TRANSPORT RESEARCH LABORATORY

The factors that influence a driver's choice of speed — a questionnaire study

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Executive Summary

The speed at which drivers choose to drive is a major component of their behaviour on the road, and one that plays a major role in the frequency and severity of accidents. In-depth accident studies in the UK and the US have identified inappropriate speed choice as being one of the factors most frequently contributing to accidents, while a recent study of police reports in this country has shown that they record speed as a factor in up to a third of all accidents.

Considerable progress has been made in recent times in researching the relationship between speed and accidents at an aggregate level. However, the factors that influence the speeds adopted by individual drivers are less well understood, and there is a need for such information in order to develop more effective ways to modify drivers' speed choice. The objectives of this study are to identify those characteristics of a driver that are most influential in determining his or her choice of speed, and to explore the links between these characteristics, the speeds chosen, and the accidents in which the drivers are involved.

The study used a combination of on-road observation and survey techniques. The first stage consisted of taking unobtrusive speed measurements of a sample of free-flow vehicles on a variety of roads, and at the same time recording the vehicle registration numbers on video. Twenty-four sites were surveyed on a variety of roads in the vicinity of TRL. The second stage involved identifying the owners (and thus ultimately the drivers) of selected vehicles through the Driver and Vehicle Licensing Agency (DVLA). The owners of the sampled vehicles were then sent a self-completion questionnaire. This collected personal details of the driver, and information about the trip being undertaken when the vehicle was observed, as well as opinions about speed and speed limits.

The main part of the questionnaire comprised eight psychological scales on which the respondents were asked to rate themselves. Some of these scales were derived from earlier work in the behavioural studies programme, and others were constructed for the present investigation. The eight scales were: Decision Making Style; Mild Social Deviance; Violation Scale; Sensation Seeking; Intolerance; Driving Stress; Hazard Involvement; and Driving Style. A final section of the questionnaire obtained information on the numbers and details of accidents that the driver had been involved in over the last three years.

It should be noted that the sample of drivers used in this study do not represent a 'random' sample of UK drivers. Because the study was a study of speed choice, only drivers with more than a 3 second headway between themselves and the car in front were sampled. Also, to maximise the number of free flowing vehicles in the traffic stream, the speed surveys were carried out mainly during off-peak periods. The sample of sites used in the study excluded higher speed roads such as motorways, and because some drivers were to be invited to take part in later experimental studies, the sites were local to the Transport Research Laboratory. In addition, the effects of weather on speed could not be evaluated during the analysis independently of the permanent geometric and design features of the sites.

A further non-random element is introduced into the sampling as a result of the use of a postal questionnaire to collect personal data, since this technique will inevitably introduce some bias arising from the self selecting nature of the respondents who completed and returned the questionnaires. Nevertheless, despite these limitations, the sample of drivers obtained represents a significant section of the driving public.

Of the more than 5000 drivers in the sample, the faster drivers tended to be young, driving high annual mileages in large cars; they also tended to be travelling alone to or from work. While there are a variety of interacting factors which determine an individual driver's choice of speed, the largest single influence was the site characteristics, which accounted for over half of the variation in speed. Because of the dominance of the site to site variations, there is no meaningful relationship between *absolute* speeds and individual driver characteristics, and in order to detect associations between speed choice and individual characteristics it was necessary to use *relative* speed as the dependent variable.

A regression analysis of individual driver speeds relative to the site mean speed showed that the variables which best predicted the speeds of drivers were age (11% effect size) and annual mileage (2.7%). Overall, the difference between the sexes was not statistically significant. In the discriminant and logistic regression approaches used, age remains a very strong predictor of relative speed, whereas the relatively small effect of annual mileage became non-significant when other variables were included in the models.

When the psychological variables were used on their own to predict speed, the largest positive association arose from the violation scale (an 8% effect). Mild social deviance was also a positive speed predictor, and provided some additional explanatory power, though it ceased to be significant when age and other explanatory variables were added to the model. The sensation seeking scale was a significant positive correlate of speed for male drivers only. Out of the eight psychological scales used in this study, the violation, sensation seeking and stress scales appeared to be reasonably robust in all the analyses attempted.

Once age, annual mileage and trip frequency effects had been allowed for, speeds were influenced by the driver's occupational group and the following driving conditions: driving to or from work, driving without a passenger, and engine size of the car being driven.

Drivers were also asked to report the number of accidents in which they had been involved in the last 3 years. The results of modelling this data were very much in line with what would be expected from other recent accident studies. Thus, accident frequencies are strongly dependent on age and driving experience. Although in the earlier studies age and driving experience were fitted using a reciprocal relation, in the present case, a simple negative exponential proved to be an adequate descriptor of the age effect. As expected, both age and experience are very significant correlates of accident liability, as also is exposure.

Of the psychological variables included in this study, hazard involvement, driving style and violation score related to accidents for both male and female drivers, with driving style having the largest effect. Mild social deviance appeared to be significant as a predictor of accident liability for female drivers only, whilst decision making style was significant for male drivers only. There is no obvious explanation for these sex differences.

By using predicted speeds as an explanatory variable in the model of accident involvement it was possible to obtain an apparent relationship between speed and accidents. This relationship suggested that a 1% change in a driver's choice of speed is associated with a 7.75% change in accident liability. This apparent strong 'cross-sectional' association between speed and accidents does not necessarily imply a causal link between the two, and it cannot be assumed that reductions in speed by particular drivers (a 'within driver' effect) will necessarily result in accident reductions of a size predicted by this association. It seems probable that the association arises from the fact that both speed and accidents are related in similar ways to the same variables - particularly age, experience, and exposure.

1 Introduction

1.1 Speed and accidents

The speed at which drivers choose to drive is accepted as being not just a key indicator of driving style, but also as having a major influence on both the number and the severity of traffic accidents. This has resulted in a sizeable amount of research being conducted in an attempt to better understand the characteristics of this relationship and the underlying mechanisms through which it operates, in order to develop more effective measures for changing speed behaviour.

It seems logically reasonable to see speed as being involved in both the causes of accidents and in their consequences. The basic dynamics of an impact will determine that the outcome of an accident - in particular the severity of any resulting injury - will increase non-linearly with speed as the kinetic energy of impact increases. The causal pathways relating speed with the probability of having an accident are less clear-cut. However, it is certainly reasonable to hypothesise that higher speeds will mean shorter decision times which will in turn place greater demands on the perceptual, cognitive and judgemental abilities of drivers. Situational factors - such as the demands on drivers when overtaking - will also place greater demands on drivers when the speeds are higher, and in near-accident situations, avoidance strategies and recovery from perceptual and decision-making errors will be more critical. All these mechanisms would be expected to result in causal links (albeit complex ones) between speed and the likelihood of a driver becoming involved in an accident.

Attempts to quantify the size of the speed element in accident causation have produced a wide variety of results. However, there is general agreement that inappropriate speed choice is one of the factors most frequently contributing to accidents. For example, in-depth accident investigations conducted in the UK (Staughton and Storie, 1977; Sabey, 1983), identified excessive speed (or driving ‘too fast’) as a contributory factor in between 10 and 15% of all accidents studied. A major study in the US (Treat, 1980) found a generally similar pattern of results.

A more recent in-depth study conducted in the UK again highlighted excessive speed as an important contributory factor in accidents (Carsten *et al.*, 1989), while a review of contributory factors using a number of UK police databases suggested that speed plays a key role in accident causation, being identified as a factor in up to a third of all accidents.

A number of studies have attempted to model the link between speed and accident rates. However, in considering this relationship it is necessary to draw a distinction between two kinds of association:

i the relationship between the parameters of the speed distribution on a particular road and accidents on that road, with speeds and accidents aggregated over all drivers using the road, and

ii the relationship between the speed an individual driver typically adopts and the accident liability of that individual driver, averaged over all roads.

With regard to the former type of speed-accident relation, a recent review based on the findings of a large number of international studies has suggested that an increase of 1 mph in mean speed on a stretch of road can be expected to lead to a 5% increase in the number of accidents (Finch *et al.*, 1994). The analysis of the data, however, revealed that the mechanisms behind this relationship are in fact extremely complex.

Early studies suggested that it was speed variance rather than mean travel speed that determined accident rate (Solomon, 1964; Munden, 1967), possibly because the variance influences the rate of overtaking in a stream of traffic (Hauer, 1971). This would result in a U-shaped relationship between accident involvement and driving speed. However, more recent studies have failed to support the idea that slow drivers have high crash rates (Garber and Gadirau, 1988; Fildes, Rumbold and Leening, 1991).

In recent times, interest is increasingly being directed to studies of the second type referred to above, where the focus is on the individual driver. The aim has been to find some explanations for the statistical relationships established in the first type of study, and to use this knowledge as the basis for developing measures designed to modify drivers’ speed choice in such a way as to reduce accidents. The findings of these studies will be reviewed briefly in the next section.

1.2 Studies of speed choice

Much of the available information on the speeds chosen by drivers has been obtained from large roadside surveys. Typically these have used unobtrusive observation methods, though in some cases drivers have been stopped and asked to participate in a brief interview. To ensure that only genuine speed choices are recorded, observations are confined to free-flowing traffic. An early study by Smeed (1973) reported on speed measurements taken in four European countries. It was found that both driver age and driver sex were good predictors of selected speeds, with the young driving faster than the old, and males driving faster than females. Speeds also increased with vehicle power-to-weight ratio, and decreased with vehicle age.

Similar results were obtained by Herberg (1978), who suggested that the faster driver characteristically drives a powerful car, often for business purposes, and has a high annual mileage. Herberg also found that fast drivers are younger, and tend to have slightly higher accident rates, but found no significant sex differences.

A multiple regression analysis was undertaken by Galin (1981), in which a number of human, mechanical, traffic and environmental variables were studied. The results showed that driver age acted as a predictive variable for the speed of light vehicles, but not for heavy vehicles. Distance travelled before being observed influenced travel speeds, with the observed speeds of heavy vehicles being affected in this way three times as much as cars. Whilst vehicle age was found to influence the speeds of cars (with older vehicles travelling slower) no such influence was found for heavy vehicles.

An interesting result reported by Galin was that the regression equations for the 85th and 95th %ile speeds were substantially different. For instance, driver age and the percentage of male drivers affected the 85th but not the 95th %ile, while the number of occupants and journey purpose had no affect on the 85th %ile but did on the 95th %ile speed.

