorcycle the operator needs to be constantly aware of the road environment and often predict the movements of other road users due to a general lack of awareness of motorcyclists by car drivers (RTA, 2004). As such, the heightened demand on cognitive resources whilst riding may result in energy expenditure and an increased potential for fatigue. Ma et al. (2003) found a significant increase in self-reported mental demand and effort for participants during a five hour ride compared to a non-riding day. However, at this point of time there is no direct research to confirm or disprove that riding is more mentally demanding than driving a car.

Countermeasures and Rider Strategies to Combat Fatigue

Some of the countermeasures that are designed to combat driver fatigue are also applicable to rider fatigue. These include breaks/naps, public education campaigns, pre-trip planning (e.g. ensuring adequate sleep prior to commencement), and avoidance of driving/riding during circadian low points. However, there are particular considerations in this regard for motorcyclists. For example, whilst car/truck drivers are able to pull off the road to take a short nap in their vehicle, this is less practical for a motorcycle rider (ROSPA, 2001).

Other strategies are specific to riders and generally relate to rider comfort. One such option is modifying the motorcycle to decrease physical strain and stiffness (although legal requirements need to be considered). For example, throttle assists are available that are designed to relieve the pressure on the rider’s hand and wrist from gripping the throttle on long rides. Suspension, steering, and seat modifications may alleviate excessive vibration in the vehicle. Additionally, fairings and screens may relieve constant buffeting by winds. Perhaps an obvious strategy is to ensure that adequate warm clothing is worn to protect against extreme cold caused by wind chill. The Gloucestershire County Council (2006) recommends that riders carry an extra set of gloves inside their jacket as well as wearing appropriate weatherproof clothing. In contrast, specific motorcycle apparel has also been designed to alleviate the effects of heat on the rider using materials that breathe and absorb sweat. New materials have also been incorporated into motorcycle helmets to reduce heat (Tan & Fok, 2006).

Additional strategies to avoid fatigue include wearing ear plugs to prevent excessive noise and ensuring screens and visors are clean to avoid eye strain. Consistent with these strategies ROSPA (2001) recommended the following countermeasures to rider fatigue:

- do not ride when feeling tired;
- avoid riding in the early hours or when you would normally be asleep;
- plan and take regular rest stops on long journeys;
- take a break about every two hours;
- try to avoid riding after a heavy meal;
- do not drink and ride;
- avoid riding if affected by drugs or medicines that may cause drowsiness;
- adopt a comfortable position on the machine with your instep resting on the footrests;
- consider wearing internal ear protection (ear-plugs) to reduce noise;
- wear comfortable clothing that provides physical protection and is appropriate to the weather.

A CONCEPTUAL MODEL OF MOTORCYCLE FATIGUE FACTORS

On the basis of the available evidence it is possible to conceptually represent the factors contributing to fatigue in motorcycling (as shown in Figure 6) by modifying the model developed for truck drivers in the Fatigue Expert Group report (NTC, 2001). The right-hand side of the diagram "Rider Factors" represents the biological and psychosocial/life activities that may influence fatigue states. The influence of biological factors on fatigue states (e.g. age, health, subjective stress, circadian rhythms, and sleep deprivation / disorders) is well established and, as such, rider fatigue states are influenced similarly to other road users. It is important to note that as in the Fatigue Expert Group report (NTC, 2001) there is a reciprocal relationship between these factors, indicating possible interaction. Similarly, the current model reflects this notion. Life activities and psychosocial factors that are specific to riding are also proposed to contribute to fatigue. For example, drowsiness is a common effect of alcohol, cannabis, opiates, benzodiazepines, barbiturates, and medications such as antihistamines (McKim, 2003). Drummer (2003) found that similar percentages of riders and drivers were alcohol-positive in fatal crashes, however riders were twice as likely to show recent cannabis use. Peer influence has also been found to have a substantial impact on the way that individuals ride (Tunnicliff, 2005). This may potentially be in terms of the type and length of trip undertaken, whether rest breaks are taken, alcohol and/or drugs use, and the type of bike that is ridden; all of which may in turn contribute to rider fatigue. Socioeconomic status may also influence the type of bike purchased, who the individual rides with (i.e. peer group), the type of riding undertaken (i.e. a more inexpensive form of transport for commuting), and is additionally associated with patterns of substance use (O'Malley, Schulenberg, Bachman, & Johnston, 2004).

