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INFORMATION FOR DEVELOPMENT OF AN EDUCATIONAL PROGRAM TO REDUCE FATIGUE-RELATED TRUCK ACCIDENTS

Narelle L. Haworth
Colleen J. Heffernan

MONASH UNIVERSITY ACCIDENT RESEARCH CENTRE

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Author(s)

HAWORTH, N.L.
HEFFERNAN, C.J.

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Abstract:

This report provides information for the development of a heavy vehicle driver education package regarding fatigue.

Driver fatigue is recognised as a contributory factor in some accidents. It is more likely to be associated with long hours of driving, without adequate rest periods, loss of sleep, food or drug intake and night driving.

Various methods are recommended to counteract fatigue. They include limitation of total driving hours, regular rest stops before fatigue sets in, avoidance of alcohol and drugs (although moderate use of caffeine is not harmful), use of radio to maintain alertness and adequate cabin ventilation, as well as introducing variation in the driving environment.

Key Words:
(IRRD except when marked*)
Fatigue (human), Education, Driver Information, Safety, Accident Rate, Tachograph, Hour, Lorry, Industry, Victoria*

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EXECUTIVE SUMMARY

This report is one of several to be produced as part of a study of driver fatigue in heavy vehicle accidents. It provides information for use in developing a program to educate heavy vehicle drivers about the role of fatigue in crashes, factors which contribute to its onset and measures to counter it. The study was commissioned by the Victorian Road Freight Transport Industry Council and funded by the Road Construction Authority in May, 1988.

The report comprises two sections. The first section addresses issues relating to the provision of education programs, including the need for such programs. The second section presents information about driver fatigue which has been gathered to provide the background material for development of the educational package.

In the first section, which provides information for educators, the following main points are made:

- The road transport industry and government authorities perceive a need for both general education and specific fatigue educational programs for heavy vehicle drivers.

- An educational program specifically addressing driver fatigue would aim to provide heavy vehicle drivers with skills to recognise fatigue and methods to counter it.

- In any one year of driving there is a one in 200 chance of a semi-trailer being involved in a fatal accident.

- Semi-trailer accidents are more likely to be severe and involve fatalities, as compared with car accidents.

- Fatigue-related accidents are a major occupational hazard for truck drivers, especially long distance drivers.

- A NSW study reported that "articulated trucks have a high involvement in fatigue accidents in comparison with their involvement in other accidents".

- A recent Victorian study reported that car or truck driver fatigue was a contributing factor to between 9.1% and 19.9% of fatal accidents involving trucks, with fatigued car drivers being involved at least as much as fatigued truck drivers.

- In interviews of owner-drivers in NSW 94 per cent stated that a low accident rate was important in getting and keeping regular work.

- Owner-drivers often face a range of problems (including economic factors, oversupply, ease of entry into the industry and poor business skills) which can potentially add to the likelihood of driving while fatigued. Resistance to implementing fatigue countermeasures may arise as a result of these additional work pressures.

- In overcoming this resistance educators need to acknowledge the reality of such constraints, the current attempts by the road freight industry and the government to minimise these constraints, and the role heavy vehicle drivers may be able to play in effecting changes in the industry which could improve safety and other working conditions.

In the second section, which details information regarding driver fatigue and ways to counter it, the following main points are made:

- Fatigue has proved difficult to define precisely and some researchers view fatigue as arising from conditions of over-stimulation while others view it as arising from conditions of boredom or under-stimulation.

- Factors which have been shown to contribute to the onset of fatigue include inadequate sleep or rest (long- or short-term disturbance to sleep patterns, certain phases of circadian rhythms, sleep disorders), prolonged hours of service (prolonged driving periods, night-time driving), and food and drug intake (eating patterns, intake of alcohol and other drugs).

- Driving behaviour while fatigued can include zigzag driving within the permitted lane, crossing the centre line, and running off the road.

- Accidents in which fatigue is involved are often severe. Examples of actual fatal accidents involving heavy vehicles, in which the Coroner found fatigue to be a contributing factor, are presented in Appendix 1.

- Methods of counteracting fatigue include: compliance with hours of driving regulations including regular rest stops, using CB and AM/FM radio, avoidance of driving if narcoleptic, or under the effects of alcohol, depressants or amphetamines, using moderate amounts of caffeine, and introducing variation into the environment. Further study of the effects of adequate cabin ventilation and reduced cabin vibration is needed before these methods can be recommended.

1 INTRODUCTION

The aim of the report is to assemble information about driver fatigue which could be used in the development of an educational package for heavy vehicle drivers. The report does not constitute an educational package but is a source of information which can be used in the preparation of such a package.

While fatigue is experienced by car drivers as well as truck drivers, it is felt that heavy vehicle drivers may be able to be reached by an industry-based educational program.

This report comprises two sections. The first section addresses issues relating to the provision of education programs for heavy vehicle drivers, including the need for such programs and possible resistance. The second section contains the information about driver fatigue which has been gathered to provide the background material for the development of the educational package.

2 EDUCATION OF HEAVY VEHICLE DRIVERS

Fatigue is not a subject currently included in heavy vehicle driver education and training programs (Cavallo, 1987). However, Haworth, Triggs and Grey (1988) expressed the need for specific education regarding fatigue and its countermeasures to be included in future programs. They concluded that education regarding fatigue in heavy vehicle drivers could provide a useful short-term countermeasure for driver fatigue.

The road transport industry and government authorities perceive a need for education and training programs for heavy vehicle drivers, both general programs and those specifically addressing driver fatigue (National Roads and Motorists' Association, 1986; New South Wales Road Freight Transport Industry Council, 1984; W. D. Scott and Company, 1983).

General educational programs could be beneficial in reducing the conditions that give rise to owner-drivers operating while fatigued. Such programs could teach skills in areas such as business management, aiming to reduce the stress associated with financial matters. If improved business management skills reduced the need to work excessively long hours, a reduction in the contribution of fatigue to heavy vehicle accidents would be expected.

In a submission to the Standing Committee on Road Safety regarding driver licensing, the NSW Road Freight Transport Industry Council listed "desirable features in a heavy road freight vehicle driver". One desirable feature was:

> Appreciation of the effects of fatigue, drugs and alcohol on personal performance. The sensible heavy vehicle driver will know when he should rest and the dangers associated with drugs, alcohol and/or personal stress. (NSW Road Freight Transport Industry Council, 1984, p.2)

It is hoped that specific education about driver fatigue would provide drivers with skills to recognise fatigue and methods to counter it.

2.1 Why is fatigue education needed?

Driver fatigue is a major occupational hazard for heavy vehicle drivers and the consequences are often accidents which can result in injuries or fatalities as well as lost income, higher insurance premiums, and reduced employability. By reducing driver fatigue these occupational hazards could be reduced. This section outlines the accident risks of heavy vehicle drivers and the contribution of fatigue to such accidents.

2.1.1 Overall accident risks

The average semi-trailer travels some 72,000 kilometres per year. From statistics published by the National Road Freight Industry Inquiry Report (May, Mills and Scully, 1984), Vulcan (1987) showed that semi-trailers were more over-represented in fatal accidents than in less severe accidents. Using these data, further calculations demonstrate that in any one year of driving there is a one in 200 chance of a semi-trailer being involved in a fatal accident. The person killed in the accident is most commonly not the driver of the semi-trailer. There are likely to be more drivers than semi-trailers and so the probability of a driver being involved in a fatal accident is probably less than one in 200. Nevertheless, the probability is alarmingly high.

The probability of being involved in a non-fatal accident is greater than the probability of being involved in a fatal one. Articulated trucks have a 14 per cent chance of involvement in an accident which results in someone being admitted to hospital in any one year. Over a five year period this rises to a 70 per cent chance. In addition there is an annual 17 per cent chance of an articulated truck being involved in an accident which results in non-hospital-admission injury.

The risk (per 100 million vehicle kilomeres travelled) of articulated vehicles being involved in accidents resulting in hospital admission is almost the same as it is for cars, while for non-hospital-admission injuries it is less than half that of cars (Vulcan, 1987). These figures show that semi-trailer accidents are more likely to be severe and involve fatalities, as compared with car accidents. The higher relative risk of being involved in a fatal accident is a major cause for concern.

2.1.2 Fatigue-related accidents

Fell (1987) reported that "articulated trucks have a high involvement in fatigue accidents in comparison with their involvement in other accidents" (p.60). Articulated trucks in N.S.W. were found to have 3.7% of all fatigue-related accidents but only 1.5% of all non-fatigue-related accidents.

In the companion volume to this report, Haworth, Heffernan and Horne (1989) reported that fatigue was a contributing factor to between 9.1% and 19.9% of fatal accidents involving trucks. It should be noted that fatigued car drivers contributed at least as much to these figures as did fatigued truck drivers.

An educational program designed to inform heavy vehicle drivers about fatigue and its countermeasures would attempt to reduce the risk of involvement in fatigue-related accidents. For the truck driver the reduction of such a major occupational hazard should result in safer working conditions, and potential major savings in monetary and health terms. In a report by the New South Wales Road Freight Industry Council on the operations of long distance owner-drivers (W. D. Scott and Company, 1984), 94 per cent of owner-drivers interviewed stated that a low accident rate was important in getting and keeping regular work.

