Fatigue, Work-Rest Cycles, and Psychomotor Performance of New Zealand Truck Drivers

Samuel G. Charlton
Waikato University, & Transport Engineering Research New Zealand Ltd

Peter H. Baas
Transport Engineering Research New Zealand Ltd

The goal of the present research programme was to find out how common driver fatigue is among New Zealand truck drivers and the degree to which they suffer from fatigue-related effects on their driving performance. To that end, 606 truck drivers were tested at a variety of sites throughout the North Island of New Zealand. The results showed that a considerable number of drivers are operating in excess of the hours of service regulations. The three fatigue measures in our survey indicated that there are significant levels of fatigue in the New Zealand transport industry. One out of four of the drivers' self-ratings of fatigue were in the "tired" range, even though many of them were surveyed at the beginning of their shift. A psychomotor test also indicated a very high level of fatigue in the sample. Overall, 24% of the sample failed the psychomotor performance criteria. Amount of rest and sleep, shift length, and number of driving days per week were all significantly related to psychomotor performance. The results of the daytime sleepiness inventory showed that the drivers in our sample had somewhat higher levels of daytime sleepiness than do heavy goods vehicle drivers in Great Britain. There was significant correspondence between drivers' self-ratings, psychomotor performance, and daytime sleepiness fatigue measures.

Brown (1994) has offered the following definition of driver fatigue: "*...the subjective experience of fatigue involves conflict between the desire to rest and the inclination (or perceived commercial pressure) to continue driving to their planned destination...The main effect of fatigue is a progressive withdrawal of attention from road and traffic demands...the withdrawal of attention will be involuntary and difficult, if not impossible to resist...Individuals so affected have been described as 'driving without attention' (DWA) because they are apparently oblivious to impending collisions..*(pp. 311-312)." The present study adopts the above use of the term driver fatigue, treating the phenomenon as a generalized subjective state resulting from a combination of task demands, environmental factors, arrangement of duty and rest cycles, and factors such as drivers' consumption of alcohol and medications. Of particular importance to the present study are the performance decrements in driving that arise from the psychological state of fatigue.

While it is difficult to quantify the contribution of driver fatigue to crash rates, a number of overseas studies have produced estimates. The state roading authority in Victoria Australia, has estimated that it is a factor in approximately 25% of all truck-related crashes (Vic Roads, 1995). In the United States, it is estimated that fatigue-related crashes in transportation claim over 15,000 lives and cost more than 12 billion dollars a year in lost productivity and property damage (Caldwell, 2000; Rau, 1996). Other estimates place the incidence of fatigue in commercial driver crashes somewhere between 1% and 56% depending on whether the estimates are from safety researchers, transport regulatory agencies, or coroner's findings (Mitler, Miller, Lipsitz, Walsh & Wylie, 1997). In New Zealand, The 1996 House of Representatives Report of the Transport Committee on the Inquiry into Truck Crashes found that: "*fatigue is likely to be a significant contributing factor in all types of crashes, not just truck crashes. Despite its importance, however, it is largely unrecognised as a problem in New Zealand.*" Estimates of the incidence of fatigue-related crashes vary widely, primarily because fatigue leaves no direct physical evidence at the scene of a crash and thus must be inferred from the circumstances of the crash and potentially unreliable reports from individuals involved (Summala & Mikkola, 1994). Nonetheless, it is generally acknowledged that fatigue is significantly under-reported in official crash statistics, and is a high-priority safety issue for the transport industry (Moore & Brooks, 2000).

Various subjective measures of fatigue and sleepiness have been developed. These have ranged from formalised expert observation (by trained driving instructors or traffic safety officers) to self-rating scales and activity inventories completed by drivers. The success of these measures has been mixed. While expert observations of driving behaviour, or of fatigue correlates such as facial symptoms, have issues of inter-observer reliability, they do appear to possess good sensitivity if the criteria for impaired driving can be appropriately defined (Brookhuis, 2000). The implementation of expert observation as a measure, however, is fairly intrusive and typically the knowledge that they are being observed has the effect of arousing drivers and masking their fatigue. Self-report inventories of sleep and fatigue have also met with mixed success. Some researchers have argued that drivers are not good assessors of their own momentary levels of fatigue (Bartlett, 1943 cited in Holding, 1983, Brown, 1994) with individuals tending to overestimate their levels of alertness (Rosekind et al., 1994). Recently, however, a number of researchers have found good correspondence between subjective sleepiness and driving impairment (Maycock, 1995, 1997; Neville, Bisson, French, Boll, & Storm, 1994). In a recent study of subjective sleepiness it was observed that "major incidents" on a driving simulator (all four wheels out of the lane) were preceded by self-awareness of increasing sleepiness as early as 40 minutes prior to the incidents (Horne & Reyner, 2000).

Fatigue has well-documented adverse effects on multiple aspects of cognitive and psychomotor performance. As a result, psychomotor performance tests of cognitive and behavioural impairment associated with fatigue have been among the most successful measures of fatigue to date. These psychomotor tests have included a wide variety of measures including digit-span, memory, vigilance, divided attention, and eye-hand tracking tasks. Of these tests, the vigilance, divided attention, and tracking tasks have enjoyed the greatest acceptance by researchers and industry professionals. Part of the reason for this acceptance is their clear relationship to the elements of driving. Tracking task performance closely parallels vehicle steering and lane-keeping abilities, while divided attention and vigilance tests correspond to the attentional demands of traffic and road conditions. In a series of studies of driver performance in driving simulators (Stein, Paraseghian, Allen, & Miller, 1992; Stein, 1995), fatigue effects were found to be manifested in reliably measurable changes in drivers' ability to maintain their vehicle in the proper lane, maintain appropriate speed, and their ability to divide their attention.

At present, the only measure in place in New Zealand with which to estimate the incidence and extent of driver fatigue is the examination of the driving hours in truck drivers' logbooks. Inasmuch as logbooks are used as the means of compliance checking for hours of service violations (drivers are allowed to drive a maximum of 11 hours in 24), and the fact that the recent Truck Crash Inquiry report recognised that the system is widely abused, there is a need to find alternative methods of determining the extent of the driver fatigue problem in New Zealand. The goals of the study were to find out how common driver fatigue is in the New Zealand transport industry and the degree to which truck drivers suffer from fatigue-related effects on their driving performance. Specifically, we set out to: 1) identify demographic and work/rest patterns, 2) collect information on drivers' attitudes towards fatigue and propensity towards daytime sleepiness for comparison with overseas studies of driver fatigue, 3) obtain self-assessments on drivers' momentary levels of fatigue, and 4) collect performance data on fatigue-related driving impairment.

Method

Participants

A total of 606 truck drivers participated in the study. Drivers were tested at a variety of North Island sites, including truck stops, depots, and ferry terminals in Northland, Auckland, Waikato, Bay of Plenty, Gisborne, Hawkes Bay, Taranaki, Wanganui, and Wellington. The number of drivers tested at each location and the number of rigid versus articulated trucks stopped was in approximate proportion to the fleet composition and distribution across the North Island as determined from Land Transport Safety Authority (LTSA) data. Drivers taking the test a second time and occasional drivers (e.g., farmers moving stock) were removed from the data set prior to analysis, leaving a total sample of 596 drivers. The average age of the drivers sampled was 37.05 years (ranging from 18 to 62 years, standard deviation of 9.84). Two of the older drivers declined to give their age. Driving experience averaged 13.43 years (ranging from less than 1 year to 42 years, standard deviation of 9.38 years). All but 6 (1%) of the drivers participating in the study were male.