At General Motors in the early 1980s, Evans and Wasielewski (1982, 1983) had investigated close following behaviour in a series of large scale on-road studies. Wasielewski (1984) then developed this line of research further by using driving speed as a surrogate for risk-taking behaviour.

In line with earlier work, Wasielewski found that younger drivers adopted faster driving speeds. When a multivariate analysis was employed, there was no effect of sex on driving speed. Lone drivers tended to drive faster than accompanied ones, and regular users of the road tended to be faster drivers. Seat belt use, at least in the US at the time of the study, did not appear to influence driving speed. In terms of the vehicle, Wasielewski found that the slowest speeds were exhibited by light vehicles (<1600 kg), and that vehicles of intermediate and heavy mass were driven at higher speeds. The study also revealed that newer cars were driven faster.

An Australian study by Fildes, Rumbold and Leening (1991) set out to examine whether the profile of the typical fast driver might change depending upon the road environment. The authors studied two types of road (straight and curved) in two environments (urban and rural) and found - contrary to expectation - that the results from all four locations were remarkably similar.

In accordance with expectation, though, was the finding that driver age is a significant factor in speed choice. Younger drivers (those under 34 years of age) were more likely to be driving above the 85th %ile speed, and older drivers (those over 45 years of age) were more likely to be excessively slow drivers. However, the sex of the driver was not found to be a significant factor. There were other factors in this study that did have a significant effect on observed travel speed including vehicle age, type of vehicle, trip purpose, and the number of occupants in a car.

All these studies were consistent in finding an effect of age, with younger drivers tending to drive faster. Sex differences are less clear-cut, with some studies finding that male drivers tend to drive faster, and others failing to find an effect of sex. Vehicle age and the presence of passengers also recur in this literature as significant influences on speed choice.

In addition to these roadside surveys, there have been a number of investigations that have attempted to collect more information about the individual driver. Often, these studies have been concerned more with general aspects of driving behaviour than with speed choice itself. For instance, the selection of extreme speeds has been looked at in research projects investigating driving violations, either from a criminological viewpoint (Corbett and Simon, 1991) or when considering attitudinal influences (Parker *et al.*, 1992). These studies used survey techniques, where self-reported speed was the variable of interest.

Another approach, using relatively small numbers of subjects, has been to observe a driver's choice of speed while on a test drive, and then to relate this to the results of a range of laboratory tests (e.g. Quimby and Watts, 1981) or else to a variety of questionnaire scales (e.g. West, Elander and French, 1992, who also reported a small scale validation study of self-report against actual speed). Further still from 'real life' behaviour are those investigations that have used simulators to study speed behaviour (e.g. Hagan, 1975; Dorn *et al.*, 1992).

The variety of approaches adopted in the past is to a large extent a reflection of the methodological problems that confront researchers in this area. These will be addressed briefly in the next section.

1.3 Methodological issues

The objective of this project is to provide information that could be used to develop ways of changing the speed behaviour, and it sets out to do this by identifying those characteristics of a driver that are most influential in determining the choice of speed. In order to achieve this objective, it is necessary to decide on two issues: what data to collect, and how to collect it. The first question is surprisingly difficult. As well as driver characteristics, there are potentially many other factors that can influence a driver's speed and safety. Table 1 lists some of the factors that are known to influence different aspects of driving behaviour. Although it is reasonably extensive it does not represent a complete list, but serves to illustrate the complexity of this particular issue. A general understanding of the problem is further complicated by the likelihood of interactions between the various factors.

In the face of such a wide range of possibilities, one course of action might be to look for some form of theoretical structure to employ in guiding data collection. However, an examination of the dozen or so theories that could be relevant to speed choice indicates that no single theory or model is adequate, and points to the need for a more eclectic approach. An opportunity to do this has been provided by the output from the research carried out over the last decade in the behavioural studies programme (Grayson, 1997), where a variety of approaches have been deployed towards gaining a better understanding of the mechanisms underlying driver behaviour. Much of the work in the programme has been concerned with investigating the link between psychological factors and accident liability; the present study provides an opportunity to look at the relation between these factors and the intervening behavioural variable of speed choice. The variables selected from the programme for inclusion in the present study are discussed in Section 2.3.

The second methodological issue - how to collect data - inevitably involves an element of compromise. In order to relate individual drivers' choice of speed to their psychological and personal data, it is necessary to collect the observed on-road speed data and psychological information from the same group of subjects. Roadside surveys are capable of obtaining very large samples of drivers, but are usually restricted to investigating only those variables that can be derived from observation, such as age, sex, and vehicle type, or from very short interviews with drivers. At the other extreme, studies using instrumented vehicles or simulators can collect very detailed information, but are usually restricted to very small samples.

Table 1 Factors influencing driver behaviour

	Driver factors	*Other factors*	
Demographics	Age/driving experience Sex Exposure (annual mileage, type of road, light/dark etc.) Occupational group	Trip characteristics	Length Purpose Urgency
Visual ability	Static and dynamic acuity Visual field Field dependence	Car characteristics	Performance Comfort
Driving skill	Car handling ability Hazard perception Judgemental skills	Road environment	Road type Design speed Speed limit Enforcement levels Maintenance
Psychological factors	Risk tolerance Social/driving deviance Thrill/sensation seeking	Environmental factors	Presence of passengers Presence of pedestrians Time of day Signs/warnings Local knowledge Weather
Temporary states	Mood Fatigue Impairment due to drink or drugs Illness Speed adaptation		

The problem was overcome in the present study by collecting the information in two separate stages. The first stage consisted of taking single speed measurements of a sample of free-flow vehicles on a variety of roads, and at the same time recording the registration numbers on video. The second stage involved identifying the owner (and thus ultimately the driver) of the vehicle through the Driver and Vehicle Licensing Agency (DVLA). The owners of the sampled vehicles were then sent a self-completion questionnaire in order to collect information on a range of biographical, driving history, and psychological variables.

The use of a single speed measurement allows for a range of sites to be studied, with a small unit cost per observation. The assumption of consistency in speed choice implicit in selecting this procedure was deemed justified on the basis of evidence from earlier large scale field studies (Wasielewski, 1984) and more recent work in the behavioural programme (West, Elander and French, 1992). If one accepts this assumption, a further consideration is to define the meaning of 'free-flow'. Generally speaking, free-flow traffic is such that a driver is at liberty to choose his or her own speed, with no influence of either preceding or following traffic. Evans and Wasielewski (1982) suggest that vehicles travelling with a headway of 2.5 seconds or more can be considered to be driving at their preferred speed. The present study adopted three seconds as the criterion.

The use of self-completion questionnaires to study psychological variables is a well-established technique that has played a central role in the behavioural studies research programme in the last decade (Grayson, 1997). TRL has used the technique extensively in its investigations into accident liability (e.g. Maycock, Lockwood and Lester, 1991), and in a unique follow-up study has demonstrated the basic reliability of exposure and accident data collected in this way (Maycock and Lester, 1995).

In order to complement the survey data, a further phase of the study involved asking a number of the sampled drivers to attend TRL and undergo a series of accompanied test drives and to take part in a series of laboratory tests. This phase is reported in a companion volume (Quimby *et al.*, 1999).

2 Method

2.1 Sites and equipment

Speeds of vehicles were sampled at 24 sites in all on a variety of roads, but excluded motorways. Vehicle spot speeds were obtained by using a radar 'gun' positioned alongside the road. The radar was mounted inside an unmarked vehicle that was parked off the main carriageway (either in a lay-by or on a grass verge. Vehicle registration numbers of all passing vehicles were obtained from the same position using a video camera linked to a recorder. The equipment was not visible to drivers.

The video recordings were analyzed at a later date, when each vehicle's headway was measured from a counter on the playback machine. To simplify the video analysis, the vehicle speeds taken from the speed gun were superimposed onto the continuously recorded video image.

2.2 Sampling

Only cars were included in the study. Taxis and obvious business vehicles, such as Post Office vans, were excluded. So also were those drivers who had a headway of less than three seconds. The intention of this was to include only drivers who were driving at their personally selected speed. The three second criterion is a conservative one when compared to some other research (e.g. Evans and Wasielewski, 1982).

The vehicle registration numbers of the sampled cars were then sent to the Driver and Vehicle Licensing Agency, who provided the names and addresses of the registered keepers. These were then sent a questionnaire together with a covering letter. The letter informed the drivers of the date and time of observation and asked them either to complete and return the questionnaire if they were driving on the observed occasion, or else to pass the questionnaire on to the appropriate driver concerned.

It was only possible to sample traffic in one lane at a time. On multi-lane roads and dual carriageways the speed gun and camera were trained on each carriageway and on each lane in turn for equal periods of time so as to obtain a representative sample of vehicles from each lane.

Drivers were sampled according to their speed relative to the characteristics of the speed distribution at the particular site at the time at which they were observed. From the distribution of free-flow speeds, drivers in each of five speed bands were selected for inclusion in the study, as shown in Table 2 below.

Table 2 Driver sampling strategy in relation to observed speeds

	Speed range	*Sample*	*Proportion of respon -dents*
Band 1 (Fast)	Speed $\geq$ 85th %ile	All	18%
Band 2	70th %ile speed < 85th %ile	All	19%
Band 3	Around the median speed	3 out of 8	20%
Band 4	15th %ile < speed 30th %ile	All	20%
Band 5 (Slow)	Speed $\leq$ 15th %ile	All	23%

Because the drivers of particular interest in relation to individual speed choice are those in the upper and lower tails of the speed distribution, all drivers in bands 1,2,4 and 5 were included in the sample, but only a proportion of drivers in the 40th %ile band around the mean; in fact the same number of drivers as in each of the other four bands was sampled from this central band.

Because the registration numbers were not readable in the dark, it was not possible to include daylight/darkness as an experimental factor in this study.

2.3 Questionnaire

The questionnaire was designed to obtain information about a range of those factors regarded as likely to influence both speed and accidents, and that could be measured by means of a questionnaire. As mentioned earlier, when devising the scales intended to measure the psychological factors account was taken of those that have been effective in recent behavioural studies.

The questionnaire (see Appendix) was structured into five sections.

The first section (Q1-Q5) asked about factors which were relevant to the particular journey being made when the driver's speed was measured. These factors were: the purpose of the trip, information about any passengers being carried, vehicle ownership, and engine size. The second section (Q6-Q9) asked respondents for their views about the behaviour of other drivers, about the seriousness of specific speeding offences, and about the probability of being stopped by the police for speeding.