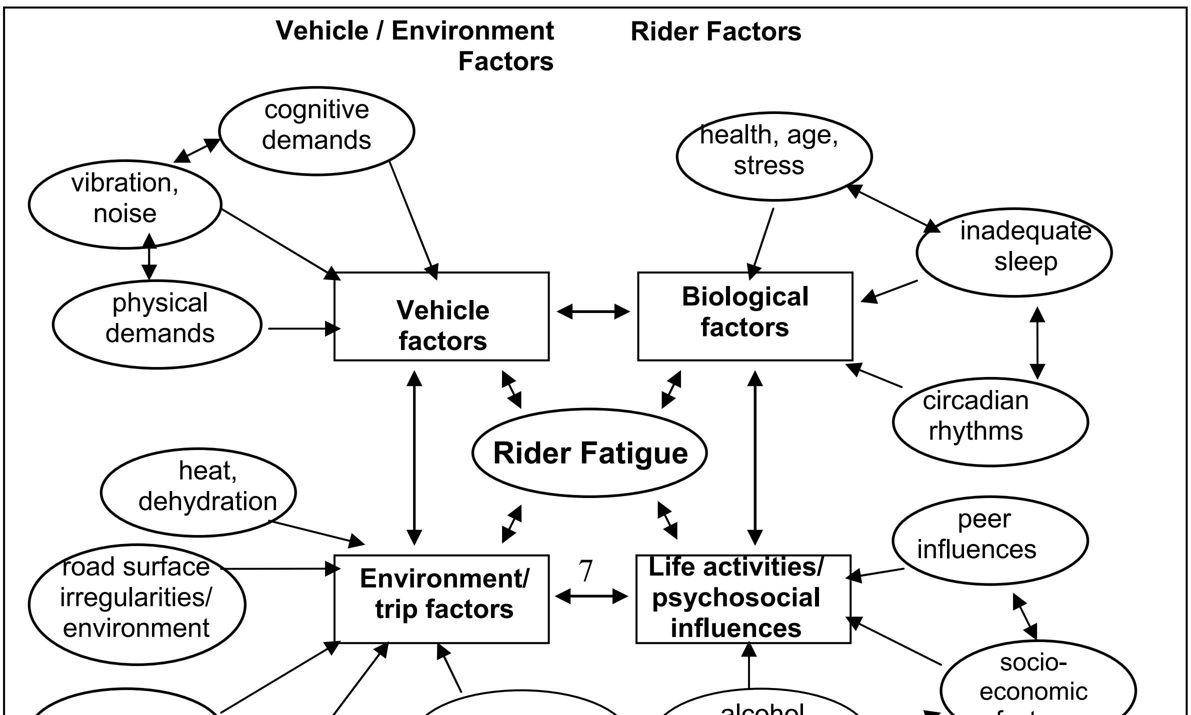

Figure 6. Motorcycling Fatigue Model. A conceptual representation of factors that potentially contribute to fatigue in motorcycling (adaptation from NTC, 2001).

The left-hand side of the figure "Vehicle/Environment/Trip Factors" represents the on-road demands and vehicle characteristics that potentially contribute to rider fatigue. As previously mentioned, vehicle-related factors such as vibration and noise directly contribute to fatigue states. Other physical demands associated with riding such as posture (ergonomics of the vehicle) and vehicle control also have an impact, as do the cognitive demands associated with vehicle operation. Environment/trip factors such as monotonous road environments and weather conditions have been reported to affect rider fatigue states (Ma et al., 2003; Robertson & Porter, 1987). The Fatigue Expert Group (NTC, 2001) identified time on task as an important contributor to fatigue in professional heavy vehicle drivers. Trip length is a measure of time on task. In car drivers, many fatigue-related crashes occur during trips of less than two hours (Fell, 1995; Haworth & Rechnitzer, 1993). However, the relationship between trip length and rider fatigue may be qualitatively different from car or truck drivers due to the excitement and alerting nature of motorcycling over the short term. This remains to be explored further. Finally, trip purpose (e.g. commuting vs recreational riding) may result in distinctly different patterns of riding in terms of urban weekday riding compared to rural/highway weekend riding, as well as trip length. The effect is shown in data presented earlier in this paper. Whilst all of the above factors are tentatively proposed to contribute to rider fatigue, as previously mentioned, further research is required to determine the exact nature of such. Accordingly, there is scope for further development of the model as these issues are explored further.

CONCLUSIONS

Fatigue in motorcycling has been largely ignored by road safety practitioners and governments. Currently, researchers do not have sufficient information needed to draw reliable conclusions regarding the magnitude of the effects of factors that may contribute to motorcycle fatigue or subsequent crashes. Hence, more knowledge of the phenomenon is needed to allow countermeasures to be developed. The Motorcycling Fatigue Model presented in this paper (Figure 6) highlights key factors for consideration and will assist in guiding such research. It is an endeavour to integrate all motorcycle specific fatigue factors in addition to the known factors that contribute to fatigue in all road users.

Future research into the phenomenon of rider fatigue needs to explore the extent to which riders experience both mental and physical fatigue and the circumstances under which these effects occur (e.g. which is the bigger problem, objective measures of performance degradation); the rider, vehicle and trip factors that influence the development of mental and physical fatigue (e.g. do novice riders develop mental fatigue more quickly?); the extent to which riders believe fatigue has contributed to their crashes and near-misses; methods of preventing or reducing mental and physical fatigue.

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