Apparatus

The apparatus consisted of a questionnaire and psychomotor performance test. In order to minimise the disruptive effects of the survey on the drivers' schedules, it was desirable to make the testing protocol short enough to complete in 15-20 minutes at a variety of roadside locations. The demographic portion of the questionnaire contained approximately one dozen questions about the drivers' age, their years of professional driving experience, their type of employment, vehicle type, average workday length, and typical driving distances. The demographic questions were followed by three questions on the degree to which driver fatigue is perceived as a hazard to road safety, for purposes of comparison to prior studies (Hartley et. al., 1996) and in order to determine any relationship between these attitudes and driving schedules and driver performance.

The second page of the questionnaire contained a rating scale intended to capture driver estimates of their own levels of momentary fatigue. The fatigue scale was a seven-point, bipolar, equal-interval scale adapted from the USAF School of Aerospace Medicine Crew Status Survey (CSS) employed in studies of operator workload and fatigue in aviation and command and control systems (Charlton, 1996). The fatigue scale was followed by an activity survey which inventoried the drivers' time spent driving, sleep periods, timing of meals, physical exercise and freight loading duties, time spent engaged in any desk work, their rest periods, and any partying or drinking over the preceding 48 hours. This activity survey was also adapted from a USAF School of Aerospace Medicine instrument that was developed to study the activity and rest cycles of military personnel in extended-duration duties. (Neville, Bisson, French, Boll, and Storm, 1994)

The last page of the questionnaire contained eight questions on the degree to which the drivers were likely to feel sleepy in various situations. These questions, known collectively as the Epworth Sleepiness Scale, or ESS (Maycock, 1997), while not an indicator of a driver's momentary sleepiness or fatigue, have been shown to be a good indicator of overall sleep debt and have been used in several studies linking the likelihood of daytime sleepiness with accidents by car drivers and heavy goods vehicle drivers (Maycock, 1995, 1997).

The psychomotor performance test was based on hardware and software purchased from Systems Technologies Inc. of Hawthorne California. The hardware consisted of a Pentium™ computer equipped with a 34020 TIGA graphics board and 20 inch monitor for displaying the driving scenario; a Metrabyte M5312-4 optical encoder interface card, throttle/brake pedal controller and active steering controller providing force feedback; a sound board and amplified stereo speakers for presenting audio feedback and instructions to the participants; a VGA display card and 14 inch monitor for displaying control information to the experimenter; and a printer. The equipment was configured and installed in a caravan for transport and set-up at the data collection sites.

The software consisted of the commercially available Truck Operator Proficiency System (TOPS) testing software (from Systems Technologies Inc., see above). TOPS is based on a dual-axis sub-critical tracking task (maintaining speed and steering in a controlled but unstable environment, a virtual roadway affected by the appearance of random wind gusts requiring steering correction), and a divided attention or side-task requiring driver monitoring and periodic responses[1]. The divided attention events consisted of symbols presented in the side mirrors to which the driver responded by indicating for a left turn, right turn or pressing the horn button (as appropriate to the type of symbol displayed). The TOPS scenarios were modified to make them more relevant to New Zealand drivers (i.e., road markings, left-side driving, display of metric speedometer units). The resulting test scenario consisted of an eight-minute testing session composed of a straight road scene and 27 to 30 (depending on the driver's speed) divided attention events.

Calculation of pass/fail scores was based on five performance index coefficients (linear combinations of 40 performance variables) such that a driver's performance was transformed according to five performance indices and compared to established performance criteria for each of the indices. The development of the TOPS performance indices used expert judgements of driver performance and physiological measures of decreased alertness (i.e., EEG, EOG, and EMG) as criterion variables (Stein, 1995). The performance index algorithm was defined such that the resulting criterion would have a fatigued driver failure rate of at least 50% (correct detection of fatigued drivers) with a non-fatigued failure rate of 5% (failure by non-fatigued drivers) (Stein, Parseghian, Allen, & Miller, 1992; Stein, 1995). Although the criteria were composed of different weightings of the 40 performance variables, they can be characterised as focussing on the following five general categories: curvature error variability, divided attention response time variability, throttle activity variability, steering activity variability, and longitudinal speed variability (Stein, Parseghian, Allen, & Miller, 1992). A driver was required to obtain a passing score on each of the five performance indices in order to receive a passing score for the trial as a whole. As was the case in these original TOPS studies, data from the first two minutes block of the present test was excluded from the analysis.

Procedure

Prior to data collection, transport companies, dispatchers, or depot managers at a data collection site were contacted and the research program was described to them. During a data collection session the caravan was parked so that it was visible and accessible to drivers as they moved between their vehicles and the dispatchers' office, break room, or dining room. Individual drivers were approached by one of the experimenters who briefly described the purpose of the study and the time required to participate. In some cases, drivers approached the experimenters after conversing with the dispatcher or other drivers. Drivers expressing a willingness to participate were then shown the informed consent form guaranteeing confidentiality of their psychomotor test performance and responses to the survey questions. Drivers were asked to sign a copy of the form and then verbally administered the questionnaire by one of the experimenters. Completion of the questionnaire took 10-15 minutes and was followed by the psychomotor performance test.

The psychomotor performance test began by seating the drivers in front of the monitor and simulator controls and showing them how to adjust the truck seat so that they were comfortable and could easily reach the hand and foot controls. This was followed by presentation of a two-minute orientation scenario which automatically presented visual and auditory instructions on what to expect, practice in "driving" the simulated vehicle, and practice responding to the divided attention symbols. After completion of the orientation scenario the drivers were given a final opportunity to ask questions and the eight-minute performance test was conducted. All drivers were then thanked for their participation, provided with a Land Transport Safety Authority fact sheet on driver fatigue, and given a complementary chocolate bar. The performance-testing portion of the survey took 12-15 minutes to complete per driver. Drivers were sampled across the full range of duty shifts, ranging from 0 to 19 hours driven just prior to