Section 3 of the questionnaire (Q10-Q14) asked drivers to assess their own driving. In particular, respondents were asked to rate themselves as faster or slower than other drivers, about the frequency with which they were prepared to exceed the speed limit, and about the reasons for infringing the limit. A question intended to elicit their views about what kinds of measures might cause drivers to drive more slowly was also included in this section.

The central part of the questionnaire (Q15-Q19) consisted of 57 separate behavioural and attitudinal items. Many of these items were drawn from scales that had been used in previous behavioural research, together with other items added to cover new constructs. In all, eight scales were used, as set out below.

1 Decision making style: This scale was taken from French *et al.* (1993), who have established a relation between aspects of decision making in everyday life and road accident involvement.

2 Mild social deviance: A scale of general anti-social motivation developed by West *et al.* (1992), and shown by them to be associated with the risk of accident involvement.

3 Violation scale: Reason *et al.* (1991) developed a scale measuring a driver's self-reported frequency of committing traffic violations (including speeding), which has been linked to accident liability.

4 Sensation seeking: Previous research on the motivational aspects of driving (e.g. Naatanen and Summala, 1974) has suggested that speed might be influenced by a driver's desire for excitement. Questions on 'sensation seeking' were therefore included in the questionnaire.

5 Intolerance: A link between intolerant attitudes and accidents has been postulated for many years, while more recently there has been interest in the role of Type A behaviour (e.g. Perry, 1986). Some questions were added to explore this possibility.

6 Driving stress: In a similar vein, questions were included relating to the stress perceived by drivers in order to test the hypothesis that stress and speed (and accidents) are related.

7 Hazard involvement: A link between hazard perception and accident liability has been established by Quimby *et al.* (1986), based on responses to filmed events in a simulator. A new scale termed 'hazard involvement' has been constructed for the present study, asking how frequently drivers find themselves in hazardous situations as a result of perceptual failures.

8 Driving style: This scale was an abbreviated version of one developed by Guppy (1993), and subsequently found to be of value in the analysis of the TRL cohort study of novice drivers (Maycock and Forsyth, 1997).

The final section of the questionnaire (Q20-Q38) obtained information about accidents and offences and elicited some personal details about the drivers. Accidents were defined as any incident which occurred on a public road and which involved injury or damage to property. Accident involved drivers were asked to provide details of the accidents they had experienced in the last three years, giving the date, the lighting conditions at the time of the accident, the type of road on which the accident happened and details of other road users or objects involved.

In making the link between speeds and accident liability, it is important to bear in mind that whereas accident liability is a representation of the propensity of a driver to become involved in accidents averaged over both space (the road network) and time (3 years), the objective speed measure obtained in this study has been measured at one point on the network at a unique moment in time. The assumption in attempting to relate these two quantities is that the single measure of individual speed choice is in some way a behavioural manifestation of that individual's cognitive, social, attitudinal and motivational characteristics which not only determine his or her choice of speed, but also driving behaviour more generally.

3 Results

3.1 Response rate

Questionnaires were sent to 9,453 registered keepers of observed cars. Reminder post cards were sent out to non-responders after about 3 to 4 weeks. Table 3 shows the response rate achieved by the survey. Over 500 questionnaires were returned, either by the Post Office or the home owner, with a message stating that the addressee was not available or unknown, possibly because the person had changed address and not notified DVLA.

Table 3 Questionnaire responses

	No reminders	*Reminders sent*	*Total*
Valid responses	4526	554	5080
Driver not available	522	31	553
No response	413	3407	3820
Total	5461	3992	9453

Table 3 shows that the response rate for the return of valid questionnaires before reminders were sent was 47.9%, which is quite low compared with other recent TRL surveys. The poor response may have been something to do with the length of the questionnaire, the length of time that could have elapsed before the questionnaire was received (although this period was kept to a minimum), the possible sensitivity of some questions, or because some drivers may have felt that being selected by on-road observations was an invasion of their privacy.

The response to the reminder cards was particularly poor, making this an ineffective way of increasing the sample size, although some of the reminders will possibly have been sent (again) to inappropriate addresses as a result of DVLA records not being up to date.

It is impossible to evaluate the effect of the low response on the analyses to be presented in the following sections, but it is necessary to bear in mind that the sample of respondents was never intended to be representative of all licence holders or car drivers. Even if the response rate had been higher, the sample sent questionnaires was limited to drivers actually observed on the road largely during off-peak hours and constrained also by the sampling strategy described above.

Because of instances of missing data, the number of respondents available for inclusion in the analyses to be described in the following sections will be less than the maximum number given in Table 3 and will vary from analysis to analysis.

3.2 Psychological scales

As mentioned above, the psychological scales were based on drivers' responses to questions 15 to 19. The items in this section were in part drawn from scales used in recent behavioural research, with the remainder being original. In order to construct the scales to be used in the analysis, the raw response data was subjected to a factor analysis. The resulting scales were assessed for reliability using Cronbach's Alpha. Ineffective items were dropped until each scale reached an acceptable level of internal consistency (with an Alpha value of about 0.6 or better for 6 items). The resulting scales used in the analyses are shown in Table 4 which gives the number of items in each scale and the value of Cronbach's Alpha. The table also shows the mean value for the scale and range of scores observed.

Table 4 Psychological scales

Scale identifier	*Description*	*Number of items*	*Cron-bach's Alpha*	*Mean score*	*Range of scores*
DECISION	Decision making style	5	0.58	18.9	6-25
MSD	Mild social deviance	10	0.73	12.5	10-30
VIOLATE	Willingness to commit driving violations	9	0.73	15.9	9-35
SENSAT	Sensation seeking propensity	7	0.68	8.4	7-32
INTOL	Intolerance	7	0.75	11.2	7-29
STRESS	Driving stress	4	0.65	5.7	4-17
HAZARD	Hazard involvement	9	0.63	11.5	9-25
STYLE	General driving style	6	0.77	14.0	9-35

In all cases, the 'sense' (or direction) of the scales shown in Table 4 is that the higher the score the 'worse' the driver's performance from the road safety point of view. Thus, for example, a high score on the decision making scale will mean the driver does not plan well ahead, does not make decisions carefully, and often changes his or her mind after having made a decision. A high violation score will mean that the driver is likely to report committing the various violations included in these scales more often than those with lower scores. A high score on the hazard involvement scale will mean that the driver relatively often becomes involved in hazardous situations - for example, misjudging gaps in main road traffic or swerving suddenly to avoid an accident. A high driving stress score means that drivers find driving stressful - for example, they get flustered when too much is going on at once, and they relatively often get into situations in which they find it hard to cope.

The driving style scale is rather different. Respondents were asked to describe their driving style using six bipolar scales (a subset of the scales originally proposed by Guppy *et al.* (1990) that had been found to be of value in the TRL cohort studies of novice drivers (Maycock and Forsyth, 1997). The scales were presented with contrasting descriptions of the driving style characteristics at each end of a segmented scale, and the respondents asked to put a tick somewhere on the line at a point which corresponded to their assessment of their own driving style. For example, the scale representing patience was presented as follows:

Patient :__:__:__:__:__:__:__: Impatient

The resulting scores (1 to 7, but reversed where necessary) when factor analyzed gave a two-factor solution identical to that found in earlier studies in which this scale was used (Forsyth, 1992). The two factors combine the following qualities - Factor 1: attentive, careful and safe, and Factor 2: placid, patient, tolerant. For the present study, since these two factors are themselves correlated with each other, they have been combined into one scale. Low scores on this scale correspond to drivers who consider themselves as attentive, careful, patient and tolerant, whilst high scores correspond to drivers with the opposite characteristics.

3.3 The sample

Although 5080 drivers returned completed questionnaires, not every driver provided information on every questionnaire item. The numbers of drivers in the analyses varies because of such missing data. Tables 5 - 7 show how the sample of respondents is distributed by age, sex, driving experience and annual mileage.

Table 5 shows the average ages and the distribution of the sample of drivers by age group (in five bands) for male and female drivers. Overall there is a fairly even spread of ages, though there are rather more young women drivers than young men, and fewer women than men drivers over 60. This may be a consequence of the fact that the majority of speed observations were made during off-peak periods in order to sample free-flow traffic conditions, and may include, for example, mothers fetching children from school and older drivers making daytime shopping or leisure trips.

Table 6 shows the distribution of the sample of drivers by driving experience (the length of time since passing the test, grouped into 4 bands, and the average value for men and women drivers. There is a clear difference between the sexes reflecting the age structure shown in Table 5; far more men than women have 31 years or more of driving experience, and more women drivers than men have less than 30 years of driving experience.

Table 5 Distribution of drivers' ages

Age group	*Males*	*Females*	*Both*
Percentage of drivers			
17 - 29 years	13	16	15
30 - 39 years	18	30	23
40 - 49 years	20	28	24
50 - 59 years	18	16	17
60 years and over	31	10	21
Average age	49.0	42.4	45.9
Total numbers	2693	2363	5065

Table 6 Distribution of driving experience

Driving experience	*Males*	*Females*	*Both*
Percentage of drivers			
1 - 10 years	14	22	18
11 - 20 years	19	36	27
21 - 30 years	23	30	26
31 years and over	44	12	29
Average experience	28.2	19.4	24.1
Total numbers	2693	2362	5055

Table 7 Miles driven per year

Annual mileage band	*Males*	*Females*	*Both*
Percentage of drivers			
Up to 5000	12	35	22
5001 - 10000	28	40	34
10001 - 15000	27	17	22
15001 and over	33	8	22
Average mileage	15,890	8,810	12,670
Total numbers	2662	2223	4885

Table 7 gives the breakdown of the driver sample by annual mileage (grouped into 4 bands) for male and female drivers. As might be expected, females drive on average about half the mileage of men, and this fact is reflected in the distributions for men and women drivers. Three-quarters of the women drivers reported annual mileages of less than 10,000 miles; in contrast, 60% of male drivers drive over 10,000 miles per year. This probably reflects the fact that women driving during the day are more likely to be making short local trips whilst many of the male drivers will be driving during the course of their work.

3.4 Speed preliminary analyses

3.4.1 Mean speed by age, sex and mileage

Table 8 shows the mean speed of the sampled drivers averaged across all drivers and all roads, by sex and age group.

The table shows that there is a clear age effect; 17-29 year old male and female drivers drive 4-5 mph faster than

Table 8 Mean speed (mph) by age group

Age group	*Males*	*Females*	*Both*	*Number of cases*
17 - 29 years	44.9	43.7	44.2	744
30 - 39 years	44.3	42.7	43.4	1185
40 - 49 years	42.4	41.0	41.6	1194
50 - 59 years	42.5	41.1	41.9	871
60 years and over	39.4	39.2	39.4	1070
All age groups	42.2	41.8	42.0	5064

those over 60 - an effect which is highly significant statistically (F= 38.6, p < 0.001). Also, women drivers drive about 1 mph slower than men (F=20.05, p < 0.001) when no adjustments are made for other speed related effects (particularly annual mileage).