2.2 Implementing fatigue prevention programs

While the educational program may provide important reasons for avoiding fatigue and positive strategies for how to prevent or counter fatigue, some resistance to implementing these measures may be present amongst the heavy vehicle driver population. This resistance relates to the economic constraints within which many drivers operate. In order to maximise its effectiveness, the program needs to address and acknowledge the broader social framework within which it is to be implemented.

The National Road Freight Industry Inquiry Report (May, Mills and Scully, 1984) stated that ample evidence was collected to indicate that "highly stressed operators were working extraordinary long weeks and driving more than 80 hours per week to keep up with financial commitments" (p.151). It seems then, that very real pressures operate to induce owner-drivers into driving in situations where fatigue is likely.

In the Report on Long Distance Owner-Drivers in NSW (W. D. Scott and Company, 1984) four factors were cited which were seen to contribute to problems in owner-driver business operations: economic factors, oversupply of owner-drivers and ease of entry into the industry, company pressures and poor business skills of owner-drivers. As a result of these problems, certain negative outcomes were predicted. These included bankruptcy, poor business practice, corruption, and safety risks (p. 6). Hence the report identified a range of problems for owner-drivers, some of which add to the likelihood of driving while fatigued.

In response to the identified problems the following recommendations were made. For the over-supply of owner-drivers it was recommended that there be tighter licensing requirements and that prospective entrants and their wives be informed of the realities of life as an owner-driver. To minimise company pressures it was recommended that companies be encouraged to share responsibility for driver training, keeping within speed limits and loading limits, enforcing payment of at least the minimum rate, stipulating work breaks and discouraging tax avoidance. It was further recommended that companies improve conditions of service such as hours of work, and improve representation through associations. To improve the business skills of owner-drivers it was recommended that prospective entrants be educated in some apprenticeship scheme and that existing owner-driver's wives be educated in business skills. Finally, with regard to safety, it was recommended that regulations be updated, that all parties share responsibility, and that further research be conducted on the relationship between rates and conditions and accident frequency (p.9).

The constraints which may work against heavy vehicle drivers implementing fatigue prevention strategies have been identified and discussed in a number of reports. Acknowledging the reality of these constraints and the moves currently being made to minimise these creates a more credible atmosphere, allowing a better response to the educational program. By emphasising the very real advantages of providing business skills management, for example, drivers can learn that this is a way to minimise pressures which contribute to driving when fatigued.

Linklater (1977) made the following comments in her discussion of fatigue in long distance truck drivers.

> Despite the fatigue generated by their method of operation, most truck drivers seemed genuinely to like their work. The long absences from home were regretted, but the appeal of the open road and entrepreneurial nature of their occupation appeared to compensate for many of the discomforts and worries that were expressed. The long hours away from home tend to encourage mateship among truck drivers. Drivers seem to form a cohesive fraternity with its own vocabulary, hierachy and folklore. This subculture should be taken into account when any measures to counteract fatigue in the long-distance transport industry are being considered. Many truck drivers seem to have a strong inner drive to achieve by their own efforts and a restless energy to keep moving. They need to be convinced of the need for restrictions [countermeasures] and this may be achieved if they have a say in what form such restrictions should take and how they are to be enforced. (p.53)

In the design of an educational program, extensive consultation with drivers and industry representatives will be needed to maximise the likelihood that the program will be effective.

3 INFORMATION ABOUT DRIVER FATIGUE

3.1 Definition of fatigue

Fatigue has proved difficult to define precisely (Cameron, 1973). Most definitions include the concept of a deterioration with extended effort in work output, physiological well-being or feelings (Haworth, Triggs and Grey, 1988).

Driver fatigue has been described as a state of drowsiness that ends in the driver falling asleep at the wheel (Näätänen and Summala, 1978). Kleitman (1963) defined drowsiness as a succession of stages between definite sleep and wide-awakeness. A general feeling of loss of attention, loss of interest and sometimes boredom accompanies the onset of fatigue.

Movements of the steering wheel become less frequent and larger with fatigue, resulting in a tendency to zigzag within the driving lane and drift across driving lanes (McFarland and Mosely, 1954, cited in Crawford, 1961; O'Hanlon and Kelley, 1977).

The most dangerous aspect of driver fatigue is falling asleep at the wheel. While drivers affected by fatigue may have slower reactions and impaired visual scanning, they may be able to compensate to some extent for these impairments by, for example, slowing down or being less willing to overtake (Brown, Tickner and Simmonds, 1970). Näätänen and Summala (1978) conclude that "research has not generally been able to show that driver fatigue increases the risk of an accident except by increasing the probability of falling asleep during driving" (pp.27-28).

3.2 Causes of fatigue

Grandjean and Kogi (1971) produced the schematic presentation of fatigue in Figure 1 which illustrates the many factors that can contribute to the development of fatigue. It should be noted however, that Grandjean and Kogi were discussing fatigue resulting from a number of activities, not driver fatigue specifically.

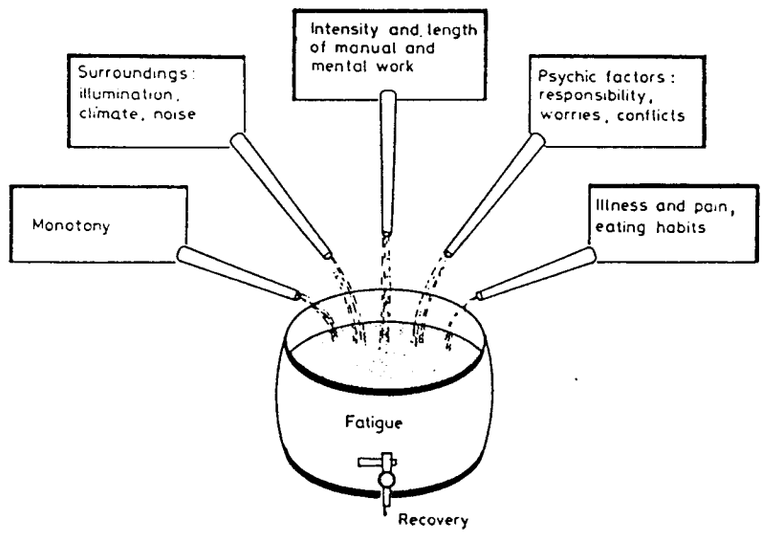

Figure 1. The cumulative effect of daily causes of fatigue (Grandjean and Kogi, 1971). Fatigue is compared to the level of liquid in a container, and recovery is shown as the outflow from the container.

Early research in the area concluded that fatigue may develop when the work lacks interest, or makes no demands on the driver's skill, or when the working environment is unexciting (National Road Safety Council, 1978). The traditional view is that monotony contributes largely to driver fatigue. This is supported by the findings that fatigue-related accidents often occur on rural highways, particularly at night (Fell, 1987).

More recent research suggests that driver fatigue may not be caused by monotonous or boring driving conditions (Fisk and Schneider, 1981). This view is outlined below.

> Any driving requires concentration; the effort involved eventually becomes too much, and concentration lapses. These attentional lapses can occur after only a short period of time when the effort required is nearer to maximum, but it may be a long time before lapses occur when conditions require minimal concentration such as on freeways and rural highways. Under conditions of minimal concentration, the driver is actually asleep during these lapses. Under more demanding conditions it is unlikely that drivers sleep, but they may become inattentive. It appears that easy driving conditions actually postpone the onset of fatigue; it is the driver choosing to drive for longer than physiologically possible who creates conditions where fatigue can occur. (Federal Office of Road Safety, 1987, p.11).

Whether fatigue results from too little stimulation or too much has implications for the type of countermeasures that will help prevent driving fatigue. Adequate sleep and regular rest stops are countermeasures which would help prevent fatigue from over-arousal. Listening to the radio may help reduce fatigue from boredom. In this report fatigue countermeasures are discussed which relate to both the over-arousal definition and the boredom definition.

The following sections describe factors which have been shown to contribute to the onset of fatigue.

3.2.1 Inadequate sleep or rest

Inadequate sleep or rest can take the form of long- or short-term disturbance to sleep patterns or sleep disorders.

Long- or short-term disturbance to sleep patterns. Irregular sleep or disturbances in the normal sleep pattern disrupt the natural waking/sleeping rhythms of the body. This may result in drivers becoming more likely to fall asleep in the early hours of morning. Lubin (1967, cited in Johnson, 1982) hypothesised that short-term sleep loss results in mental and motor lapses. Between lapses the subject may perform normally. Johnson (1982) conducted an experiment in which reaction times were measured after a period of sleep loss. It was found that, as sleep loss increases, "performance becomes more and more uneven, with efficient behaviour alternating with faltering responses" (p. 114).

The quality and quantity of sleep the night before or when the driver last slept influences the onset of fatigue. Tilley (1985) investigated the relative effects of sleep loss during different stages of sleep. The resulting sleep patterns differed to those of continuous sleep. It was concluded that "loss of the last four hours of a night's sleep results in differential sleep stage deprivation" (p.133).

Irregular sleep is likely as a result of sleeper berth use (Hertz, 1987). Some drivers have a sleeper berth located in the truck cabin or bus and use this to accumulate several hours of recovery sleep. Hertz reports that drivers who use sleeper berths to accumulate their required off-duty rest time report more subjective fatigue than drivers who do not. "Studies of steering maneuvers, lane tracking, and lane drifting have demonstrated that decrements in performance occur earlier for drivers using sleeper berths than for other drivers" (p.2).