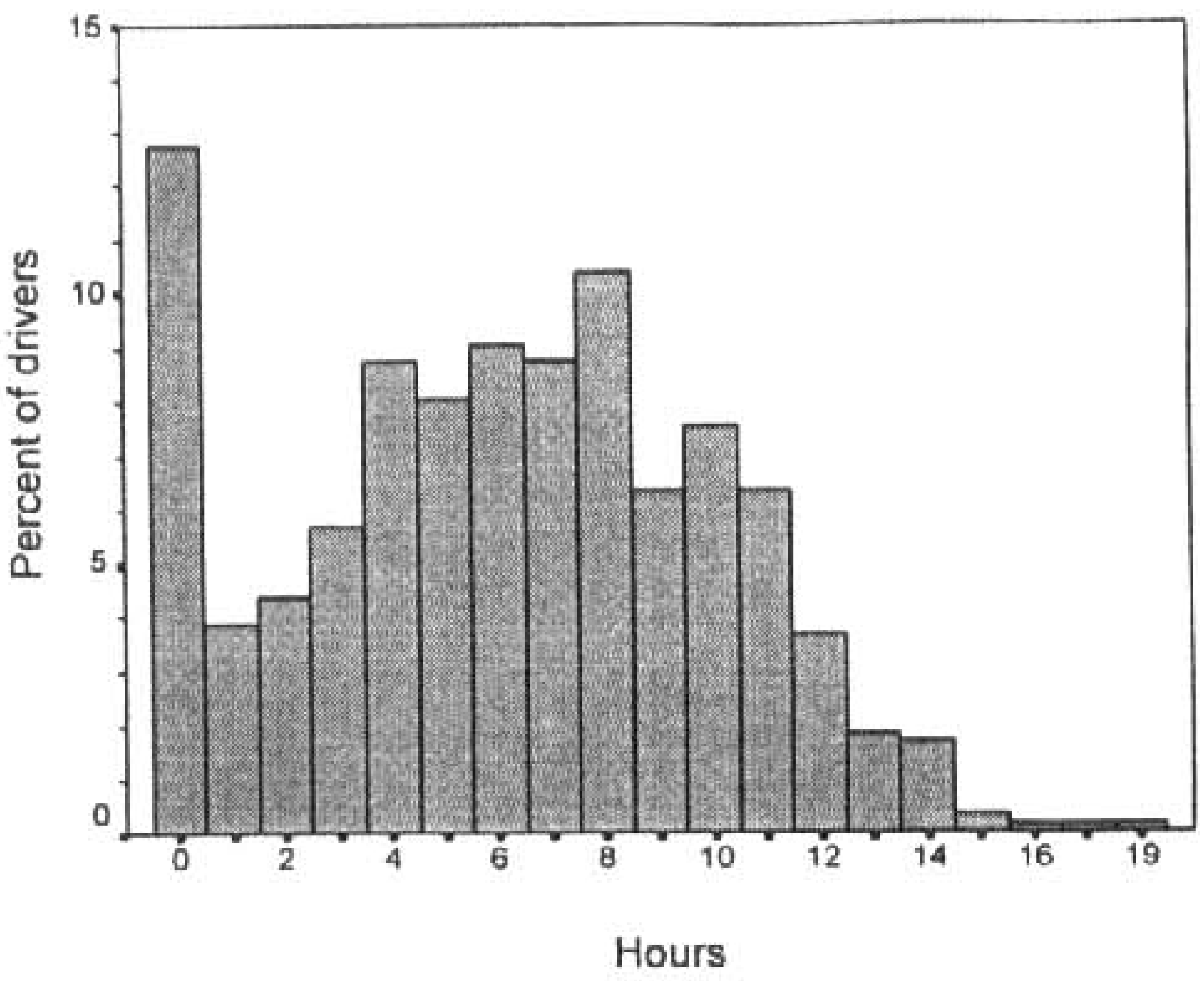

Figure 1. Hours driven prior to survey

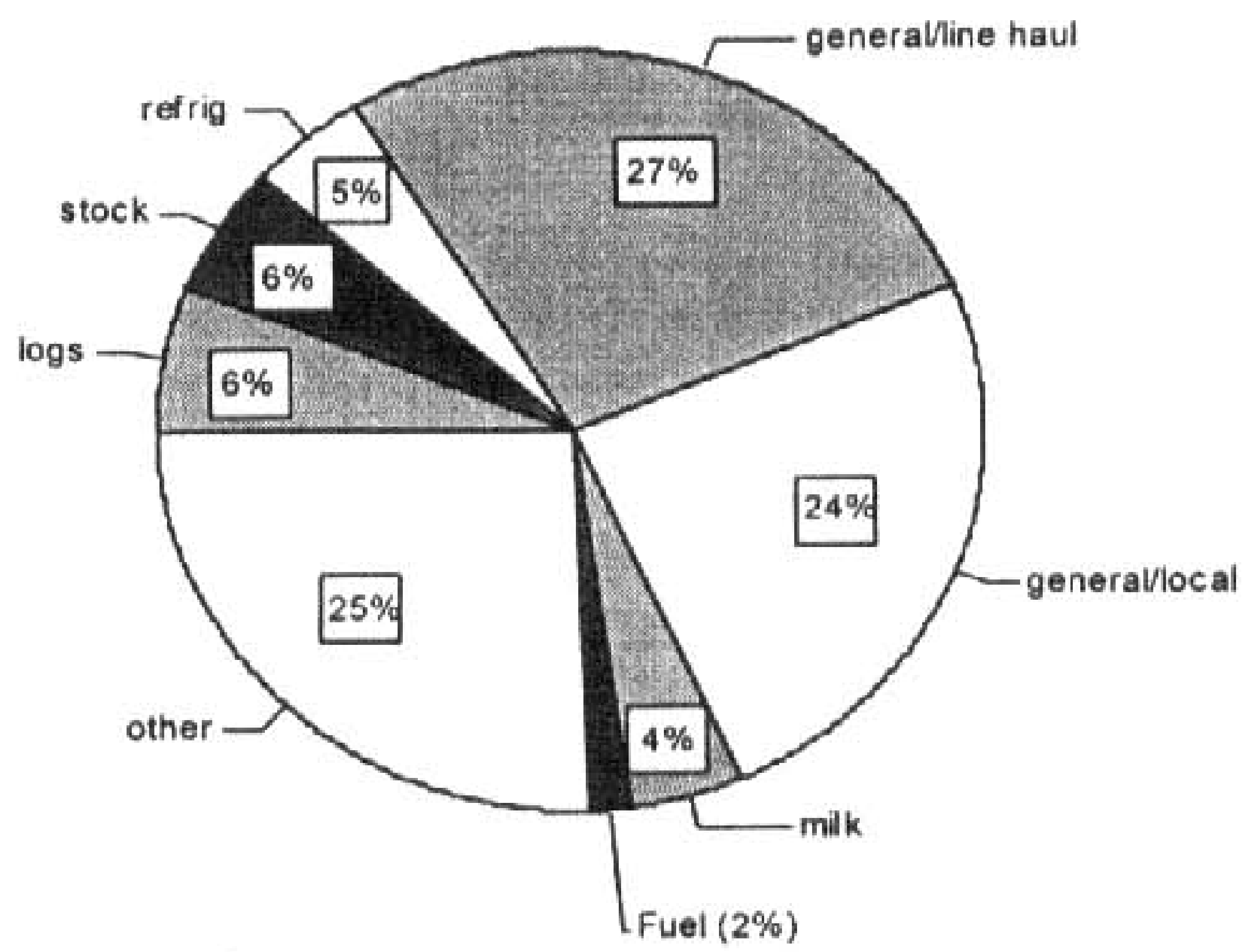

Figure 2. Freight types of participating drivers

testing (an average of 6.03 hours). The distribution of hours of driving immediately prior to participating in the survey is shown in Figure 1.

Results and Discussion

Driver and freight categories

Of the drivers sampled, 74% were company employees. The next largest category, owner-drivers subcontracting to one or more transport companies, comprised 17% of the sample. Drivers working for owner/drivers and freelancers made up 6% and 2% of the sample respectively. Figure 2 shows the percentage of participating drivers in each freight category. As can be seen in the figure, general goods (local and line haul routes) constituted the largest freight categories. Review of the individual survey forms showed that drivers indicating the "other" category were typically carrying bulk goods such as fertiliser or grain.