Table 9 shows the mean speed for groups of drivers with different annual mileage.

Table 9 Mean speed (mph) by annual mileage group

Annual mileage	*Males*	*Females*	*Both*	*Number of cases*
Up to 5000 miles	39.3	40.5	40.2	1081
5001 - 10000 miles	40.9	42.2	41.6	1654
10001 - 15000 miles	42.8	42.8	42.8	1095
15001 miles and over	43.8	43.0	43.6	1060
All mileage bands	42.2	41.8	42.0	4890

The table shows that high mean speeds are strongly associated with high mileage drivers (F= 24.3, p < 0.001), though the results of the multivariate modelling to be presented later will suggest than a large part of this apparent mileage effect is due to a correlation between age and mileage - young higher speed drivers tending to drive higher mileages (r=-0.13 p < 0.001). Women drivers (covering similar mileages) are still 0.4 mph slower than the men, though this effect is now at the margins of statistical significance.

3.4.2 *Speed band distribution by age, sex, mileage and self-reported speed*

As an alternative way of examining age effects, Table 10 shows the proportion of drivers (for males and females) in the five speed bands as a function of age (also grouped into five bands). Focusing on the speed band 5 (slower drivers), it will be seen from the table that only 14% of young drivers (male or female) feature in this band compared to 37% of drivers over 60. Conversely in speed band 1 (faster drivers), 32% and 24% of male and female drivers respectively feature in this speed band compared with less than 9% of over 60s.

Reflecting the speed-mileage effects shown earlier, Table 11 shows the way in which the proportions of drivers in the 5 speed bands varies between the annual mileage groups - though of course the mileage effect is still compounded with age effects. Low mileage (and older) drivers are more likely to be found in speed band 5

Table 10 Distribution of sample by age group and speed band

Age group	*Speed band 5 (Slow)*	*Speed band 4*	*Speed band 3*	*Speed band 2*	*Speed band 1 (Fast)*	*Number of Cases*
	Percentage of drivers					
Males						
17 - 29 years	14	12	19	23	32	364
30 - 39 years	17	15	20	21	27	481
40 - 49 years	22	22	19	18	19	536
50 - 59 years	23	21	19	20	17	490
60 years and over	37	25	17	12	9	822
All ages	25	20	18	18	19	2693
	Percentage of drivers					
Females						
17 - 29 years	14	11	22	28	24	374
30 - 39 years	19	20	20	21	20	704
40 -49 years	21	22	20	23	14	379
50 -59 years	27	19	23	18	13	658
60 years and over	37	28	17	11	7	247
All ages	22	20	20	21	17	2362

Table 11 Distribution of sample by annual mileage and speed band

Annual mileage	*Speed band 5 (Slow)*	*Speed band 4*	*Speed band 3*	*Speed band 2*	*Speed band 1 (Fast)*	*Number of Cases*
	Percentage of drivers					
Males						
Up to 5000 miles	35	23	15	14	13	308
5001 - 10000 miles	30	23	18	16	13	755
10001 - 15000 miles	21	18	21	19	21	725
15001 miles and over	21	18	17	20	24	874
All mileages	25	20	18	18	19	2662
	Percentage of drivers					
Females						
Up to 5000 miles	25	25	18	20	12	773
5001 - 10000 miles	21	17	22	22	18	897
10001 - 15000 miles	16	17	24	23	20	368
15001 miles and over	21	17	20	20	22	184
All mileages	21	20	21	21	17	2222

(slow) for both men and women, and high mileage (and younger) drivers in speed band 1 (fast). The largest sex difference in the table appears in the slow speed band (5), where low mileage women drivers make up 25% of this group compared with 35% for the men.

In the questionnaire, drivers were asked to rate themselves on a 5-point scale as being ‘fast’ or ‘slow’ drivers. Although this self-rating is not the same kind of objective measure as age and mileage, Table 12 shows how drivers were distributed in the five observed speed bands according to their self-rated speeds.

The association between self-assessed speed and observed speed band is clear. Drivers who rate themselves as ‘much slower’ represent over a third of drivers in the slow speed band (5) compared with only 7% of drivers who rate themselves ‘much faster’. In the fast speed band (1), the

Table 12 Comparing the speed at which you drive with that of other drivers, would you say that, in general, you drive faster or slower than them?

Drive faster or slower than other drivers?	*Speed band 5 (Slow)*	*Speed band 4*	*Speed band 3*	*Speed band 2*	*Speed band 1 (Fast)*	*Number of Cases*
	Percentage of drivers					
Males						
Much faster	18	12	7	20	43	40
A little faster	13	13	19	23	32	486
About the same	24	19	18	20	19	1236
A little slower	32	26	19	21	12	848
Much slower	35	28	21	12	4	75
All speeds	25	20	18	18	19	2685
	Percentage of drivers					
Females						
Much faster	6	20	13	13	48	15
A little faster	14	13	19	21	33	205
About the same	19	17	22	23	19	1262
A little slower	28	25	19	18	10	826
Much slower	35	23	18	20	4	51
All speeds	22	20	20	21	17	2359

effect is more pronounced, with over 40% of drivers rating themselves as 'much faster' compared with only 4% of drivers rating themselves as 'much slower'. This indicates that drivers are generally quite good at assessing their speed in relation to other drivers.

3.4.3 Speed band distribution: psychological variables

The principal aim of this study was to quantify the relationship between the psychological variables, the relevant demographic variables, and the speeds at which drivers were travelling when they were observed. The first step towards this aim was to perform simple one-way analyses of variance using speed band as the independent variable, and each of the psychological variables in turn as dependent variables. The results are shown in Table 13.

Table 13 Analyses of variance exploring the effect of the psychological variables on speeds within the five speed bands

Psychological variable	*Scale score (Speed band 5 (slow) - band 1 (fast))*	*Significance F*	
Decision making style	19.0 - 19.0	F = 0.8	Not significant
Mild social deviance	12.1 - 12.9	F = 21.8	$p < 0.0001$
Violations	14.7 - 17.4	F = 70.4	$p < 0.0001$
Sensation seeking	8.1 - 9.1	F = 41.8	$p < 0.0001$
Intolerance	10.6 - 11.9	F = 28.5	$p < 0.0001$
Stress	5.7 - 5.5	F = 5.0	$p < 0.001$
Hazard perception	11.4 - 11.5	F = 0.7	Not significant
Driving style	13.3 - 14.8	F = 15.5	$p < 0.0001$

The table shows that in six out of eight cases there was a significant effect of speed band on psychological scale scores. However, as has been noted earlier, there are also strong age and mileage differences in mean speed and in the distribution of subjects between the speed bands. The next stage therefore was to perform similar analyses of variance, but to include age and mileage (and sex) as covariables, so adjusting for the variance attributable to each of these variables before assessing whether there are significant differences in the psychological variables between the speed groups. The results of these analyses are shown in Table 14.

Table 14 Results of ANOVA showing effects of sex and speed band with age and mileage as covariables

Psychological variable	*Speed effects Speed band*	*Sex*	*Age*	*Mileage*
Decision making	F = 0.8 n.s.	F = 6.0 $p < 0.05$	F = 71.1 $p < 0.001$	F = 27.1 $p < 0.001$
Mild social deviance	F = 2.1 n.s.	F= 129.3 $p < 0.001$	F = 742.4 $p < 0.001$	F = 8.9 $p < 0.01$
Violations	F = 26.9 $p < 0.001$	F = 285.9 $p < 0.001$	F = 637.2 $p < 0.001$	F = 72.7 $p < 0.001$
Sensation seeking	F = 13.9 $p < 0.001$	F = 144.0 $p < 0.001$	F = 379.1 $p < 0.001$	F = 19.5 $p < 0.001$
Intolerance	F = 4.2 $p < 0.01$	F = 94.0 $p < 0.001$	F = 648.6 $p < 0.001$	F = 6.2 $p < 0.05$
Stress	F = 5.0 $p < 0.01$	F = 258.9 $p < 0.001$	F = 16.4 $p < 0.001$	F = 23.8 $p < 0.001$
Hazard perception	F = 0.2 n.s	F = 22.8 $p < 0.001$	F = 23.0 $p < 0.001$	F = 1.6 n.s.
Driving style	F = 1.6 n.s.	F = 63.0 $p < 0.001$	F = 425.4 $p < 0.001$	F = 2.2 n.s.

This analysis showed, as expected, that there are very significant age and sex effects for all the psychological variables, with the mileage effects being rather weaker. However, once the effects of age, sex and annual mileage have been allowed for, the table shows that significant differences between the speed bands remain for only four of the eight psychological variables: Violations, Sensation seeking, Intolerance and Stress - with the size of the relationship for the first two being considerably stronger.

These preliminary analyses have confirmed the findings of earlier studies that speed choice is strongly associated with age and mileage, and have also established that there are psychological variables which can also help to explain variation in speed choice. However, it is also clear that these effects are strongly inter-correlated, and so to explore these effects further it is necessary to employ multivariate methods.

3.4.4 Speed differences between various driver sub-groups

Table 15 below shows the proportion of drivers in different vehicle ownership categories and their average speeds. The majority of vehicles were privately owned, and the proportion of drivers in company cars - predominantly men - is very similar to the figures obtained in other recent TRL surveys. An analysis of variance based on the log of speed shows that both vehicle ownership and sex effects are statistically significant (F=7.6, p<0.001 and

Table 15 Vehicle ownership and mean speeds

	Percentage of drivers			Mean speed (mph)	
Vehicle ownership	*Males*	*Females*	*Both*	*Males*	*Females*
Privately owned	81	94	87	41.6	41.7
Company owned	17	5	11	44.9	42.8
Owned by hire company	1	<1	1	41.7	38.8
Other	1	<1	1	44.4	42.1
Total numbers	2690	2360	5050	42.2	41.8

F=3.9, p<0.05 respectively); the main speed difference responsible for this result is that male company car drivers drive on average just over 3 mph faster than those driving private cars, and about 2 mph faster than their female counterparts. Speed effects corrected for age and mileage are presented below.