These studies have shown that the length of each sleep period is important in counteracting fatigue, not merely the total hours of sleep in a given period.

Certain phases of circadian (daily) rhythms. A well-identified circadian rhythm exists for body temperature, in which the temperature rises steadily during the day to peak in the evening (Lisper, Eriksson, Fagerstrom and Lindholm, 1979). Research has shown evidence that a circadian rhythm exists for traffic accidents.

In an analysis of US interstate truck accidents involving dozing drivers, Harris (1977) found that about twice as many of these crashes occurred between midnight and 8 a.m. as in the rest of the day and about half of the single-vehicle accidents occurred in the early morning hours. Studies conducted in France (Hamelin, 1980, cited in McDonald, 1981) and Sweden (Lisper, Eriksson, Fagerstrom and Lindholm, 1979) have demonstrated similar patterns of results. Hoback (1959, cited in Lisper et al., 1979) stated that "a driver is fifty times more likely to go to sleep between 2 a.m. and 6 a.m. than from 8 a.m. to noon".

Drivers need to be aware that they are at greater risk of falling asleep at the wheel in the early hours of the morning than at other times. While refraining from driving at this time would be the most effective way to avoid the high level of risk, this will not be practicable for many drivers. An alternative is to take more rest breaks and other steps to avoid fatigue during that period.

Sleep Disorders. Sleep disorders, which include sleep apnea and narcolepsy can contribute to driver fatigue.

Sleep apnea is a more common sleep disorder than narcolepsy. Johns (personal communication, 1988) estimated that between one and three percent of Victoria's male population suffer from sleep apnea, with most sufferers being aged in the 35 to 55 year age bracket.

Aldrich, Aldrich, Aldrich and Aldrich (1986) reported that "sleep apnea usually, but not always, occurs in association with snoring and is somewhat more frequent among those who are overweight. Its onset is insidious, and the patient may not be aware of the amount of sleep that is lost. A common early symptom is the tendency to fall asleep while watching television, usually as soon as they begin watching. As sleep apnea progresses, sleepiness becomes more severe, and 'microsleeps', or episodes of altered consciousness with automatic behaviour, may occur" (p.233). Sleep apnea occurs most commonly in middle-aged, overweight, males who lead a sedentary lifestyle and consume moderate to heavy amounts of alcohol. The resulting daytime somnolence, together with more night wakings, tends to increase with age.

Narcolepsy is characterised by excessive daytime sleepiness, and can also include loss of muscle tone, hallucinations, sleep paralysis, and disrupted night time sleep. The excessive daytime sleepiness occurs every day, regardless of the amount of sleep obtained at night (Narcolepsy and Overwhelming Daytime Sleep Society self-help group leaflet, undated).

There is some dispute about the true incidence of narcolepsy (Roberts, 1971). Laurell (personal communication, 1988) reported current research in which several narcoleptic persons who were bus drivers were found to be falling asleep at red traffic light signals. This suggests that narcolepsy is not "extremely rare". Dr Johns of the Sleep Disorders Unit at Epworth Hospital in Melbourne estimated that there are 500 to 1000 sufferers of narcolepsy in Victoria (personal communication, 1988).

Narcolepsy was addressed in the National Guidelines for Medical Practitioners in Determining Fitness to Drive a Motor Vehicle (Federal Office of Road Safety, 1988). In those guidelines it was stated that "applicants who are subject to attacks of narcolepsy cannot drive any type of motor vehicle safely. Applicants with narcolepsy, whether adequately treated or not, cannot drive a passenger transport or heavy commercial vehicle safely because

the risk of a crash is too great to accept should they run out of or neglect to take their medication" (p.7-3).

3.2.2 Prolonged hours of driving

Defining hours of driving. Long or irregular hours of driving increase the likelihood of fatigue. Driving hours, sometimes termed hours of service, include "time spent on all the tasks connected with the trip that are carried out in the one session of work. It includes collecting and delivering the load, loading and unloading the vehicle, securing the load and servicing of the vehicle" (Road Traffic Authority, 1988, p.7). All of these tasks (and activities undertaken before work) contribute to the build-up of fatigue; it is not only driving that produces fatigue.

In situations where drivers spend time collecting and securing their load before beginning a long distance drive, they may need a rest period before commencement of driving. Since the effects of the various causes of fatigue are likely to be cumulative, the onset of fatigue may be hastened in circumstances where no rest is taken between loading and driving.

Prolonged driving periods. A survey of truck drivers and operators (Siromath Pty Ltd, 1988) showed that slightly over a third of owner drivers (34.5%) and almost a third of employee drivers (30.9%) were travelling on a 10-11 hour trip when surveyed. Just over 17 per cent of drivers were travelling on a 16-30 hour trip and 4.7 per cent of owner drivers and two per cent of employees were on trip of more than 50 hours duration. Clearly, long trips are common.

Hertz (1987) reported a U.S. study which showed that 41 per cent of heavy truck crashes occurred after 16 or more consecutive hours of on-duty time. This 'on-duty' time included driving as well as other activities for the employer. On these long trips the very real danger of driver fatigue can occur if sufficient rest breaks and sleep are not built into the trip. Mackie and Miller (1978) found that the likelihood of having an accident increased dramatically in the second half of the driving trip.

Night-time driving. Research conducted by Fell (1987) found that fatigue accidents in N.S.W. peak in the early morning at 4-5 a.m. with 17.8% of fatigue accidents occurring then. Over 60% of fatigue accidents occur between midnight and 8 a.m. (Fell, 1987). Driving after midnight therefore is associated with higher levels of fatigue accidents. "Late night and early morning driving also tends to co-incide with other factors thought to cause fatigue - lack of sleep, long hours of driving and monotonous driving conditions with little change in the visual surroundings" (p.51, Fell, 1987).

In addition, an analysis of casualty and fatal accidents by time of day (adjusted for exposure) showed that accident risks were highest during the night on all five Victorian highways studied (Haworth, Heffernan and Horne, 1989). Driver fatigue is one of the possible factors underlying this pattern of elevated risk.

The advantages perceived by drivers of driving in hours of reduced traffic flow, i.e., at night-time, are offset by the large increase in fatigue and accidents caused by fatigue. Such accidents are costly, both in terms of health and lost work-time.

3.2.3 Food and drug intake

Eating patterns. Lisper and Eriksson (1980) studied the effects of food consumption on drivers' reaction times. In this study rest breaks were taken after four hours of driving. Some drivers were then given a meal of meatballs, potatoes, bread and butter, and milk. Those drivers who ate food subsequently performed better on the reaction task than those who did not have any food to eat during the rest break. While these results suggest that food has a positive effect on alertness in drivers it must be noted that driver's reaction time performance was only measured immediately after the rest break. It is not known how long the improvement lasted.

It is widely thought that performance on a number of tasks shows a 'post-lunch dip' in which performance is reduced immediately following lunch (Colquhoun, 1982; Monk, 1982). Further research has been conducted to establish whether this 'post-lunch dip' is due to eating or the time of the day. While there is an effect on performance due to bodily rhythms that vary throughout the day, this is influenced by the eating of meals (Colquhoun, 1982). It is recommended that the eating of large meals be avoided and that these be substituted by smaller, more frequent, low carbohydrate meals (NODSS leaflet) when driving. Often the food served at roadside truck stops is high in carbohydrate. Substituting this food by more fresh fruit and vegetables would be one way to reduce carbohydrate-loaded meals.

Intake of alcohol and other drugs. The effects of alcohol and fatigue are closely related because alcohol is a central nervous system depressant and makes a driver more likely to fall asleep. Even small quantities of alcohol (below .05 blood alcohol concentration) reduce alertness and simultaneously increase a driver's feelings of confidence (Ryder, Malin and Kinsley, 1981). This combination can lead to risk taking behaviour which may cause accidents. In larger quantities, alcohol slows down the body's functioning and can exacerbate fatigue.

Ryder et al. reviewed the literature regarding the effects of alcohol and fatigue on highway safety. They reported effects of alcohol and fatigue in the following areas of driver behaviour: perception and attention, decision making, motor and sensorimotor control, overall vehicle control.

With regard to perception and attention both alcohol and fatigue were found to cause decreases in information-processing capacity and rate, reduced ability to process information from the peripheral retina, and less active eye movements. Complex decision making tasks were found to be more impaired by alcohol than fatigue, with the reverse being true for simple tasks. For motor and neuromuscular control, alcohol was found to produce greater impairment than fatigue. Alcohol increased reaction times slightly. Both alcohol and fatigue reduced tracking task accuracy. Vehicle control was shown to increase in variability as a result of either fatigue or alcohol.

It is clear from the review by Ryder et al. that both alcohol and fatigue reduce driving performance. In their paper it was noted that most studies attribute 40 to 55 per cent of highway fatalities to alcohol intoxication. However it is likely that fatigue also contributes to many of these accidents but is less likely to be identified as the major cause because it is more difficult to identify than alcohol consumption. The combined effects of alcohol and fatigue have proven difficult to research because of the difficulties associated with defining and measuring fatigue.

The close relationship between alcohol and fatigue was recognised in the Federal Office of Road Safety's Road Crash Statistics of March 1987. In that report it was noted that measures which reduce drink driving are also likely to reduce fatigue.