Driver activities and hours of service

The drivers reported an average of 5.35 days worked per week, (ranging from 0.5 to 7 days, std. deviation of .62). The drivers reported a typical shift length averaging 11.11 hours (ranging from 3 to 16 hours, std. deviation of 2.02 hours). Examining the driver activity data shown in Table 1, however, shows that the number of hours spent driving in the previous 24 hours ranged from 0 to 23 hours (an average of 8.98 hours, std. deviation of 3.99 hours). This latter statistic is shown in Figure 3, and as can be seen over 30% of the drivers sampled had exceeded their 11 hours of service maximum in the previous 24 hours. The total number of hours of driving in the previous 48 hours ranged from 0 to 45 (an average of 15.89 hours, std. deviation of 7.28 hours).

Figure 4 shows the median, inter-quartile range (25th to 75th percentiles), and the range of hours driving in the past 24 hours across the different freight categories. It can be seen that 50% of the logs, stock and line haul drivers exceeded 11 hours of driving in the past 24. Fuel drivers also had a median of 11 hours of driving, but the upper

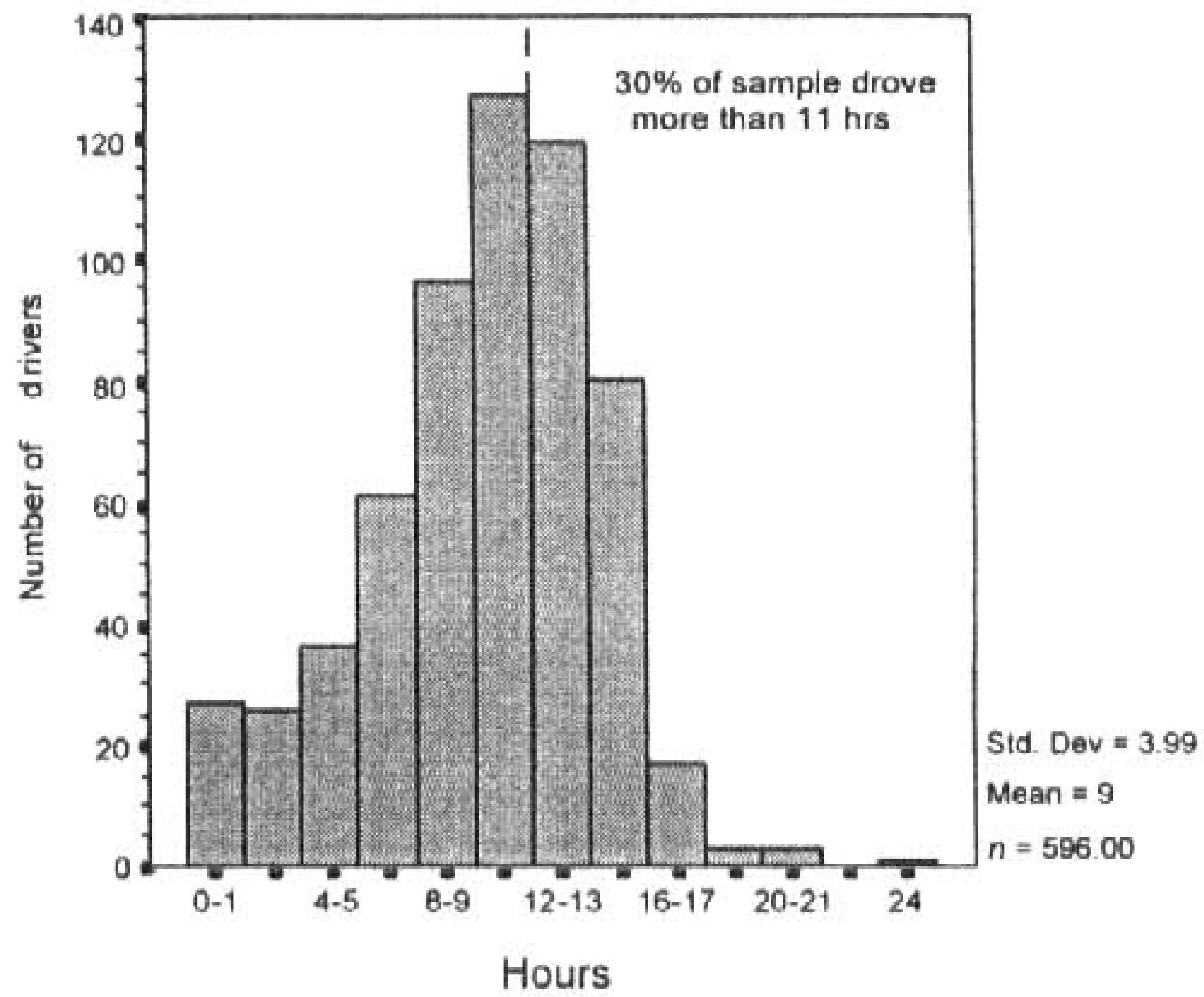

Figure 3. Hours of driving in past 24 hours

limit of their range was less than 12 hours. In contrast, 25% of the logs, stock, and line-haul drivers exceeded 13 hours of driving in the past 24. Examining the total number of hours on duty in the previous shift, the average was 10.50 hours (std. deviation of 3.44, ranging from 1 to an astonishing 37 hours), with 8% of the sample reporting shift lengths greater than 14 hours, the maximum allowed under the hours of service regulations. The average distance driven per shift reported by the drivers was 353.49 kilometers (std. deviation of 202.88 km).

The average amount of sleep reported for the past 24 hours was 7.24 hours (std. deviation of 1.72), although there were drivers reporting as little as 3 hours of sleep in the past 48 hours. In a complementary pattern to the hours of driving data, the logs and line haul drivers reported fewer hours of sleep than other drivers. Drivers of refrigerated freight reported the fewest hours of sleep in the past 24 hours (a median of 6.25 hours). Looking at the total length of their last sleep and rest period, the drivers reported an average of 12 hours (std. deviation of 3.62) with 11% of the sample reporting their last rest/sleep period was less than the statutory requirement of 9 hours.

Also of note was the relatively low number of meals reported by the drivers (an average of 1.90 meals in 24 hours, std deviation of .71). A typical pattern was for a driver to have one very large meal at the end of their shift with a few snacks in the break room or behind the wheel. Some drivers reported substantial hours spent in physical work or desk work, 10% of the sample reported more hours of physical work or desk work than driving over the previous 48 hours. When asked if they drove to a fixed company schedule, 45% of the drivers answered "yes." Eighty-six percent of the drivers said, however, that they could stop and rest when they wanted to. Finally, 73% of the drivers said that they loaded, or helped to load the freight they were transporting that day.