Table 16 shows the distribution by trip purpose for men and women drivers. Journey purpose and the interaction between journey purpose and sex of the driver are statistically significant in this case (F=21.9, p<0.001, and F=4.6, p<0.001). The speed difference between male and female drivers is small for both driving to work and for shopping or leisure trips. Male drivers, however, appear to drive about 3 mph faster when they are driving as part of their work. For both sexes, shopping and leisure driving is 2-3 mph slower than driving to work.

Table 16 Journey purpose and mean speed

	Percentage of drivers			Mean speed (mph)	
Journey purpose	*Males*	*Females*	*Both*	*Males*	*Females*
Driving to or from work	23	21	22	43.4	43.3
Driving as part of work	21	7	15	44.8	41.8
Shopping or leisure	40	47	43	40.4	41.2
Cannot remember/other	16	25	20	41.4	41.6
Total numbers	2675	2347	5022	42.2	41.8

Table 17 gives the distribution of car drivers in the sample by the engine size of the car they were driving, and shows that women tend to drive smaller cars than men. Average speed clearly increases with the engine size of car (F=13.2, p<0.001); cars with engine sizes over 2000cc are driven at speeds which are about 4 mph faster than cars with engine sizes less than 1000cc. The differences between male and female drivers in the table are not significant. There is a correlation between the size of the vehicle being driven, the occupational group of the driver, and whether or not it is company owned. The larger cars tend to be company owned vehicles driven by respondents belonging to the senior managerial, administrative or professional group.

Table 18 shows the effect on speed of whether the driver is carrying a passenger or not. It can be seen that between 30 and 40% of both men and women were carrying a passenger (the sampling procedure included relatively few commuter trips), and that drivers with passengers drive somewhat slower than those without. Both the passenger main effect and the interaction term are significant in this case (F=29.3, p<0.001; F=10.3, p<0.001).

Table 17 Engine capacity and mean speed

	Percentage of drivers			Mean speed (mph)	
Engine capacity	*Males*	*Females*	*Both*	*Males*	*Females*
Up to 999cc	4	10	6	39.8	40.9
1000 - 1499cc	29	47	37	41.1	41.2
1500 - 1999cc	51	13	43	42.5	42.5
2000 cc or over	16	10	14	43.8	42.8
Total numbers	2683	2312	5002	42.2	41.8

Table 18 Passengers and mean speeds

	Percentage of drivers			Mean speed (mph)	
Whether carrying a passenger or not?	*Males*	*Females*	*Both*	*Males*	*Females*
Yes	32	38	35	40.6	41.4
No	68	62	65	42.9	42.0
Total numbers	2616	2286	4902	42.2	41.8

Table 19 shows the proportion of drivers in the sample classified into five occupational groups, and the mean speeds associated with them. The speed differences are not large, however, and the effects shown in the table are not statistically significant.

Table 19 Occupational group and mean speeds

	Percentage of drivers			Mean speed (mph)	
Occupational group	*Males*	*Females*	*Both*	*Males*	*Females*
Senior managerial, administrative or professional	44	22	34	42.6	42.1
Junior managerial, administrative or professional	27	40	33	41.9	42.5
Skilled manual	18	3	11	41.7	41.3
Semi skilled or unskilled manual	6	5	6	41.5	40.6
Student, housewife/ husband, unemployed	5	30	16	42.7	40.8
Total numbers	2663	2319	4982	42.2	41.8

The questionnaire asked drivers how many penalty points they currently had on their licence, and whether in the last 5 years they had been warned or prosecuted by the police for any motoring offence (other than parking offences). The distribution of penalty points was, as expected, very non-uniform; most drivers had either none (86.5%), 3 (10.7%) or 6 (1.4%) points. Table 20 shows the responses to these questions and the average speeds of the various sub-groups of drivers.

Table 20 shows that drivers with more penalty points on their licence are faster drivers - a statistically significant main effect (F=5.8, p<0.003). Similarly drivers who have

Table 20 The consequences of motoring offences and mean speeds

Offence related category		*Percentage of drivers*			*Mean speed (mph)*	
		Males	*Females*	*Both*	*Males*	*Females*
Penalty points:	0, 1 or 2	83	91	87	42.1	41.9
	3, 4 or 5	14	8	11	44.0	43.4
	6 and over	3	1	2	45.6	41.2
Total numbers		1963	1545	3508	42.2	42.0
Warned by the police:	No	84	89	86	41.9	41.7
	Yes	16	11	14	43.8	43.3
Total numbers		2570	2136	4706	42.2	41.8
Prosecuted:	No	86	94	90	41.9	41.8
	Yes	14	6	10	44.4	43.6
Total numbers		2557	2130	4687	42.2	41.9

been warned by the police or who have been prosecuted in the last five years are faster drivers - again both main effects are significant ($F=21.1$, $p<0.001$; $F=19.3$, $p<0.001$ respectively). It is interesting to note that 58% of those warned by the police were warned for a speeding offence, and 81% of those prosecuted were for speeding offences.

3.5 Speed: multivariate analysis

3.5.1 Multiple regression

The object of the analysis reported in this section is to relate the observed speeds of individual drivers to site, demographic and psychological variables using a multivariate regression approach. Figure 1 shows a 'box plot' of the speed distributions observed at the 24 sites at which measurements were made - ordered in terms of ascending mean speeds; the central band of the box plot is the 25-75%ile range. It will be seen that the spread of speeds increase as the mean speed increases - that is, the variance of the speed distribution is not constant, violating one of the assumptions of linear regression. In order to stabilise the variance and to improve the Normality of the speed distributions, the analysis will use the natural logarithm of observed speed (Ln(speed)) as the independent variable. The use of the log transformation has the added advantage that the resulting regression equation expresses the explanatory effects as speed ratios rather than speed differences. This is particularly useful in relation to the site to site variation which will now be considered.

3.5.2 Site to site variation in speed

Given the relatively large site to site variations in mean speed, the first step therefore in the speed analysis was to fit 'site' as a category variable with 24 levels. The resulting model is:

$$\ln(V_{ij}) = [\text{Mean } \ln(V_i)]_{j=1 \text{ to } 24} + \ln(S_{ij}) \qquad (1)$$

where V_{ij} is the speed of vehicle 'i' (i=1...n_j) at site 'j', and the term in the square brackets is the mean value of $\ln V_i$ averaged over all n_j vehicles observed at site 'j'. $\text{Ln}(S_{ij})$ - the residual of the regression equation at this stage - is the difference on a log scale of the speed of the individual vehicle 'i' to the mean (logged) speed at the site 'j'. S therefore (dropping the subscripts for clarity) represents the *within site speed effect relative to the site mean speed* thus effectively normalising the speed data in relation to the geometric mean speed for individual sites. ln(S) will be used as the dependent variable in the subsequent analysis.

The site to site variation in speed represents a large proportion of the total variation in the speed measured in the survey. Based on ln(V), the total sums of squares about the mean for the dataset as a whole is 211.2. The addition of the site term (equation (1)) results in a residual sum of squares of 95.6. Thus 55% of the variation in observed speed is due to site to site variations in road geometry and other site specific effects such as weather and road condition. It is also possible, even though the observed vehicles were intended to be 'free flowing', that traffic flow conditions may have influenced site mean speeds. The subsequent analyses (using ln(S)) as the dependent variable will largely exclude site to site effects.

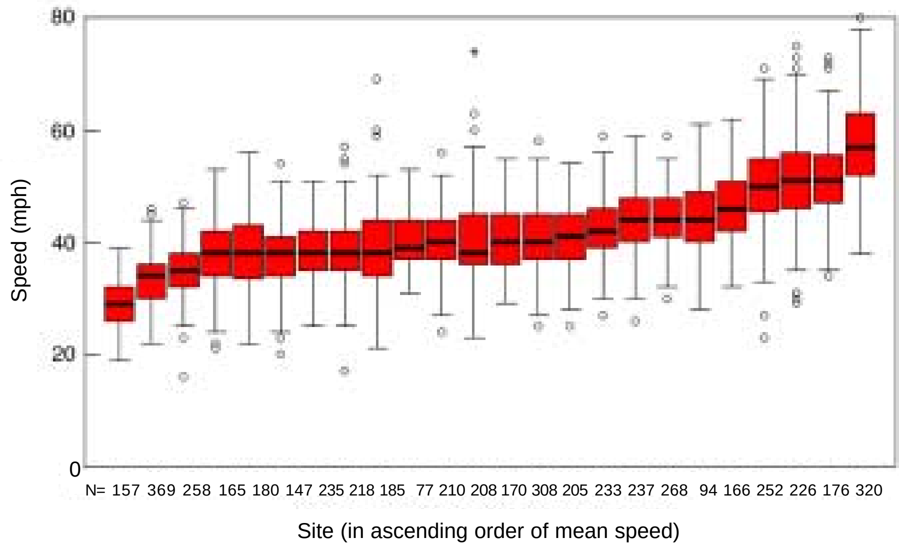

Figure 1 Boxplot showing the distribution of speed at each of the 24 sites

3.5.3 Age, sex and annual mileage effects

Tables 8 and 9 above have shown that age and annual mileage are strongly related to speed choice with an indication that some rather more subtle differences might exist between male and female drivers. Moreover, Tables 15-20 above have shown that in terms of the raw speed averaged across sites, vehicle ownership (company or private), engine size, journey purpose (mainly work versus non-work), whether a passenger is being carried or not, and the consequences of motoring offences all significantly distinguish between groups of drivers in terms of the speed at which they drive. The present section aims to determine the age, mileage and sex effects on speed using lnS as the dependent variable, and to assess the size of the speed effects of the various category variables when age and annual mileage have been adjusted for.

In order to achieve this, a linear statistical model has been fitted to a sub-set of the data containing 4730 cases having no missing data for age, annual mileage or sex. The model is as follows:

$$\ln \mathbf{S} = b_1(\mathbf{AGE} - 46) + b_2(\mathbf{MILEAGE} - 12{,}440) + b_3\mathbf{SEX} + [b_4\mathbf{CATEGORY}] \qquad (2)$$

The left hand side of the above equation is, as we have already seen, the natural logarithm of the ratio of the individual driver's speed to the geometric mean speed for the site; S therefore has an average value of 1, and lnS an average value of 0. Ignoring for the moment the term CATEGORY on the right hand side of equation (2), the use of 'reduced variables' for age and mileage in which both variables are expressed as the difference between the observed value and the mean values for age and mileage in the data set as a whole (46 and 12,440 respectively), results in there being no constant in this equation. The model coefficients for equation (2) including only the age, mileage and sex terms are shown in Table 21 (the CATEGORY term will be considered later).