Certain medicines such as some cough mixtures, cold tablets, hay-fever and allergy medications, and minor tranquilizers are also depressants and can induce fatigue. Many of these medications are available over the counter while some, such as minor tranquilizers, are available on a doctor's prescription. Medications which may cause drowsiness have that information written on their labels. If unsure whether a medication causes drowsiness it is advisable to ask the chemist or doctor as ingestion of such medications before driving can increase fatigue and should therefore be avoided.

Certain stimulant drugs are used by some drivers to help them keep awake. Regular use of stimulant drugs to stay awake for long periods of time may lead to hallucinations and will lead to reduced performance, which in turn increases the risk of having an accident.

In addition the repeated use of some stimulants, such as amphetamines, leads to tolerance of the drug, so increasing amounts are required to maintain alertness (Milner, 1972). The problem of drug dependency in this situation means that driving performance could be expected to reduce dramatically when sufficiently high levels of amphetamines were not available to meet the body's increased demand for them. The body would not be able to function with a normal (i.e., drug free) level of performance unless some level of amphetamines were present. This need for increased dosages of amphetamines to maintain even normal alertness levels means that amphetamine-dependent drivers who are unable to secure sufficient dosages may actually become more fatigued than would normally be the case if no drugs were used (Goodman and Gillman, 1965).

The development of dependence on stimulant drugs means that their use may result in increasing the possibility of a fatigue-related accident, rather than the reverse.

3.3 Effects of fatigue on driving

Driver fatigue results in an identifiable pattern of deterioration in driver performance. Depending on the environmental factors such as the width of the roadway and the presence or absence of other vehicles, the deterioration in driver performance may result in an accident.

3.3.1 Changes in driver performance

Hattori, Matsuura, Narumiya, Araki and Ohnaka (1987) demonstrated three stages of driver performance in extended driving. The driver began in Stage One, characterised by alertness. In Stage Two (drowsy driving) drivers appeared to be sleepy, and "had a tendency to decrease their close attention to safety and to drive gazing vacantly at one unspecified point" (p.249.4). The car speed was kept fairly constant but there was often a delay changing speed in response to change of gradients of the road. This type of driving has been referred to as highway hypnosis (Williams, 1963).

Hattori et. al. (1987) report that in Stage Three (dim driving) "the consciousness level of the driver seemed to become even lower and blinkings were extremely reduced. The steering operation became more dilatory than in stage two and the zigzag driving within the permitted lane became pronounced. During this repeated zigzag driving the car sometimes crossed the centre line or ran off the side of the road" (p.249.4). In Stage Three a high level of fatigue is present and vehicle control is difficult to maintain.

3.3.2 Increased accident risk

May, Mills and Scully (1984) reported that "truck drivers appear to be far better at driving safely than other vehicle drivers" (p.135). However, fatigue accidents are a recognised hazard for heavy vehicle drivers (Brookhuis, 1988). While articulated trucks have only 1.5% of all non-fatigue accidents, they have 3.7% of all fatigue accidents (Fell, 1987). Fatigue accidents happen more frequently between midnight and 8 a.m. and more on rural highways than elsewhere (Fell, 1987). This combination of night-time driving and rural driving is typical of heavy vehicle drivers. Their reasons for night-time driving include avoiding heavy traffic which occurs on the roads in the daylight hours, and meeting agreements to transport goods between cities overnight. However, this combination of extended driving hours during the night and travelling for long stretches on rural highways, produces a situation which is highly fatiguing to most drivers.

The consequence of this work pattern is that heavy vehicle drivers are at very high risk of having a fatigue accident. As noted in the previous section, fatigue can lead to zigzag driving, lane drifting and running off the road. Seko, Kataoka and Senoo (1986) found that fatigue was present in seven percent of all accidents and in 49 per cent of fatal accidents. Hence fatigue accidents are more likely to be fatal than non-fatigue accidents. It is likely that fatigue contributes to a proportion of the serious accidents involving trucks.

Johnston (1980, cited in Chapman, 1985) studied night-time rural accidents in South Australia. In this study 71 per cent of accidents were found to be single-vehicle accidents. Of the single-vehicle accidents, Johnston found that 92 per cent were run-off-road accidents. These accidents mainly occurred either on curves or hitting fixed roadside objects (usually trees). Other studies have shown that a proportion of single-vehicle accidents involve driver fatigue. Michon and Wertheim (1978) quoted the findings of Forbes who reported that in at least 13 per cent of single vehicle car accidents drowsiness or dozing was a determining factor.

The role of fatigue in Victorian fatal accidents involving trucks has been investigated in a recent study (Haworth, Heffernan and Horne, 1989). Based on Coroners' verdicts, fatigue of car or truck drivers was a contributing factor in 9.1% of the crashes. Based on the presence of factors such as extended driving hours, falling asleep at the wheel, comments about tiredness, driving right of centre and night-time driving, the authors estimated that fatigue contributed to 19.9% of the accidents. Fatigued car drivers were involved at least as often as fatigued truck drivers.

A set of accident vignettes based on the Coroners' reports are presented in the Appendix. The vignettes are based on fatal accidents to which driver fatigue contributed. All details of the accidents are authentic except the names of drivers and companies.

3.4 Methods of counteracting fatigue

A number of engineering methods for counteracting driver fatigue have been proposed. These include changing the road surface to include rumble strips which alert drivers by providing an audible warning. The countermeasures described here are those under driver control.

3.4.1 Limitation of hours of work

Ample evidence exists linking long hours of work with fatigue-related accidents. For example, Jones and Stein (1987) conducted a study of large truck crashes in the United States. They found that the relative risk of crash involvement for drivers whose reported driving time exceeded eight hours was almost twice that of drivers who had driven fewer hours.

In July 1988 the Australian Transport Advisory Council (ATAC) recommended changes in the driving hours legislation. To quote ATAC

> Ministers agreed on revised driving hours in the eastern States with enhanced log book information and the optional use of tachographs. The revised driving hours reflect modern industry conditions and allow a maximum 6 hours driving shift, 15 hours daily, 75 hours weekly and 150 hours fortnightly.

The effect of ATAC's recommendations would be to increase Victoria's present limits for hours of driving. The Victorian limit stipulates a maximum five hour driving shift, 12 hours daily and 72 hours weekly. As at December, 1988 the new national agreement had not been enacted in the state of Victoria so the five hour maximum shift was still current.

Under the proposed regulations while driving a vehicle for which a log book must be kept a driver can work for a maximum of six hours without rest. The driving hours include travel in any vehicle immediately before driving the work vehicle.

In addition to actual driving, 'driving hours' include time spent on all tasks connected with the trip that are carried out in the one session of work. This includes collecting and delivering the load, loading and unloading the vehicle, securing the load and any servicing of the vehicle completed by the driver.

Awareness of various State regulations and compliance with them is necessary if drivers are to be protected from work situations which lead to fatigue. In a survey of N.S.W. truck drivers Linklater (1978) found that the "critical point at which truck drivers' crash rates rose was 55 hours driving time in a typical week" (p.i). This finding provides evidence that keeping the total driving hours well below that specified in the regulations will reduce the likelihood of having a crash.

3.4.2 Regular rest stops

McPherson, McKnight and Oates (1984) developed knowledge and performance tests for heavy vehicle operators in the United States. With regard to measures to overcome fatigue they listed the following rules:

> Stop to Sleep: when your body needs sleep, that is the only thing that will work. If you have to make an enroute stop anyway, make it whenever you get tired, even if it is earlier than you planned. By getting up a little earlier the next day, you can keep on schedule without the danger of driving while you are tired.
>
> Take a Nap: If you can't stop for the night, at least pull off the road and take a nap. A nap as short as half an hour will do more to overcome fatigue than a half-hour coffee stop" (p.142).

Rest breaks are more effective when taken before the driver begins to doze at the wheel than once this stage is reached. A Swedish study showed that short rest breaks after the driver had fallen asleep at the wheel postponed falling asleep at the wheel again by only about 20 minutes (Lisper, Laurell and van Loon, 1980).

The regulations recommended by ATAC include the following prescriptions concerning rest stops. A rest period has a minimum duration of 30 minutes away from the vehicle. One rest stop of at least half an hour must be taken after six consecutive hours of driving and at least one period of five consecutive hours of rest must have been taken in the immediately preceding 24 hours. At least one period of 24 consecutive hours of rest must have been taken in the immediately preceding seven days. In addition, at least 48 hours comprising two periods of 24 consecutive hours each must have been taken in the immediately preceding fourteen days. For approved 'sleeper cab' vehicles time spent in the sleeping compartment is not regarded as time spent in driving if it can be proven that each of the two drivers has spent at least 24 consecutive hours resting outside the sleeper cab vehicle during the immediately preceding 96 hours.

These regulations stipulate the minimum rest which must be taken and it should be noted that more rest may be necessary to overcome fatigue on some driving journeys. Compliance with the regulations may not necessarily ensure that drivers are protected from having fatigue related accidents.

3.4.3 Use of radio to maintain alertness

In a survey conducted by the Traffic Authority of NSW (Webster, 1987), a commonly reported strategy to help overcome fatigue was listening to the AM/FM radio or CB radio. This was used to either 'sing along to' or talk to other drivers in a bid to stay awake. These results are in agreement with an earlier German survey (Prokop and Prokop, 1955, cited in Langlois, Smolensky, Hsi and Weir, 1985).