Table 1. Driver activity data

	Mean (hours)	*Std. Deviation*	*Minimum*	*Maximum*
Driving prior to survey	6.120	3.920	.00	19.00
Driving in past 24hrs	8.978	3.993	.00	23.00
Driving in past 48hrs	15.895	7.283	.00	45.00
Length of last duty shift	10.503	3.439	1.00	37.00
Sleeping in past 24hrs	7.241	1.723	.00	16.00
Sleeping in past 48hrs	14.688	2.947	3.00	27.00
Length of last sleep	7.267	1.782	1.00	17.00
Length of last rest & sleep	12.009	3.619	1.00	32.00
Physical work/exercise past 24hrs	1.242	2.300	.00	17.00
Physical work/exercise past 48hrs	2.702	4.217	.00	23.00
Desk work in past 24hrs	0.418	1.576	.00	15.00
Desk work in past 48hrs	0.810	2.759	.00	27.00
Relaxing in past 24hrs	3.940	2.925	.00	17.00
Relaxing in past 48hrs	8.746	5.760	.00	28.00
Partying in past 24hrs	0.216	0.937	.00	8.00
Partying in past 48hrs	0.555	1.844	.00	17.00

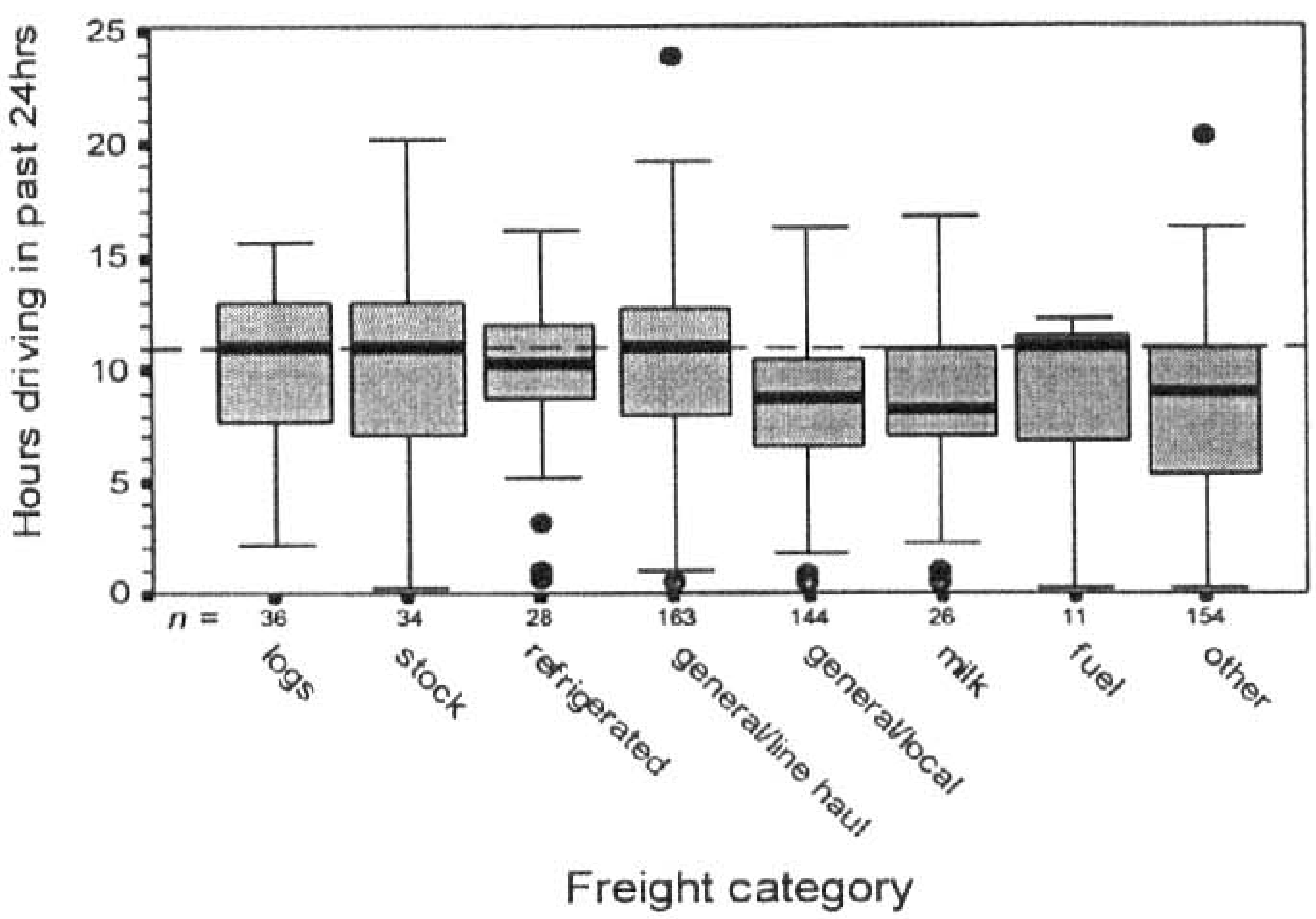

Figure 4. Hours of driving for each freight category

Note: Filled circles indicate outliers, data points further than twice the inter-quartile range from the median.

Fatigue measures

There were three fatigue measures included in the survey: the CSS self-report fatigue scale, the ESS daytime sleepiness inventory, and the TOPS performance test. The CSS self-ratings of fatigue ranged from 1 "*Fully alert*" to 7 "*Completely exhausted*" The median rating across all drivers was a 3, "*Somewhat fresh*" A stepwise multivariate regression analysis identified the 5 principal activity predicting the CSS self-ratings as follows: hours driven immediately prior to the survey, hours of sleep in the past 48 hours, hours of partying in the past 24 hours, whether or not they drove a night shift, and the number of hours of physical work or exercise in the past 48 hours (adjusted $R^2 = .123$, $F_{(5, 565)} = 16.95$, $p < .001$, stepwise criterion for inclusion was p = 0.05, maximum model size was limited to 5 predictors). There were no significant differences across freight categories in the CSS ratings. Drivers' ratings of how great a problem fatigue is for themselves and other drivers showed that most drivers in the sample thought that fatigue was a greater problem for other drivers than for themselves (see Figure 5). When asked if fatigue was dangerous for drivers, however, 63% of the sample answered "*always*" with 19% and 16% of the sample answering "*often*" or "*sometimes*" respectively. This is essentially the same pattern of results obtained in surveys of truck drivers in Western Australia (Hartley, et. al., 1996) where other drivers were seen having a problem with fatigue *always* or *often* by 35.8% of drivers, and *always* or *often* a problem for themselves by only 10% of drivers.

The results from the daytime sleepiness ratings are shown in Figure 6. The average ESS score in our sample, 6.13, was somewhat higher than the score of 5.70 reported for heavy goods vehicle operators in the UK. (Maycock, 1997). There was also good correspondence between the ESS ratings and the CSS ratings; Pearson's $r = .202$, $p < .001$. A stepwise multivariate regression analysis predicting ESS ratings from the activity measures identified length of last sleep, length of last rest and sleep, the hours relaxing in the past 48 hours, and the number of meals in the past 24 hours together significantly predicted drivers' ESS ratings (adjusted $R^2 = .070$, $F_{(4, 532)} = 11.12$, $p < .001$, stepwise criterion for inclusion was p = 0.05, maximum model size was limited to 5 predictors). There were no appreciable differences across freight categories observed for the drivers in our sample.

Of the 596 drivers in the sample, 450 met the performance criteria associated with the TOPS test (a failure rate of 24%). As shown in Figure 7, some types of freight category were associated with higher than average rates of failure. The figure shows that logs, stock, refrigerated, and "other" freight categories were substantially worse than average (the dashed line figure shows the overall failure rate), and that fuel drivers, with no failures, were by far the best. In order to address the question of which duty and lifestyle factors were most closely associated with TOPS failure rates, a stepwise discriminant analysis was calculated using the demographic and activity data as predictors. This analysis found two highly reliable predictors: driver age and the length of their last rest and sleep (Wilks' Lambda = .932, $F_{(2, 580)} = 21.31, p<.001$, stepwise criterion for inclusion was minimising overall Wilks' Lambda, p = 0.05 to enter, p = 0.10 to remove). Thirty-four percent of the drivers over the age of 37 (the average age in the sample) failed the performance test as compared to only 17% of drivers aged 37 or younger. Drivers reporting fewer than 8 hours of rest and sleep prior to that day's shift had a 30% failure rate on the TOPS test. In addition, the type of driving appeared to make a difference on pass rates; 28% of drivers working night shifts and 27% of drivers on short haul routes (250 km or less) failed the TOPS test (see Table 2).