Table 21 LnS (speed ratio) as a function of age, annual mileage and sex

Variable		*Coefficient (t-value)*	*Effect size for S*
Age	b_1	-0.0023 (17.0)	+5.4% to -5.6%
Mileage	b_2	$6.70\ 10^{-7}$ (3.5)	-0.7% to 2.0%
Sex	b_3	*-0.006 (1.3)*	

Coefficients in italics are not statistically significant at the 5% level.

It will be seen that the overall difference between the sexes corresponds to an effect on the speeds of about 0.6% relative to the site mean speed (women driving slower than men), and that this term was not statistically significant. This overall gender term was therefore omitted from the subsequent analysis. Age has by far the largest effect on relative speed. The 'effect size' for age in Table 21 is the percentage change in speed relative to the site mean speed predicted for a driver aged 23 (the 5th %ile age) and a driver aged 71 (the 95th %ile age) respectively compared to a driver of average age, which was 46. The speed of the younger driver is just over 5% above the site mean and that of the older driver nearer 6% below the site mean - an overall change of 11% in speed across the age range - in approximate agreement with the absolute speeds shown in Table 8. The mileage effect has the opposite sign. A driver driving only 2,000 miles a year (the 5th %ile mileage) has a speed which is just under 1% below the site mean speed, whilst a driver driving 30,000 miles a year (the 95th %ile mileage) has a speed which is 2% above the site mean - an overall 3% effect which is considerably smaller than that shown in Table 9 because of the correlation between age and mileage.

In terms of residual variance, the addition of age and mileage terms reduces the initial residual sum of squares of 95.5 (i.e. after the site to site variation has been removed) to 89.5 - a reduction of 6.3%.

3.5.4 Speed differences between various driver sub-groups (corrected for age and annual mileage)

In order to evaluate the effect of the various category variables on speed adjusting for age and annual mileage, each of the variables of interest were added to the above model singly -the 'CATEGORY' variable in equation (2) - with the resulting coefficient b_4 quantifying the magnitude of the effect and its statistical significance. The results are shown in Table 22. The category variables correspond to those already considered in Tables 15-20: vehicle ownership (mainly whether the car is privately owned or company owned), journey purpose, engine capacity, whether or not the driver was carrying a passenger at the time of the observation, occupational group, the number of penalty points on the driver's licence (in three bands), and whether or not the driver had been warned by the police or prosecuted for a motoring offence in the last five years.

The coding scheme is such that the first level of each category variable is always the reference category (denoted by R in the table); the values of the coefficients (b_4) estimated for the other levels of each category then reflects the differences in ln(S) between the reference level (the first) and each of the other levels. Moreover since S is the ratio of speed to the site mean speed, it follows that $100(\exp(b_n) - 1)$ - the 'effect on speed' given in the final column of the table - is the percentage amount by which the speed associated with a particular level is greater (positive) or less (negative) than the speed associated with the first (reference) category - all effects being corrected for differences in age and mileage between the various levels. In examining the effect on speed of these variables the, sex-category interaction was tested in all cases; if there was no significant interaction, the results for males and females are combined into a single figure, otherwise effect sizes are given for male and female drivers separately.

Considering first those categories in the upper half of Table 22 which correspond to Tables 15-19. The consequences of using relative speeds instead of absolute speeds and in particular of correcting for 'between sub-group' differences in age and annual mileage has changed the pattern of results reported earlier. In Table 22, with the exception of driving company cars and driving as part of the job (driving for work), sex differences are not

Table 22 The associations between speed, and other category variables corrected for age and mileage effects

		Coefficient b_4 (t-value)		*Effect on speed*	
Category	*Level*	*M*	*F*	*M*	*F*
Vehicle ownership	Private	R			
	Company	0.025 (3.0)	ns	+2.5%	–
Journey purpose	Driving to work	R			
	Driving for work	-0.039 (2.9)	ns	-3.8%	–
	Leisure/shopping	-0.030 (5.6)		-3.0%	
Engine capacity	<1000cc	R			
	1000 - 1499cc	*0.009 (1.1)*		+0.9%	
	1500-1999cc	0.030 (3.4)		3.0%	
	≥2000cc	0.042 (4.3)		4.3%	
Carrying passengers?	Yes	R			
	No	0.030 (7.0)		+3.0%	
Occupational group	Senior Managerial	R			
	Junior, managerial, and manual workers	-0.014		-1.4%	
	Students, housewives etc.	-.027		-2.7%	
Penalty points	0,1 or 2	R			
	3, 4 or 5	0.022 (2.2)	ns	+2.3%	–
	6 and over	0.055 (2.8)	ns	+5.7%	–
Warned by the police	No	R			
	Yes	0.030 (3.8)	ns	+3.0	–
Prosecuted for a motoring offence	No	R			
	Yes	0.034 (4.0)	ns	3.5%	–

Coefficients in italics are not statistically significant at the 5% level, but are included for completeness

statistically significant for these categories. By contrast, significant speed differences exist for male drivers who drive company cars or while driving for work, which are not significant for female drivers.

Similarly, there are significant speed differences between the groups defined by the three categories at the bottom of the table (penalty points, warned by the police or prosecuted), but unlike the raw speeds shown in Table 20 these differences are significant only for male drivers. Table 22 indicate that drivers who have been warned or prosecuted by the police drive 3 to 3.5% faster than those who have not been warned or prosecuted. This effect is reinforced by the classification based on penalty points. Drivers who have acquired three, four or five (mostly three) penalty points on their licence drive on average just over 2% faster than those without, and drivers with six points or more on their licence drive nearly 6% faster.

The magnitudes of the speed effects in Table 22 are usually smaller that the raw percentage differences found in Tables 15-20. For example, whereas in Table 15 a male company car driver would appear to drive just under 8% faster than a male private car driver, the corresponding figure in Table 21 is only 2.5%. This difference arises from the fact that company car drivers will be both younger and higher mileage drivers than those driving private cars, and both these factors will tend to reduce the apparent difference in speed when speeds are adjusted for age and mileage.

In the case of occupational group, the correction for age and mileage has introduced a speed difference which was not apparent earlier. Table 22 shows that when the occupational group categories which proved not to be statistically different are combined to give the three categories shown in the table, there is a consistent trend for junior managers/manual workers to drive more slowly than senior managers and for the third category (students, housewives/househusbands and the unemployed) to drive slower than junior managers/manual worker combined category. Age and mileage corrections have even produced a reversal of a speed effect apparently present in the raw speed data. Table 16 showed that male drivers driving as part of the job drive on average slightly faster than when they drive to or from work (44.8 compared to 43.3mph). The Table 22 analysis on the other hand shows that the age and mileage correction has turned this small positive difference into a sizeable negative one - for the same reasons as those that reduced the speed difference between company car drivers and private car drivers.

In summary, speed choice strongly depends on age and mileage. In addition, a variety of other category distinctions can be made - engine size, journey purpose, occupational group and company or private car - which influence a driver’s choice of speed for both men and women drivers. Other distinctions, notably those concerned with the committal of driving offences - penalty points score, being warned or prosecuted by the police - also define groups of *male* drivers whose choice of speed is significantly different from their fellows. Although these distinctions may be important in some contexts, for the purpose of exploring the psychological determinants of speed choice in the following section, they will be ignored.

3.5.5 The psychological variables

This section uses a multivariate regression approach to explore the relationship between relative speed (using the ratio S) and the psychological variables used in this study: decision making style (DECISION), mild social deviance (MSD), willingness to commit driving violations (VIOLATE), sensation seeking propensity (SENSAT), intolerance (INTOL), driving stress (STRESS), hazard involvement (HAZARD) and general driving style (STYLE). One of the major difficulties in interpreting the results of statistical models involving these variables is that they are quite highly inter-correlated and that they are also correlated with age and annual mileage. This is illustrated in Table 23 which shows the relevant Pearson correlation coefficients.

It will be seen that with the exception of decision making style, all the psychological variables are quite highly positively correlated with one another, and negatively correlated with age; with the exception of stress, they are all positively correlated with annual mileage. The interpretational difficulty concerns the causal pathways involved: to what extent are the speed reductions we have already seen to occur as drivers become older a direct consequence of reduced tendency of older drivers to violate or engage in sensation seeking behaviour or indeed any of the other psychological variables measured in this study, or to what extent are they a consequence of some aspect of maturation not captured by these driving related psychological measures? Unfortunately, simple regression identifies associations within the data rather than causal pathways, and is therefore unable to answer such questions. It is nevertheless instructive to attempt to examine to what extent the psychological variables can account for the speed differences in the data with and without the addition of age and annual mileage as explanatory variables.

Accordingly two models similar in principle to that of equation (2) have been fitted to lnS - the first with the eight psychological variables potentially included as explanatory variables, and the second with age and mileage added; in both models sex has been included in an appropriate form as a potential explanatory variable. As in equation (2) 'reduced' variables (i.e. the variables' mean values) have been used, and the model is based on a reduced data set of 4162 respondents for whom full data is available. Table 24 shows the model with only those psychological variables significant at the 5% level or better included.

Table 24 shows that in the absence of age and mileage effects, five of the eight psychological variables can be regarded as significantly related to speed choice, though the last two (sensation seeking and hazard perception) are significant for male drivers only. Three are positive - mild social deviance, willingness to violate and sensation seeking behaviour. Table 23 has shown that all three are strongly correlated - particularly VIOLATE and SENSAT (0.44) - though they are clearly making significant individual contributions to explaining the variation in the speed ratio S. Violation score (VIOLATE) is by far the largest effect with a 5-95%ile range of just over 8% in speed. Sensation seeking has a total range of 3% and mild social deviance just under 1.5%. This model reduces the residual sums of squares from an initial value of 83.3 (for this data sub-set after site to site variations have been removed) to 78.6 - a reduction of 5.6%.