There is support from experimental studies that listening to the radio has some effectiveness in maintaining alertness. Fagerström and Lisper (1977) showed that listening to the car radio reduced the slowing of reaction times that occurred after several hours driving. But the benefit was greater for subjects classified as extroverts than those classified as introverts.

Hattori et. al. (1987) conducted an experiment in which vibration synchronised with music was used to help keep drivers alert. The results were as follows: "music stimulation was found to be effective to heighten the alertness level of driver subjects, but the duration of the effect was short because of habituation. The addition of vibrational stimulation synchronised with the music was judged to be more effective from the point of the effectiveness of the stimulation and the reduction of habituation" (p.249.2). The findings indicate that auditory stimulation can be useful in maintaining alertness but not for extended periods (where it would be more useful to rest).

Snook and Dolliver (1976) found recordings of "Newsweek", a current affairs magazine, to be more effective in helping drivers maintain alertness than recordings of background music of the type played on answering machine waiting queues. This suggests that listening to information which requires a higher level of concentration than that which is required for listening to background music is more stimulating.

3.4.4 Adequate cabin ventilation and changes in vibration

Many drivers state that they take steps to increase the circulation of cold air when feeling drowsy. Keeping the interior of the vehicle well ventilated and cool was recommended as a fatigue countermeasure by McKnight and Hume (1979) in their report to the U.S. Department of Transportation on Identifying Accident Avoidance Behaviours.

In assessing the effectiveness of adequate cabin ventilation as a fatigue countermeasure, the distinction must be made between its use to slow down the onset of fatigue (i.e., as a preventative measure) and its use to alleviate existing fatigue. There is evidence that the onset of fatigue is faster in hot than comfortable conditions (Mackie and O'Hanlon, 1977). This suggests that adequate cabin ventilation may be effective as a preventative measure. However, there is no experimental evidence that taking steps to increase the circulation of cold air will ameliorate a pre-existing state of drowsiness.

In their experiment Hattori et. al. (1987) found that exposure to whole body vibration, by which a driver felt a heightening of the lowered alertness level, helped severely drowsy drivers to maintain alertness for 2 to 10 minutes after removal of the vibration. Levels of constant vibration in heavy vehicles, particularly trucks, exceed these levels and may induce fatigue.

The Swedish National Board of Occupational Safety and Health have reported a series of studies on the effect of whole-body vibration on wakefulness (Landstrom, Englund, Nordstrom, and Astrom, 1985; Landstrom, Lundstrom, Soderberg and Englund, 1983). The studies conclude that constant stimulation is correlated with reductions in wakefulness and varying stimulation with alertness.

The studies reviewed suggest that constant vibration is likely to contribute to the development of driver fatigue but that changes in vibration, e.g., running over a pavement marker or hitting a pothole, may improve alertness.

3.4.5 Avoidance of driving if suffering from a sleep disorder

A driver who suffers from a sleep disorder has a much greater risk of falling asleep at the wheel. A driver who commonly experiences excessive daytime sleepiness should obtain a medical examination to determine whether he or she is suffering from a sleep disorder.

The insidious onset of sleep apnea and its most common occurrence in overweight, middle-aged males who have a sedentary lifestyle means that heavy vehicle drivers need to be informed about this form of sleep disorder.

Narcoleptic individuals may also be involved in a number of motor accidents as a result of falling asleep at the wheel. Progressive narcolepsy can occur at any age and the effects on driving can be very serious. Symptoms may be subtle at first, but become increasingly severe over the years.

The National Guidelines for Medical Practitioners in Determining Fitness to Drive a Motor Vehicle (Federal Office of Road Safety, 1988) state that "applicants with narcolepsy, whether adequately treated or not, cannot drive a passenger transport or heavy commercial vehicle safely because the risk of a crash is too great to accept should they run out of or neglect to take their medication" (p.7-3).

If fatigue occurs frequently or after short periods of driving it is advised that the driver have a medical examination to determine whether a sleep disorder is present. If it is, heavy vehicle driving is not recommended as a career.

3.4.6 Abstinence from alcohol, depressants and amphetamines

Not consuming alcohol, amphetamines or depressants while driving can help reduce fatigue. In the National Road Freight Industry Inquiry Report conducted by May, Mills and Scully (1984) it was concluded that alcohol usage by truck drivers was not a major truck safety problem in Australia. In contrast, informal discussions revealed that usage of amphetamines (stimulants) was widespread amongst long distance truck drivers. Although there is no official basis to the figures, a NSW survey found that 66 per cent of long-distance owner-drivers interviewed believed that 75 per cent or more of all long distance drivers use drugs to stay alert (Nix-James, 1977).

McPherson, McKnight and Oates (1984) made the following recommendation to heavy vehicle operators regarding drugs and fatigue.

> Avoid Drugs: There are no known drugs that can overcome being tired. While they may keep you awake for a while, they won't make you alert. And, eventually, you'll be even more tired than if you hadn't taken them at all" (p.142).

The use of alcohol before or during driving can induce fatigue because alcohol is a central nervous system depressant. Other medications which are mild depressants and so may cause drowsiness include cold tablets, hay-fever and allergy medications. Before taking any medication read the label to see it there is a warning that the medication may cause drowsiness.

With regard to drug use fatigue can be countered if individuals do not drive while impaired, do not combine alcohol and drugs, and do not drive after taking any drugs which cause drowsiness (including cough mixtures) (McKnight and Hume, 1979).

3.4.7 Moderate use of caffeine

Caffeine is a mild stimulant which is found in tea, coffee and cola beverages. Being a stimulant, caffeine ingestion can increase alertness levels. Whilst it is legal, readily available and economical to use, a caution must be made that excessive amounts can produce tolerance to the substance and dependency on caffeine to maintain normal levels of alertness. Generally this occurs in individuals who consume in excess of eight standard cups of coffee a day. In moderate levels the caffeine in coffee and cola acts as a mild stimulant and is not considered harmful. McKnight and Hume (1979) recommend drinking of coffee as a fatigue countermeasure.

3.4.8 Introducing variation in the driving environment

In a study of truck drivers' susceptibility to monotony, McBain (1970) observed that some drivers introduced irrevelant tasks into long-distance driving to help reduce monotony. Drivers' activities included spotlighting deer on the roadside, signalling to other drivers, and pointing out changes in the road and on construction projects visible from the road.

Drivers can learn behaviours to reduce the loss of efficiency associated with prolonged monotonous driving. Such activities add variation to the driving environment and helped drivers maintain alertness. It may be helpful to educate and encourage drivers to engage in behaviours to reduce monotony on long trips.

4 CONCLUSIONS

The following conclusions arose from the first section which addressed the issues relating to the provision of educational programs, including the need for such programs.

Both the road transport industry and government authorities perceive a need for both general education and specific fatigue educational programs for heavy vehicle drivers. Driver fatigue is a major occupational hazard for heavy vehicle drivers and the consequences are often accidents which can result in injuries or fatalities as well as lost income, higher insurance premiums and reduced employability.

An educational program designed to inform heavy vehicle drivers about fatigue and its countermeasures would attempt to reduce the risk of involvement in fatigue-related accidents. For the truck driver the reduction of such a major occupational hazard should result in safer working conditions, and potential major savings in monetary and health terms.

Owner-drivers often face a range of problems (including economic factors, oversupply, ease of entry into the industry and poor business skills) which can potentially add to the likelihood of driving while fatigued. Resistance to implementing fatigue countermeasures may arise as a result of these additional work pressures.

In overcoming this resistance educators need to acknowledge the reality of such constraints, the current attempts by the road freight industry to minimise these constraints, and the role heavy vehicle drivers may be able to play in effecting changes in the industry which could improve safety and other working conditions.

The additional conclusions of the second section which presented information about driver fatigue to provide the background material for development of the educational package are as follows.

Driver fatigue has proved difficult to define precisely but it is recognised as a contributory factor in some accidents. It is more likely to be associated with long hours of driving, without adequate rest periods, loss of sleep, food or drug intake and night driving.

Various methods are recommended to counteract fatigue. They include limitation of total driving hours, regular rest stops before fatigue sets in, avoidance of alcohol and drugs (although moderate use of caffeine is not harmful), use of radio to maintain alertness and adequate cabin ventilation, as well as introducing variation to the driving environment.

This report has provided information from which a driver education package regarding fatigue can be developed.

REFERENCES

Aldrich, C. K., Aldrich, M. S., Aldrich, T. K. and Aldrich, R. F. (1986). Asleep at the wheel: The physician's role in preventing accidents just waiting to happen. Postgraduate Medicine, 80, 233-5, 238, 240.

Brookhuis, K. A. (1988). Profession: Truck driver. In I. van Schagen (Ed.), Annual progress report 1987 Traffic Research Centre, University of Groningen (pp.73-75). Haren, The Netherlands: Traffic Research Centre, University of Groningen.

Brown, I. D., Tickner, A. H. and Simmonds, D. C. V. (1970). Effect of prolonged driving on overtaking criteria. Ergonomics, 13, 239-242.

Cameron, C. (1973). A theory of fatigue. Ergonomics, 16, 638-648.

Cavallo, A. (1987). A review of training for the heavy vehicle driver - Implications for road safety. Melbourne: Road Traffic Authority.

Chapman, P. (1985). Rural road accident study: Literature review (Working paper 2/85 Part 3). Adelaide: Road Safety Division, South Australian Department of Transport.