Returning to the finding regarding driver age for a moment, 62% of the drivers who failed the performance test were over 37 years old. Drivers over the age of 37 displayed generally poorer and more variable driving performance as measured by vehicle heading error, speed, acceleration, and in the accuracy of their responses to the divided attention task (all important components of the TOPS performance criteria). A second stepwise discriminant analysis was calculated separately for drivers 37 years and younger and produced a different set of predictors; hours on duty on the previous shift, the amount of desk work in the past 24 hours, years of driving experience, CSS fatigue ratings, and the number of days driving per week, were significant predictors of passing or failing the performance test (Wilks' Lambda = .936, $F_{(5, 304)} = 4.14$, $p<.001$, stepwise criterion for inclusion was minimising overall Wilks' Lambda, p = 0.05 to enter, p = 0.10 to remove).

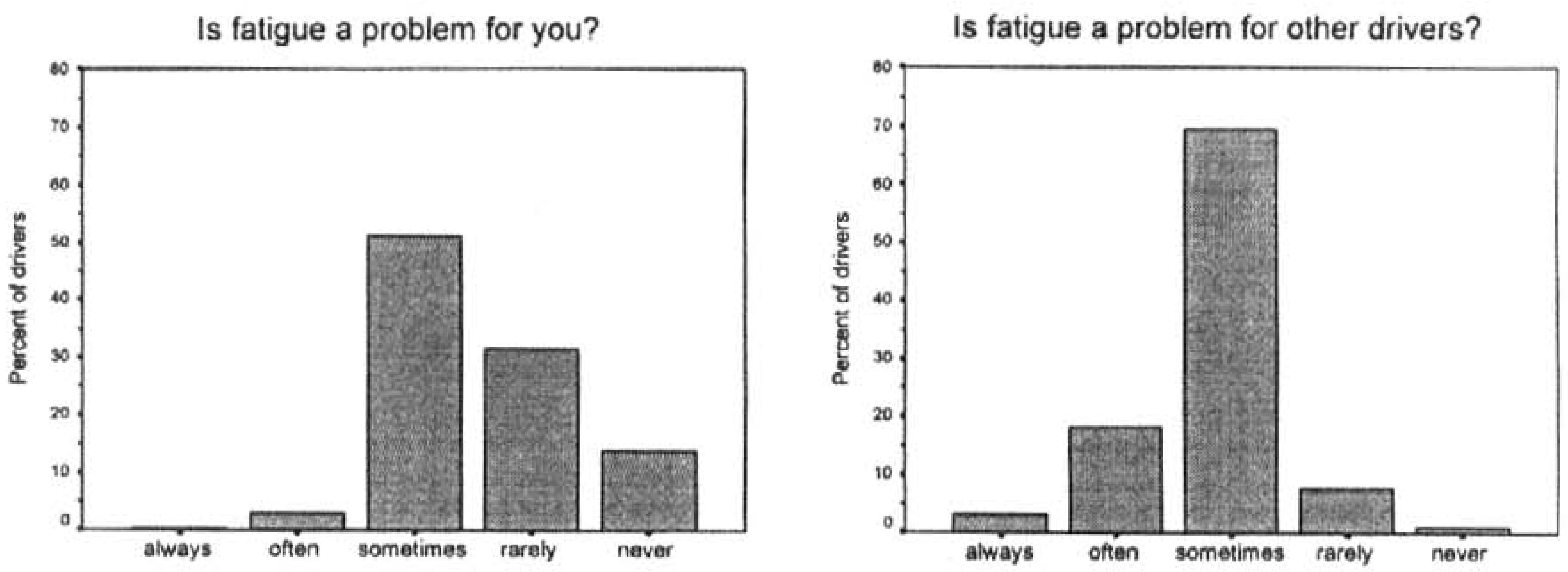

Figure 5. Ratings of fatigue as a problem for drivers

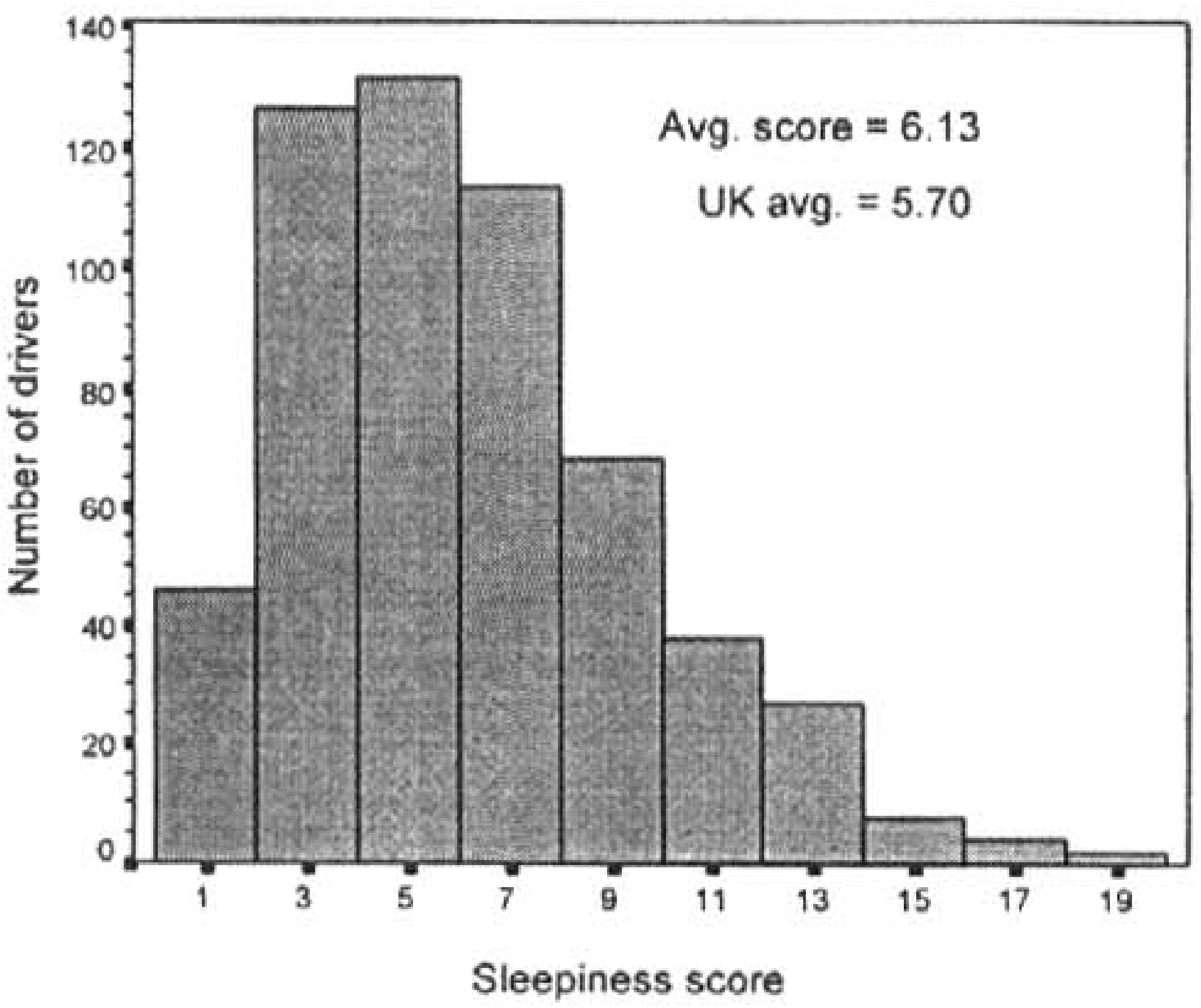

Figure 6. Epworth Sleepiness Scale scores

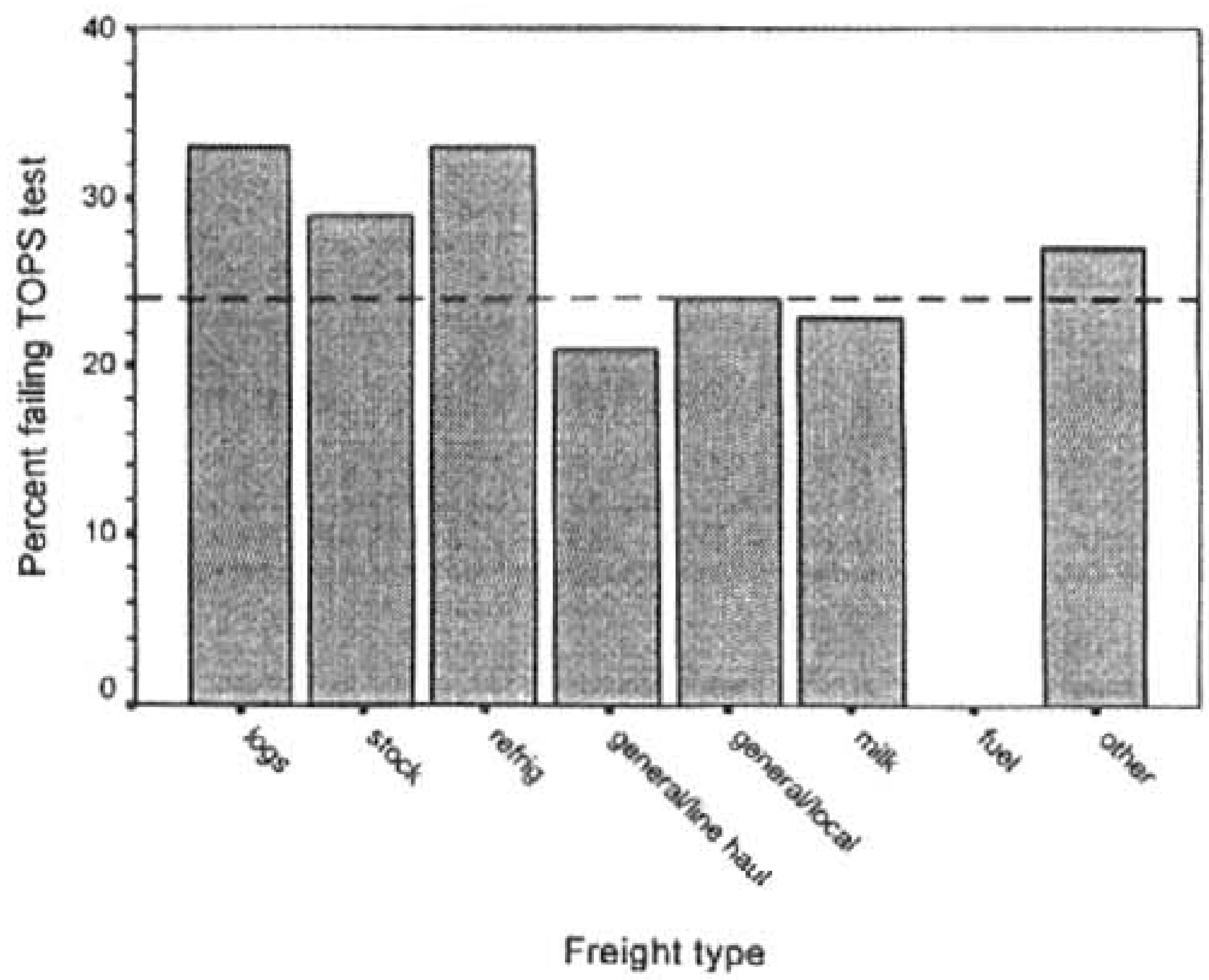

Figure 7. Psychomotor test failure rates for each freight category

Table 2. Psychomotor performance results

		No. of drivers	No. of failures	Percent failures
Driver age	> 37 yrs	268	90	33.6
	< 37 yrs	326	54	16.6
Length of last rest and sleep				
	< 8 hrs	36	11	30.6
	> 8 hrs	560	134	23.9
Type of shift	Night	60	17	28.3
	Day	532	128	24.1
Type of route	<250 kms	237	64	27.0
	> 250 kms	355	81	22.8
Freight category				
	Logs	36	12	33.3
	Stock	34	10	29.4
	Refrigerated	28	5	17.9
	Line haul	163	33	20.2
	Local	144	36	25.0
	Milk	26	6	23.1
	Fuel	11	0	0
	Other	154	43	27.9

General Discussion