Table 23 Pearson correlation coefficients between the psychological variables, age and annual mileage

	AGE	*MGE*	*DEC*	*MSD*	*VIOL*	*SEN*	*INT*	*SRE*	*HAZ*
AGE	1								
MILEAGE	**-0.13**	1							
DECISION	0.01	**0.08**	1						
MSD	**-0.33**	**0.12**	0.01	1					
VIOLATE	**-0.32**	**0.24**	0.01	**0.31**	1				
SENSAT	**-0.26**	**0.15**	-0.00	**0.26**	**0.44**	1			
INTOL	**-0.35**	**0.14**	**-0.07**	**0.30**	**0.46**	**0.45**	1		
STRESS	**-0.10**	**-0.15**	**-0.07**	**0.06**	0.01	**0.03**	**0.20**	1	
HAZARD	**-0.07**	**0.07**	**-0.07**	**0.16**	**0.28**	**0.24**	**0.34**	**0.22**	1
STYLE	**-0.28**	**0.09**	**-0.06**	**0.21**	**0.40**	**0.31**	**0.47**	**0.13**	**0.27**

Coefficients in bold figures are significant at better than the 5% level - most are significant at better than the 0.1% level

Table 24 Model 1: Quantifying the effect of the psychological variables on speed ratio (S)

Explanatory variables (reduced)	*Coefficient (t-value)*		*5-95% Range*	*Effect size*	
	M	*F*		*M*	*F*
MSD - 12.5	0.0021 (2.1)		10-17	-0.5% to 0.9%	
VIOLATE - 16.05	0.0062 (9.3)		10-23	-3.7% to 4.4%	
STRESS - 5.68	-0.0022 (1.9)		4-9	0.4% to -0.7%	
SENSAT - 8.48	0.0060 (4.2)	*0.0021 (1.0)*	7-12	-0.9% to 2.1%	–
HAZARD - 11.46	-0.0047 (3.5)	*-0.0017 (1.0)*	9-16	1.2% to -2.1%	–

Coefficients in italics are not statistically significant at the 5% level.

All these positive effects are rational and unsurprising. Indeed, the violation scale depends heavily on the infringement of speed limits - though the scale is also intended to encompass a willingness to break both formal (legal) and informal traffic ‘rules’. It has already been demonstrated that drivers are good at assessing their own relative speeds; since high speed drivers will be more likely to score highly on the violation scale, a strong positive correlation between violation score and speed is not surprising. A willingness to break rules is also reflected in the mild social deviance scale, and other studies (West et al, 1992) have shown an association between deviance as a feature of lifestyle in general and deviance (violations) in the driving context. Finally, it is not surprising that sensation seeking - driving (at speed) to impress their friends or for fun - is a feature of male driver behaviour and is associated with violations, mild social deviance and higher speeds.

Two of the psychological variables - stress and hazard involvement - have negative coefficients, implying that increases in these scores are associated with lower relative speeds. The hazard score has a 5-95%ile range of over 3% whilst that associated with stress is just over 1%. The latter seems to be a reasonable causal association, in that drivers who find driving stressful drive more slowly. The hazard result is more difficult to interpret. The implication is that drivers who report a higher likelihood of involvement in hazardous incidents drive more slowly. This may be due to the fact that ‘hazardous’ drivers recognise their lack of skill and drive more slowly as a response to a higher perceived risk - i.e. they are more cautious drivers. Alternatively, the association between speed and hazard involvement may arise as a result of both effects being consequences of some undefined aspect of driving confidence or ability.

It is worth noting that the three psychological variables which are not significantly associated with relative speed once the other variable have been included are decision making style, intolerance and the driving style scale. In the absence of the other psychological variables, both intolerance and driving style (which includes an intolerance sub-scale) are strongly related to speed. However, in the model of Table 24, the qualities measured by these scales have clearly been subsumed by the other psychological variables. Decision making style is not related to speed at all.

The upper part of Table 25 below shows a model for the speed ratio S which potentially includes both age and annual mileage in addition to the psychological variables. In fact, the annual mileage term proved not to be statistically significant once the psychological variables had been included. The correlation matrix of Table 23 showed that mileage is positively correlated with the psychological variables - particularly with the violation score - and it would appear that the violation term has absorbed all the variation in speed data which was associated with annual mileage in the model of Table 21 (the age, annual mileage, and sex model). Again the causal pathway is unclear: do high mileage drivers drive faster because of the need to cover large distances in as short a time as possible, or is it rather that the kind of driver who takes a job which requires high annual mileages (and driving large company cars) has the individual characteristics which are measured by the psychological scales used in this study?

Table 25 shows that the age effect is still very dominant - in fact it is only slightly smaller than that shown in Table 21 in the absence of the psychological variables. The mild social deviance score ceases to be statistically significant, and the effects of all the other psychological scales, with the exception of stress, have been reduced in magnitude but not in sign. Violation score remains the largest of the psychological variables, and provides a sizeable additional contribution to explaining the variation in relative speed, having a 5-95%ile range of about 6%. Sensation seeking is still significant for male drivers only, though the age correction has slightly increased the size of the female component of sensation seeking to the point where it is,

Table 25 Model 2: Quantifying the effect of age and the psychological variables on speed ratio (S) and including the effect of engine size, passengers and journey type

Explanatory variables (reduced)	*Coefficient (t-value)*		*5-95% range*	*Effect size*	
	M	*F*		*M*	*F*
AGE - 45.24	-0.0019 (12.3)		23-71	4.3% to -4.8%	
VIOLATE - 16.05	0.0046 (7.1)		10-23	-2.7% to 3.2%	
STRESS - 5.68	-0.0037 (3.2)		4-9	0.6% to -1.2%	
SENSAT - 8.48	0.0037 (2.7)	*0.0026 (1.3)*	7-12	-0.5% to 1.3%	–
HAZARD - 11.46	-0.0031 (2.3)	*-0.0009 (0.5)*	9-16	0.8% to -1.4%	–
Where appropriate add:					
Engine capacity: <1000cc	-0.044 (2.9)			-4.3%	
1000-1499cc	-0.031 (2.4)			-3.1%	
1500-1999cc	*-0.014 (1.2)*			-1.4%	
≥2000cc	*-0.004 (0.3)*			-0.4%	
Carrying passengers?	-0.019 (4.1)			-1.9%	
Journey to/from work?	0.021 (3.9)			2.1%	
Sex female?	0.014 (3.3)			1.4%	

Coefficients in italics are not statistically significant at the 5% level.

strictly speaking, not significantly different from that of the male drivers. Hazard involvement is still only significant for male drivers.

The coefficient of driving stress has actually been increased by the inclusion of the age term. The correlation matrix (Table 23) showed that older drivers report less stress than younger drivers. This may be an experience effect - experienced drivers being more confident drivers - or it may be an effect associated with a reduction of the pressures of travel, especially business journeys, for the older drivers. Either way, correcting for age in the model has had the effect of emphasising the fact that drivers who experience driving stress - who feel tense or afraid when driving - drive more slowly than others.

The model shown in the upper section of Table 25 has reduced the residual sum of squares (once site to site variation has been removed) from the initial value of 83.3 to 76.0 - a reduction of 8.8%. Thus the addition of age to the model of Table 24 has produced an additional reduction of 2.4% in the residual sums of squares.

The lower section of Table 25 shows that for prediction of speed ratio, the model in the upper part of the table benefits from the addition of three other significant terms - engine size, whether the driver is carrying a passenger or not, and a distinction between journeys to or from work and other journeys. A small positive adjustment to the mean is required for women drivers to compensate for the negative shift introduced by the engine capacity terms combined with the tendency for the drivers of the smaller cars to be female. Table 22 has already shown that these three additional variables have a significant effect on speed once age and mileage have been allowed for. The analysis shows however, that these variables do not interact with any of the psychological variables included in the model of Table 25, and can therefore be introduced into the model without affecting any of the other coefficients. A comparison of the effect sizes in Tables 25 and 22 shows that the engine size terms are almost identical, and that the effect of passengers and journey purpose are slightly smaller. The addition of these variables has reduced the residual sums of squares by a further 2%.

Vehicle ownership (company or private car), occupational group and the three variables concerned with motoring offences (warned by the police, prosecuted, or penalty points) do not significantly improve the model once the variables shown in Table 25 have been included.

The following section will attempt to illustrate the effects of age and the psychological variables on speed choice by presenting three kinds of analysis based on the speed groups.

3.6 Analysis of drivers in the speed groups

3.6.1 Introduction

As described earlier, the questionnaire respondents were sampled in five speed bands - the lowest and highest 15%ile bands and three intermediate bands - on the basis of their observed speeds. Because only 15% of drivers in the central band were included in the sample, and because of differential response rates between the bands (faster drivers not responding as well as slower drivers), the overall percentage of drivers in the five bands ranges from 18% for the fastest band to 23% for the slowest.

Previous tables showed how the proportions of drivers in the five bands vary with age, sex, and annual mileage, and indicated that, in addition to the demographic variables, psychological variables also influence the characteristics of drivers in the speed bands. So identifying the variables which determine the kinds of drivers in the five speed bands - particularly the upper and lower ones - should complement the regression approach reported in Section 3.5.

This section describes three type of analyses based on speed bands - discriminant function analysis, CHAID analysis and logistic regression - all of which aim to reveal more about the characteristics of the drivers in the speed bands.

3.6.2 Discriminant function analysis

Discriminant function analysis generates a linear function of ‘explanatory variables’ (the discriminant function) which, for a defined set of categories (groups) within the data, best discriminates between them. It does this by maximising the between groups sums of squares in relation to the within group sums of squares. The technique is intended for use in classifying data: once the function has been determined on the basis of existing data, the value of the discriminant function for a new data point enables it to be classified into one or other of the categories from which the original function was derived. To be effective, this process requires that there should not be too much overlap between the bands to be used for classification. In the case of the speed data, there is a great deal of variation in the raw data which is unrelated to speed group, so that the within group variation is large compared to the between group variation. It follows that as a system of classifying drivers into the five speed bands, discriminant function analysis is not particularly effective. Nevertheless, since the terms in the resulting function are selected as those which best discriminate between (in our case) drivers in the five speed bands, they provide a useful indication of those variables that are important for distinguishing drivers by speed group.

Table 26 shows the results of two stepwise discriminant function analyses based on the five speed groups. Clearly, what the procedure selects as a discriminating variable depends on the potential list of variables offered to it. In line with the approach used in the multiple regression the upper part of the table shows the four variables accepted by the analysis from a list consisting of age and the eight psychological variables. The lower part of the table is a similar analysis based on a complete list of potential discriminating variables, except those relating to motoring offences. The statistic used to indicate the significance of each term is the F-ratio calculated for each term prior to entry. A term is entered into the function if an F-value of 3.84 is achieved (the 5% value for $F_{1, >4000}$).