Colquhoun, P. (1982). Biological rhythms and performance. In W. B. Webb (Ed.), Biological rhythms, sleep and performance (pp.59-86). Chichester: Wiley.

Crawford, A. (1961). Fatigue and driving. Ergonomics, 4, 143-154.

Fagerstrom, K-O. and Lisper, H-O. (1977). Effects of listening to car radio, experience, and personality of the driver on subsidiary reaction time and heart rate in a long-term driving. In R. R. Mackie (Ed.), Vigilance: Theory, operational performance, and physiological correlates (pp.73-86). New York: Plenum.

Federal Office of Road Safety. (1987). Driver fatigue. In. Road crash statistics Australia. March 1987. Canberra: Federal Office of Road Safety.

Federal Office of Road Safety. (1988). National guidelines for medical practitioners in determining fitness to drive a motor vehicle. Canberra: Australian Government Publishing Service.

Fell, D. (1987). A new view of driver fatigue. Draft version. Rosebery, NSW: Traffic Authority of NSW.

Fisk, A. D. and Schneider, W. (1981). Control and automatic processing during tasks requiring sustained attention: A new approach to vigilance. Human Factors, 23, 737-750.

Goodman, L. S. and Gillman, A. (Eds.). (1965). The pharmacological basis of therapeutics. New York: Macmillan.

Grandjean, E. and Kogi, K. (1971). Introductory remarks. In K. Hashimoto, K. Kogi and E. Grandjean, Methodology in human fatigue assessment (pp.xvii-xxx). London: Taylor and Francis.

Harris, W. (1977). Fatigue, circadian rhythm, and traffic accidents. In R. R. Mackie (Ed.), Vigilance: Theory, operational performance, and physiological correlates (pp.133-146). New York: Plenum.

Hattori, H., Matsuura, Y., Narumiya, K., Araki, K. and Ohnaka, H. (1987). Effect of vibration stimulus in lowering alertness levels of drivers. Proceedings of the Fourth International Pacific Conference of Automotive Engineers (pp.249.1-249.10). Society of Automotive Engineers.

Haworth, N. L., Heffernan, C. J. and Horne, E. J. (1989). Information for development of an educational program to reduce fatigue-related truck accidents. Melbourne: Monash University Accident Research Centre.

Haworth, N. L., Triggs, T. J. and Grey, E. M. (1988). Driver fatigue: Concepts, measurement and accident countermeasures (Report No. CR72). Canberra: Federal Office of Road Safety.

Hertz, R. P. (1987). Sleeper berth use as a risk factor for tractor-trailer driver fatality. Paper presented to the Association for the Advancement of Automotive Medicine, New Orleans, September 1987.

Johnson, L. C. (1982). Sleep deprivation and performance. In W. B. Webb, Biological rhythms, sleep and performance (pp.111-141). Chichester: Wiley.

Jones, I. S. and Stein, H. S. (1987). Effect of driver hours of service on tractor-trailer crash involvement. Washington, D.C.: Insurance Institute for Highway Safety.

Kleitman, N. (1963). Sleep and wakefulness. Chicago: University of Chicago Press.

Landstrom, U., Englund, K., Lundstrom, R., Nordstrom, B. and Astrom, A. (1985). Changes in wakefulness during exposure to whole body vibration including strokes. The Swedish National Board of Occupational Safety and Health Investigation Report, 22, 1-29.

Landstrom, U., Lundstrom, R., Soderberg, L. and Englund, K. (1983). Changes in wakefulness during exposition to whole-body vibration. The Swedish National Board of Occupational Safety and Health Investigation Report, 22, 1-28.

Langlois, P. H., Smolensky, M. H., Hsi, B. P. and Weir, F. W. (1985). Temporal patterns of reported single-vehicle car and truck accidents in Texas, USA during 1980-1983. Chronobiology International, 2, 131-146.

Linklater, D. R. (1977). A profile of long distance truck drivers (Report No. 9/77). Rosebery, NSW: Traffic Authority of NSW.

Linklater, D. R. (1978). Traffic safety and the long distance truck driver (Report No. 8/78). Rosebery, NSW: Traffic Authority of NSW.

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

Lisper, H-O., Eriksson, B., Fagerstrom, K-O. and Lindholm, J. (1979). Diurnal variation in subsidiary reaction time in a long-term driving task. Accident Analysis and Prevention, 11, 1-5.

Lisper, H. O., Laurell, H. and Van Loon, J. (1980). Relation between time to falling asleep behind the wheel on a closed track and changes in subsidiary RT during prolonged driving on a motorway. Ergonomics, 29, 445-453.

Mackie, R. R. and Miller, J. C. (1978). Effects of hours of service, regularity of schedules, and cargo loading on truck and bus driver fatigue (DOT-HS-5-01142). Washington, D.C.: National Highway Traffic Safety Administration. (NTIS PB 290957)

Mackie, R. R. and O'Hanlon, J. M. (1977). A study of the combined effects of extended driving and heat stress on driver arousal and performance. In R. R. Mackie (Ed.), Vigilance: Theory, operational perform (pp.537-558). New York: Plenum.

May, T. E., Mills, G. M. and Scully, J. (1984). National Road Freight Industry Inquiry Report. Canberra: Australian Government Publishing Service.

McBain, W. N. (1970). Arousal, monotony and accidents in line driving. Journal of Applied Psychology, 54, 509-519.

McDonald, N. (1980). Fatigue, safety and the industrialisation of heavy goods vehicle driving. Human Factors in Transport Research, 1, 134-142.

McKnight, J. A. and Hume, R. D. (1979). Feasibility of developing training programs designed to improve deficient driver factors. Volume II: Identifying accident avoidance behaviors Final report (DOT HS-7-01811). Washington, D.C.: National Highway Traffic Safety Administration.

McPherson, K., McKnight, A. J. and Oates, J. F. (1984). Development of knowledge and performance tests for heavy vehicle operators. Volume II: Licence administrator/examiner manuals (DOT HS-806 689). Washington, D.C.: Department of Transportation.

Michon, J. A. and Wertheim, A. H. (1978). Drowsiness in driving. In Driver fatigue in road traffic accidents (EUR 6065 EN) (pp.62-71). Luxembourg: Commission of the European Communities.

Milner, G. (1972). Drugs and driving: A survey of the relationship of adverse drug reactions, and drug-alcohol interaction, to driving safety. Sydney: Australasian Drug Information Services Pty. Ltd.

Monk, T. H. (1982). The arousal model of time of day effects in human performance efficiency. Chronobiologia, 9, 49-54.

NODSS (Australasia) Inc. (undated). Narcolepsy: Information for patients and their families. Rosanna, Victoria: Narcolepsy and Overwhelming Daytime Sleep Society.

Naatanen, R. and Summala, H. (1978). Fatigue in driving and accidents. In Driver fatigue in road traffic accidents (EUR 6065 EN) (pp.26-32). Luxembourg: Commission of the European Communities.

National Roads and Motorists Association. (1986). NRMA Submission to the NSW Standing Committee on Road Safety. Part 6 - Heavy vehicle safety. Sydney: NRMA.

New South Wales Road Freight Industry Council. (1984). Submission to the Standing Committee on Road Safety re driver licensing. Sydney: New South Wales Road Freight Industry Council.

Nix-James, D. R. (1977). Self-reported alcohol and amphetamine usage by long-distance heavy-vehicle drives in New South Wales. In I. R. Johnston (Ed.), Proceedings of the Seventh International Conference on Alcohol, Drugs and Traffic Safety (pp.49-57). Canberra: Australian Government Publishing Service.

O'Hanlon, J. F. and Kelley, G. R. (1977). Comparison of performance and physiological changes between drivers who perform well and poorly during prolonged vehicular operation. In R. R. Mackie (Ed.), Vigilance: Theory, operational performance, and physiological correlates (pp.87-110). New York: Plenum.

Road Traffic Authority. (1988). Victorian bus and truck drivers' handbook. Melbourne: Road Traffic Authority.

Roberts, H. J. (1971). The causes, ecology and prevention of traffic accidents, with emphasis upon traffic medicine, epidemiology, sociology and logistics. Springfield, Illinois: Charles C. Thomas.

Ryder, J. M., Malin, S. A. and Kinsley, C. H. (1981). The effects of fatigue and alcohol on highway safety (DOT-HS-805-854). Washington: National Highway Traffic Safety Administration.

Scott, W. D. and Company Pty Ltd. (1983). Heavy vehicle driver training study. Final report. Sydney: NSW Road Freight Transport Industry Council.

Scott, W. D. and Company Pty Ltd. (1984). Report on operations and communications study of long distance owner-drivers in New South Wales. Sydney: NSW Road Freight Transport Industry Council.

Seko, Y., Kataoka, S. and Senoo, T. (1986). Analysis of driving behaviour under a state of reduced alertness. International Journal of Vehicle Design, 7, 318-330.

Siromath Pty Ltd. (1988). Attitude survey of truck drivers and operators (Report CR62). Canberra: Federal Office of Road Safety.

Snook, S. H. and Dolliver, J. (1976). Driver fatigue: A study of two types of countermeasures. In Proceedings of the Sixth International Conference of the Ergonomics Association, University of Maryland (pp.304-311). Santa Monica, California: The Human Factors Society.

Tilley, A. J. (1985). Recovery sleep at different times of the night following loss of the last four hours of sleep. Sleep, 8, 129-136.