The results of the activity inventory showed that a considerable number of New Zealand drivers are operating in excess of the hours of service regulations. One-third of the drivers reported driving more than the maximum of 11 hours out of 24. Some segments of the transport industry were worse than others, fully 50% of the logging, stock, and line haul drivers drove beyond the maximum allowable driving hours. Similarly, the logging, refrigerated, and line haul drivers all reported below average amounts of sleep. Many drivers reported a substantial number of hours of non-driving duties (physical work and desk work).

The three fatigue measures indicated that there are significant levels of fatigue in the New Zealand transport industry. One out of four of the drivers' CSS self-ratings of fatigue were in the "*tired*" range, even though many of them were surveyed at the beginning of their shift. The results of the ESS daytime sleepiness inventory showed that the drivers in our sample had somewhat higher levels of daytime sleepiness than do heavy goods vehicle operators in the UK. The TOPS psychomotor test also indicated a very high level of fatigue in the sample. Overall, 24% of the sample failed one or more of the TOPS performance criteria. In a pattern similar to that observed for the driving hours and sleep data, the logging, stock, and refrigerated freight categories had higher than average failure rates. There was good correspondence between the ESS, CSS, and TOPS fatigue measures. It is also noteworthy that for particularly "bad" segments of the industry (in terms of hours of driving and driving performance), there was relatively poorer correlation with self-ratings of fatigue, perhaps indicating that these drivers either weren't aware of their fatigue or were reluctant to admit it. Finally, as with results from Western Australia (Hartley, et al, 1996), the drivers in our sample typically felt that fatigue was more of a problem for other drivers than for themselves (although the majority did indicate that fatigue was "*always*" dangerous on the road).