Traffic Authority of NSW. (1982). Report of the Joint Working Party on Heavy Vehicle Safety. Sydney: Traffic Authority of NSW.

Vulcan, A. P. (1987). Bus and heavy vehicle safety: Setting the scene. Paper presented at the Truck and Bus Safety Seminar, Australasian College of Surgeons, Melbourne, November 1987.

Webster, K. (1987). Unpublished telephone survey of drivers within NSW. Rosebery, NSW: Traffic Authority of NSW.

Williams, G. W. (1963). Highway hypnosis: an hypothesis. International Journal of Clinical and Experimental Hypnosis, 103, 143-151.

APPENDIX. VIGNETTES OF FATAL TRUCK ACCIDENTS

Of the 186 truck accidents for which information was gained from the Coroner's Court, ten were chosen to be the base for accident vignettes. Of these ten, five involved fatigue on the part of the truck driver and five involved fatigue on the part of the car driver. All vignettes are true accounts of actual accidents. Only names of people and companies have been changed to protect the identity of those involved.

These reports were chosen on the basis that the Coroner had listed fatigue (or falling asleep at the wheel) as a factor contributing to culpability, and that the report contained sufficient information to warrant being written up as a vignette.

Equal numbers of vignettes depicting fatigued car and truck drivers (as identified by the Coroner) are offered as examples of actual fatalities due to fatigue. In the Coroners' reports the proportions of fatigued car to fatigued truck drivers was about 10 to 7. It is intended that these vignettes may be useful in both heavy vehicle education and more general road safety campaigns.

Vignette One

On a dry Wednesday afternoon in July, 1986, Patrick Haywood was driving a 1979 Diahatsu tray truck east along Strachans Road in the Mornington area. Patrick, who was 19 years old and held a probationary car licence, had with him a passenger, Maree Cole, who was a local resident. During the day Patrick had been engaged in hard physical labour and before driving he had complained of feeling tired. In the back of the tray truck he was carrying gardening tools. He was driving on a two-laned, straight, level road with clear visibility.

Shortly after 3.00 pm Maree, his passenger, noticed an elderly bicyclist travelling in the same direction as the truck. Just as she noticed the cyclist she realised that the truck was veering toward the cyclist. Maree called out. Patrick braked and steered to the right but still hit the cyclist and the truck then proceeded to go out of control. After skidding, the truck came to rest facing in the opposite direction from which it had come, at a distance of approximately 32 metres from the point of impact. The bicycle also came to rest here and its rider lay dead beside the truck. The pathologist reported the cause of death of Henry, the 83 year old cyclist, as being shock, haemorrhage, fractured ribs, fracture dislocation to the thoracic spine and contusion of the lungs. His bicycle incurred a dented rear wheel and mudguard, while the truck suffered impact to the front of the cabin and windscreen. No mechanical defects were found in the truck and neither Patrick or Henry were found to have positive blood alcohol tests.

Subsequent to the accident Patrick admitted to the police that he had momentarily fallen asleep at the wheel of the truck, which suggests that he was fatigued at the time.

Vignette Two

At 5.30 am on Friday, 20th December, 1985, Norman Duke was travelling north along the Hume Highway at Balmattum on a return journey from Wangaratta to Geelong. He lived in Wangaratta and drove a semitrailer for a resident of Peechelba, north-west of Wangaratta. The five-axle International semi had a gross weight of 38 tonnes and a tare of 16.2 tonnes.

The section of road on which Norman was travelling was two-laned, level and straight and the road surface was dry. Visibility was clear and the truck was in good mechanical condition. Norman had departed for Geelong on the previous day (Thursday) and had spent from midnight till 2 am on Friday morning unloading the truck, before commencing the return journey to Wangaratta. After three and a half hours night-time driving Norman's truck veered to the left off the road and travelled for a distance of approximately 75 metres before colliding with a tree. There was no evidence (such as skid marks) of firm application of the brakes at any time before the impact. No mechanical defects were found in the truck and a blood alcohol test on Norman proved negative.

Although there were no witnesses to the accident the length of continuous driving and working time, together with the non-usage of the brakes and absence of alcohol in his blood, suggests that 26 year-old Norman Duke was fatigued and had fallen asleep at the wheel. Norman was killed as a result of the accident. The prime mover was wrecked in the collision, with the main impact being to the bull bar. The cabin had become separated from the chasis.

The pathologist found that Norman's death had been caused by cerebral contusions and lacerations following multiple fractures of the skull. The Coroner found that the cause of death was accidental and that culpability was attributable to Norman Duke. The reasons given by the Coroner for this finding were inattention and fatigue.

Vignette Three

On a dry Tuesday evening in December 1985, Julie Davis, a 29 years old nurse who lived in Shepparton was driving north along the Goulburn Highway between Seymour and Murchison. During the day Julie had worked from 7 am until 3 pm. At 4 pm she left Shepparton and drove to Melbourne where she attended a lecture. At 11.30 pm that same Tuesday evening Julie was on the return journey to Shepparton.

As she was proceeding along a straight, level, two-laned section of the road with clear visibility, her car veered across the centre line. Coming in the opposite direction were two semi-trailers who were travelling in convoy at an estimated speed of 80 kph. Neil Cummings, who was driving the semi-trailer in front, saw Julie's car approaching on the wrong side of the road and took evasive action. Despite this, Julie's car struck the right-hand rear trailer wheels. Her car continued and collided with the second semi-trailer. As a result of the collisions Julie died. The pathologist found the cause of death to be shock and haemorrage due to multiple injuries and a fractured skull.

None of the vehicles involved were found to have mechanical defects. Neil Cummings was a resident of Berrigan, employed by a Finley truck company, and was transporting grain to Melbourne. The other semi-trailer was being driven by Matthew Payne, who was a resident of Coleambally, NSW and was transporting rice from there to Geelong. Neither of the semi-trailer drivers were injured in the collision with Julie's car. The length of work and travel time, the absence of alcohol in Julie's blood, the clear driving conditions and the fact that Julie's car veered across the centre line of the road, combine to suggest that Julie was fatigued and had fallen asleep at the car wheel.

The Coroner found the cause of death to be accidental. Julie was found to be culpable and the reasons given by the Coroner for this finding were fatigue and driving right of centre.

Vignette Four

Very early on a Monday morning in December, 1986 Frank Vise was travelling north along the Calder Highway on a return journey from Melbourne to his home in Sea Lake. He was 24 years old. Prior to driving to Melbourne on the Sunday Frank had been working very long hours for two days harvesting at Sea Lake. Just after midnight Frank was travelling in the Wedderburn area on a wet, two-laned, straight, graded part of the highway in his car. It was dark and raining and his car veered across the centre line.

In the opposite direction Michael Kearn was driving a Mercedes semi-trailer from Merbein to Melbourne. Frank's car had narrowly missed colliding with another semi-trailer travelling ahead of Michael and the driver of that semi had warned Michael of Frank's dangerous driving on the CB radio. When Michael saw Frank's car approaching it was on the correct side of the road. Then it sudenly swerved across the road onto the gravel. Michael steered his semi-trailer to the right to avoid a collision but Frank swung back towards his correct side of the road and collided head-on with the truck.

Frank was killed as a result of the impact. The pathologist found death was caused by shock from severe and extensive injuries. Michael, who was driving the semi-trailer, received minor injuries. Tests of blood alcohol concentration were found to be negative for both drivers and no mechanical defects were found in either vehicle. The frontal impact wrecked both vehicles. The car engine and body were demolished and the left-hand front wheel became separated. The main impact to the semi was in the front section with the front suspension and motor damaged. Michael's log book was found to be in order and it indicated he had left Merebin at 6 pm and had stopped at Ouyen for a half-hour rest-break at 8 pm.

The long working hours and driving time by Frank before the accident, the negative blood alcohol test and the erratic veering across the centre line, as was noticed by both Michael and another driver suggests Frank was fatigued. A friend expressed concern that Frank may have been too tired to drive before he left Melbourne for the return trip. It appears that Frank may have been dozing for brief periods while driving which would account for his veering across the centre line and his correction of the vehicle when he re-awoke.

The Coroner found that Frank contributed to the cause of his death. Culpability was also found to rest with Frank. The reasons given for this by the Coroner were Frank's driving right of centre and fatigue.

Vignette Five

Patrick Hamelin was travelling alone from Melbourne to Canberra on Tuesday, the 10th of April, 1984. He was aged 30 years and driving a Mazda sedan. This was his second long trip in three days and he had not had much sleep between trips. At 2.30 am he was driving along the Hume Highway near Eleven Mile Creek. The section of road was level, straight and two-laned. It was dark and the road surface was dry. At this point Ron Sanders was driving along the Hume in the opposite direction, in his Kenworth semi-trailer. The truck was owned by a large courier firm.

Patrick's car veered off the left-hand side of the road into the gravel. Patrick attempted to correct the car, skidded, and the car went out of control due to Patrick's over-correction. The car swerved across the centre line before being over-corrected again. It then swung back across to the correct side of the road and struck the railing of the Eleven Mile Creek bridge. During this time Ron took action in his semi to

avoid colliding with the out-of-control car. However, after Patrick's car hit the bridge it veered back across the centre line and collided with the semi-trailer.