Drivers with less than 10 hours rest and sleep, drivers on short routes (under 250 km per day), drivers on night shifts, and older drivers had higher than average failure rates on the TOPS test. It is not clear at this stage how to interpret the age effect in the psychomotor data. It could be the case that older drivers are more susceptible to fatigue, or that TOPS test could have captured a difference in the driving characteristics of younger and older drivers. While additional research would need to be performed to resolve the issue, analysis of the drivers' performance on the individual psychomotor measures would seem to argue against any age-related bias in the test.

Examining the comments of the drivers participating in the survey, it is apparent that the majority of those who failed knew their performance was bad even before the results of the TOPS test were made known to them. Typically, drivers would volunteer excuses or mitigating circumstances to explain why they performed poorly (or in some cases, anticipated their poor performance prior to taking the test). Some example comments from failing drivers included: "*very tired from delivering concrete tanks all day*", "*drove all day Sunday and was not used to it*", "*had a cold*", "*long hours*", "*long week*", "*sleeping badly because of family problems*", "*a new girlfriend*", "*hospital visit the night before*", "*was visiting Greenlane sleep clinic the night before and the breathing mask kept him awake*", "*worried about his truck parked outside*", "*company is 'stuffing up' his work schedule*", "*nervous ever since he rolled his truck four years ago*". As can be seen from the wide range of comments, failing drivers had a variety of reasons for their failure, but did not dispute that their fatigue test performance was poor (nor is there any reason to suspect that their performance on the road would not be similarly affected).

Taken together, these results portray a consistent (albeit disquieting) picture of the incidence and degree of fatigue to be found in the New Zealand Transport industry. It is clear that our current hours of service regulations are not effective in managing the levels of fatigue in the industry (and indeed are not particularly successful in terms of driver compliance either). There do appear to be some segments of the industry where fatigue education and awareness campaigns could be used to good effect, if the findings for the fuel drivers (which have a fatigue awareness programme) can be taken as an indication (good compliance with hours of service and excellent performance test results). Although there has been research linking ESS scores to crash rates (Maycock, 1997), no such statistical relationship yet exists for the TOPS scores.

As a next step we feel that it may be profitable to establish psychomotor performance criteria for the test by calibrating the present data set to psychomotor performance deficits observed for levels of blood-alcohol where the risk of crashes has been clearly established (Dawson & Reid, 1997; Fairclough & Graham, 1999). Further, it would be of interest to extend the work to other segments of the driving public. Other drivers, commercial and private, may suffer even greater adverse effects of fatigue if we reasonably assume that many of them will not possess the same skill levels as the professional truck drivers sampled in this study.

References

Brookhuis, K. (2000). Defining criteria for driver impairment. In *Proceedings of 4th International Conference on Fatigue and Transportation.* Western Australia: Institute for Research in Safety and Transport, Murdoch University.

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

Caldwell, J.A. (2000). Efficacy of stimulants for fatigue management: The effects of Provigil and Dexidrine on sleep-deprived aviators. In *Proceedings of 4th International Conference on Fatigue and Transportation.* Western Australia: Institute for Research in Safety and Transport, Murdoch University.

Charlton, S.G. (1996). Mental workload test and evaluation. In T.G. O'Brien and S.G. Charlton (Eds.). *Handbook of Human Factors Testing and Evaluation* (pp. 181-199). Hillsdale, New Jersey: Lawrence Erlbaum.

Dawson, D., and Reid, K. (1997). Fatigue, alcohol and performance impairment. *Nature, 388,* 235.

Fairclough, S.H. and Graham, R. (1999). Impairment of driving performance caused by sleep deprivation or alcohol: A comparative study. *Human Factors, 41,* 118-128.

Hartley, L. R., Arnold, P. K., Penna, F., Hochstadt, D., Corry, A., & Feyer, A-M. (1996). *Fatigue in the Western Australian transport industry. Part one: The principle and comparative findings.*

Holding, D. (1983). Fatigue. In R. Hockey (Ed.), *Stress and fatigue in human performance.* Chichester, England: John Wiley & Sons.

Horne, J.A. and Reyner, L.A. (2000). Sleep related vehicle accidents: Some guides for road safety policies. In *Proceedings of 4th International Conference on Fatigue and Transportation.* Western Australia: Institute for Research in Safety and Transport, Murdoch University.

Maycock, G. (1995). *Driver Sleepiness as a Factor in Car and HGV Accidents.* TRL Report 169. Crowthorne, Berkshire: Safety and Environment Resource Centre, Transport Research Laboratory.

Maycock, G. (1997). Sleepiness and driving. The experience of heavy goods vehicle drivers in the UK. *Journal of Sleep Research, 6,* 238-244.

Mitler, M.M., Miller, J.C., Lipsitz, J.J., Walsh, J.K., Wylie, C.D. (1997). The sleep of long-haul truck drivers. *New England Journal of Medicine, 337,* 755-761.

Moore, B. and Brooks, C. (2000). Heavy vehicle driver fatigue: A policy adviser's perspective. In *Proceedings of 4th International Conference on Fatigue and Transportation.* Western Australia: Institute for Research in Safety and Transport, Murdoch University.

Neville, K. J., Bisson, R. U., French, J., Boll, P. A., & Storm, W. F. (1994). Subjective fatigue of C-141 aircrews during operation desert storm. *Human Factors, 36,* 339-349.

Rau, P.S. (1996). *NHTSA's Drowsy driver research program.* Washington DC: National Highway Traffic Safety Administration.

Rosekind, M. R., Gander, P. H., Miller, D. L., Gregory, K. B., Smith, R. M., Weldon, K. J., Co, E. L., McNally, K. L., & Storm, W. F. (1994). Fatigue in operational settings: Examples from the aviation environment. *Human Factors, 36,* 327-338.

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

Stein, A. C., Parseghian, Z., Allen, R. W., & Miller, J. C. (1992). *High risk driver project: Theory, development and validation of the Truck Operator Proficiency System (TOPS). Volume 2: Report.* Hawthorne, CA: Systems Technology, Inc (Technical report 2417-1).

Summala, H., & Mikkola, T. (1994). Fatal accidents among car and truck drivers: Effects of fatigue, age, alcohol consumption. *Human Factors, 36,* 315-326.

New Zealand House of Representatives. (August, 1996). *Report of the Transport Committee on the inquiry into truck crashes.*

Vic Roads (1995, September). *Safety First, Victoria's Road Safety Strategy 1995-2000.*

Acknowledgements

We are particularly grateful for the time and support provided by the drivers that participated in the survey and the support provided by the many managers and organizations that allowed us to use their premises. They all provided their time freely and willingly, very much in the spirit of improving road safety. We were impressed by the level of interest in fatigue that exists within the industry. We are indebted to the efforts of our data collectors: Rob Emmitt, Ursula Kuhn, Alan Hall, Gary Bastin, Alister McKay and Mark Sullman. Finally, we would like to thank the Road Safety Trust for making this project possible.

Note

1. It should be emphasised that the TOPS apparatus is not intended to be a high- or even medium-fidelity driving simulation. The resemblance to the driving task is fortunate, as it affords a degree of apparent relevance to the participants, but the apparatus could as well be based on the part-task tracking and vigilance paradigms more commonly associated with laboratory studies.

Address for correspondence:

Samuel G. Charlton
Dept of Psychology
Waikato University
Private Bag 3105
Hamilton, New Zealand
Email: samiam@waikato.ac.nz