Patrick was killed in the impact, as he suffered multiple trauma including a crushed chest and fractures to the vertebral column. His car disintegrated and was totally wrecked. Ron suffered no personal injury, but there was damage to his truck's bull bar. Both drivers were found to have negative blood alcohol readings.

The Coroner's finding was that the death was accidental. Culpability was attributed to Patrick and careless driving due to fatigue was reported by the Coroner. Patrick's long hours of driving appear to have led to him falling asleep at the wheel in the early hours of the morning. When his car moved onto the gravel it appears that he awoke, over-corrected , and the car went out of control.

Vignette Six

Donald Dickens of Crib Point was driving his Holden station wagon north along the Melba Highway on Thursday, the 16th August, 1984. Donald held a probationary license and was 19 years old. Prior to the trip he had been engaging in social activities. Max and Pam Higgins of Wangarratta were travelling south along the Melba Highway on their way to Melbourne. Max was driving a Ford Fairmont sedan. Brian Vern of Lilydale was also travelling south in his Dodge tray truck.

The section of the highway on which the three vehicles were travelling was two-laned, straight and level and the road was dry. Just south of Hunt's Lane in the municipality of Dixon's Creek at 4.50 pm Brian saw Donald's car drift across the centre line onto the wrong side of the road. Donald's car hit Brian's truck then apparently pivoted to the left before veering back to the incorrect side of the road and hitting Max's car. The Dodge truck, which received the first impact, was extensively damaged, however its driver, Brian, was not injured.

Donald suffered some injuries, while Max Higgins received fatal injuries. His death was identified by the Coroner as being due to extensive fracturing of the skull, traumatic brain damage, and extensive body fractures.

Both cars were in a wrecked condition following the impact. The Coroner found the death to be due to misadventure and identified Donald Dickens as having been culpable. Fatigue and driving right of centre were reported by the Coroner as the reasons for Donald's culpability.

At the scene of the accident Donald said that the accident was 'his fault' and that he 'thought he'd fallen asleep'. The evidence strongly suggests that fatigue was the cause of this fatal accident.

Vignette Seven

Allan Black was a 19 year-old owner-driver from Melbourne. He was driving a 1976 semi-trailer loaded with furniture. At 6.00 am on Thursday, 28th of February, 1985 he was driving south along the Hume Highway near Seymour, on a trip from Sydney to Melbourne.

He was on a freeway section of the Hume, and the road was graded and curved. It was dawn and Allan had been driving for an estimated 14 hours in the last 24 hour period. He had not filled in his log book for the Thursday, so there was no record of him having stopped for any rest breaks in the trip from Sydney.

Although there were no witnesses to his crash, it appears that Allan failed to take a left-hand bend in the highway and his truck veered across the the centre line and across the road. There was no evidence of any skid marks, which suggests that Allan did not use the brakes. After leaving the road the truck continued for over 40 metres before striking some trees. Allan was killed in the collision and his vehicle was completely wrecked.

The pathologist found the cause of death to be a gross fracture to the base of the skull with inhalation of blood. The Coroner found the cause of death to be accidental, and Allan was found to be culpable due to carelessness and possibly fatigue. The long hours of driving and Allan's failure to fill in his log book suggest that he may have been driving while fatigued.

Vignette Eight

William and Ted Murray of Thomastown were driving south along the Hume Highway in the Municipality of Seymour in the early morning on Wednesday, the 25th April, 1984. William was 21 years old and, although driving, he was unlicensed. They were in a Datsun sedan owned by Kevin Bowers.

Michael Jenkins, of Pearcedale, was also driving south along the Hume Highway in an International semi-trailer owned by a furniture removalist company. His vehicle was empty, and he was on a journey from Junee, in N.S.W. to Melbourne and return. He had been resting from 11.30 pm on the previous evening until 4.15 am on the Wednesday.

At 5.40 am Michael saw William driving along slowly in the left lane and he began to overtake. Overtaking conditions were safe as it was a section of freeway with clear visibility, no other traffic and a dry road surface. As Michael was overtaking William suddenly and without signalling, moved into the right lane. Michael braked and skidded but struck William's car in the rear. The car then went out of control, left the road and overturned several times.

William and Ted had not been wearing seatbelts. Ted was killed in the impact while William received less severe injuries. The pathologist found Ted's death was due to a fractured skull and brain damage. The Coroner found the death to be due to misadventure and culpability was found to rest with William Murray. The reasons listed for this were that he was unlicensed, inexperienced, affected by alcohol and fatigue, and had been driving right of the centre line without giving warning.

Michael Jenkin's truck was not damaged in the accident but the car was totally wrecked. This case illustrates how alcohol and fatigue can operate together to form a lethal driving combination.

Vignette Nine

Just after midnight on Friday, the 17th of July, 1984 Grahame Naines of Beaufort was driving a Kenworth semi-trailer west along the Western Highway around 20 kilometres east of Horsham. Grahame was 20 years old and carrying a load of insulation batts from Melbourne to Adelaide.

He had been driving for 25 hours in the previous 48 hour period. Grahame had left Melbourne at 7 pm the previous Thursday and had stopped for half an hour at Beaufort, at 9 pm.

Barry and Nichola Adams of Woodville, South Australia, were travelling east along the Western Highway on a trip from Adelaide. Barry was 20 years old and driving a Toyota Sedan. A third vehicle was travelling behind Barry and saw the crash which happened about ten minutes after midnight.

Grahame's semi approached Barry's car on the incorrect side of the road. The road was straight, level and two-laned. There were no skid marks, which suggests that Grahame did not use his brakes. His truck smashed head-on into Barry's car killing Barry and Nichola.

After this impact Grahame then applied his brakes, and left 49 metres of skid marks before eventually coming to rest. While skidding Grahame's truck grazed the other car which had been travelling behind Barry, and this car ran off the road and hit a tree. Barry's car received the main impact on the right-hand front side which was demolished. Grahame was not seriously injured in the crash.

The pathologist found the cause of Barry's death to be basal fracture of the skull with extensive inhalation of blood in each lung. The cause of Nichola's death was found to be bisection of the face and skull with partial removal of hair, multiple fractures of legs, pelvis, spinal column, ribs and sternum.

The Coroner found Barry and Nichola's deaths to be due to misadventure, with negligence on the part of Grahame Naines. Culpability was assigned by the Coroner to Grahame and the reasons given were failure to keep left of centre and fatigue.

Vignette Ten

On Wednesday, the 1st of May, 1985, at 11.40 pm Robert Adams was driving an International LPG tanker south on the Hume Highway in the Chiltern Municipality, near Black Dog Creek. Robert was 49 years old and a resident of Cambridge Park in NSW. The LPG tanker was fully laden with butane gas. Robert had left Sydney at 1.00 pm that day and had stopped in Yass for one hour between 6.30 and 7.30 pm. His total driving time during the trip had been nine and a half hours, which was in compliance with the driving laws.

Mark Pringle, an owner-driver from N.S.W., was driving his 1981 Kenworth semi-trailer north on a return trip from Sydney to Melbourne. Mark was 21 years old and had with him a passenger, John Fields, of Wodonga. Mark was carrying a load of paper rolls on his truck.

Mark had departed Enfield in Sydney, at 7.00 pm the previous day and had driven through to Melbourne. He had arrived in Melbourne at 11.30 am on the Wednesday, at a Fairfield depot. From 2.30 pm to 6.00 pm he was loading his truck at the depot before departing for Truck City to shower and have a meal. At 8.30 pm he departed Truck City for the return trip to Sydney. Another truck driver kept in contact with Mark on the return journey by calling him frequently on the CB radio to see if Mark was alright. It appears that this was a strategy Mark and his friend were using to try and help Mark stay awake. Mark had been working continuously for over 28 hours and his last period of five hours consecutive rest had been more than 30 hours previously.

The section of road on which Mark and Robert were travelling at 11.40 pm was two-laned, level, dry and curved. A witness saw Robert's tanker travelling south at a speed of approximately 100 kilometres per hour. A witness also saw a northbound semi travelling on the incorrect side of the road on a collison course with the tanker.

The witness saw the tanker's nearside wheels go onto the nearside gravel edge in an attempt to avoid the collision.

The semi-trailer and the tanker collided in a smash that completely wrecked both trucks. The tanker with its load of butane gas disintegrated. Both drivers and the passenger in Mark's semi were killed. The pathologist found the cause of death for Robert Adams to be multiple traumatic injuries principally to the upper thoracic cage. For Mark Pringle the pathologist reported a myriad of traumatic injuries with the body being literally torn to pieces. John Fields was found to have died from severe cerebral contusion, ruptured liver, pulmonary collapse and bilateral fractures of the femur.

The Coroner found Robert Adams and John Field's deaths were due to misadventure while Mark Pringle's death was found to be accidental. No culpability was assigned to Robert Adams. Police opinion regarding Mark Pringle's culpability was that he had not had sufficient sleep for 30 hours. The evidence from skid marks indicates that he had crossed over onto the incorrect side of the road and had forseen the accident situation too late.

Mark's driving schedule in the preceding thirty hours before his death suggests that he would have been suffering from fatigue at the time of the accident. He had been receiving assistance from another truck-driver to help him stay alert, by using the CB radio. Mark was young (21 years old) and an owner-driver in partnership with one other person. By not stopping to rest overnight, or at least complying with the hours of work regulations, Mark appears to have pushed himself beyond his capacities.