Table 26 in the main confirms the results obtained using linear regression. The only variable predicting speed in the linear regression which does not feature in the discriminant analysis is hazard perception, which in the regression was significant for men but not for women. Sex is not a

Table 26 Discriminant function analysis based on the five speed groups

Variable	*F to enter*	*Standardised coefficients*
Age and psychological variables only (4730 drivers)		
Age	88.8	-0.72
Violations	25.0	0.42
Stress	6.0	-0.18
Sensation seeking	5.8	0.16
All variables (4516 drivers)		
Age	88.2	-0.64
Violations	24.8	0.38
Passengers	13.4	0.31
Engine capacity	9.8	0.27
Stress	4.6	-0.18
Sensation seeking	4.2	0.10
Sex	4.0	-0.13

significant discriminator when only the psychological variables are entered (upper part of Table 26), though it becomes significant when the other variables available for inclusion in the analysis are used (lower part of Table 26), and this again mirrors the regression analysis.

For five speed groups there are potentially four discriminant functions. Fortunately, only the first is important. The final column of the table above headed ‘standardised coefficients’ are the coefficients of the first linear discriminant function; the first functions of the two analyses shown both explain about 94% of the between groups sums of squares, the other three functions explaining the remainder in each case. The standardised coefficients provide an indication of the relative importance of each variable in contributing to the value of the discriminant function for each driver. It will be seen that, with the exception of the hazard term, the coefficients in the upper section of Table 26 have the same signs relative to one another as the coefficients in Table 25 and their relative magnitude is very similar to the ‘effect sizes’ in that table. The overall ‘eigen values’ for the first discriminant function (the ratio of the between groups to within groups sums of squares) for the two analyses are 0.10 and 0.13 respectively, confirming that there is a comparatively large element of within group variation compared to between group variation in this data set arising from the variability of the raw speed observations.

3.6.3 CHAID analysis

CHAID is a statistical algorithm designed to divide a set of cases (such as drivers) into mutually exclusive groups, each of which differs from the others with respect to a specific parameter or variable. CHAID stands for ‘CHi-squared Automatic Interaction Detector’ and the procedure builds a hierarchical tree structure which is useful for visualising interactions in complex data sets. The programme uses only categorical (grouped) data, so that in the present case, the variables of interest - age and the psychological scales - have been grouped.

The process requires a dependent variable - in this case, the numbers of drivers in each of the five speed bands - and a list of predictor variables which are used in building the tree structure. In the present study, age and the eight psychological variables grouped into categories have been used as predictor variables. The process first selects the single variable which best discriminates between the categories of the dependent variable, judged by fitting a log-linear model of between group frequencies. The process then moves to the second level of the tree, and for each sub-group defined at level 1, the process is repeated searching for the variable which best discriminates between the drivers in the sub-group at level 2. This is repeated for all sub-groups and for all levels until no further splitting of the population is possible or until user imposed constraints on the process are reached. At all stages if distinctions between the groups of the predictor variables cannot be justified, groups are combined.

There are of course many different tree structures that could be generated by this process depending on the predictor variables which are available for use and the way that they are grouped initially. Moreover, the process depends to some extent on the way the grouping and splitting algorithm in CHAID operates. In particular, the tests of significance CHAID applies depend on whether the dependent variable (speed group in our case) is treated as nominal or ordinal. Figure 2 shows an ‘ordinal’ CHAID tree for the datafile consisting of 4162 driver responses with no missing data for age or any of the eight psychological variables. Shown in each ‘cell’ of the tree of Figure 2 are the percentages of drivers in speed bands 1 to 5 (as before band 1 are the faster drivers and band 5 the slower drivers), and the number of drivers in each cell.

It will be seen that the first split is made on the basis of age, and that two of the age groups (40-49 and 50-59) have been combined. As expected, the diagram illustrates in terms of average speeds and percentages in the speed bands, the fact revealed by the regression and discriminant function analyses, that older drivers drive more slowly than younger drivers. In the youngest age group (17-29), 28.3% of drivers are in the fastest speed band and 14.2% in the slowest. Moving across the diagram from younger to older drivers, the speeds systematically fall and the proportions in the speed bands change accordingly. For the oldest group for example, the proportion of drivers in the fastest band is only 8.4% and that in the slowest band 36.8%.

For the youngest age group, the next split has been made on the basis of the stress scale - though the original five groups of this variable have been combined into only two. The group reporting lower driving stress drive faster (29.9% in the fastest band) and there are sufficient numbers of drivers in this group to justify a further split by sensation seeking; drivers scoring higher on the sensation seeking scale drive faster (33.0% in band 1). For the other age groups, the second level split is made on the basis of violation score, though the original seven groups have been combined in various ways. As has been already noted, violation score is strongly associated with speed - high violation scores corresponding with high speeds, and thus high proportions of drivers in band 1 and low proportions in band 5. The differences are considerable: 38% of high violation drivers (group 7) in the 30-39 age

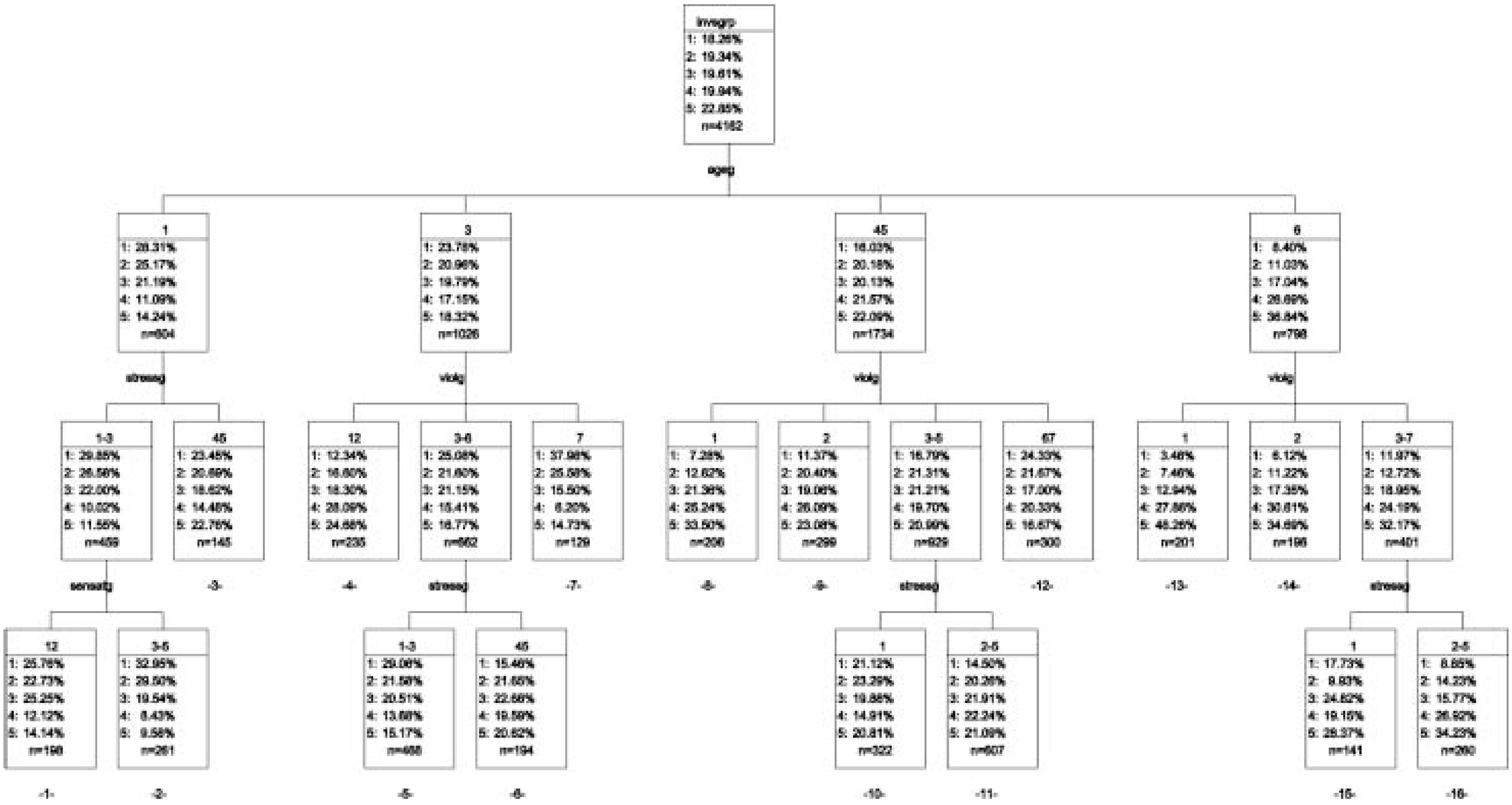

Figure 2 CHAID tree diagram showing the percentages of drivers in the speed bands

group are in band 1 (fast) compared with only 3.5% of over 60 year old drivers with low violation scores (group 1).

Where there are sufficient numbers of drivers in the cells formed at the second level of the hierarchy in Figure 2, CHAID has used the stress variable to split these groups further. As in the case of the younger drivers and as expected from the multivariate analysis, low stress scores correspond to higher speeds and a higher proportion of drivers in the highest speed band.

It has been previously observed that many different CHAID trees can be constructed, especially if variables such as whether a passenger is carried or not and engine size are used as predictor variables. However, the analysis presented here has been confined to the key psychological variables (violations, stress and sensation seeking) within age group, with the aim of demonstrating the effect of these key variables in terms of the mean speeds and the proportions of drivers in the two extreme speed bands.

3.6.4 The probability of being in the fastest or slowest speed group

It is clear from the CHAID analysis that the proportions of drivers in the speed groups - particularly the extreme speed groups - are sensitive indicators of drivers' speed choice. This suggested an alternative approach based on the logistic model. Logistic modelling is a regression technique which uses as its dependent variable the binary variable relating to whether or not an event occurs - in our case whether or not a driver features in one of the extreme speed bands. From this data, the regression estimates how the probability of the event occurring depends on other explanatory or predictor variables. The explanatory variables form a linear equation from which the log-odds of the event occurring can be predicted. Thus,

$$Z \text{ (the log odds)} = b_0+b_1x_1+b_2x_2 \ ....$$

where the x's are the significant predictor variables and the b's are the coefficients to be estimated (including a constant term), and,

$$P = e^Z/(1 + e^Z) \text{ or } 1/(1+e^{-Z})$$

where P is the probability of the event occurring - in our case the probability of the driver being in one of the extreme speed groups.

In the present case, two equations have been estimated - one for drivers in the highest speed group and the other for drivers in the lowest speed group. In order to estimate these regression equations, two new dependent variables were constructed: 'HISPEED' which takes the value 1 if a driver is in speed band 1 and 0 if not, and 'LOSPEED' which takes the value 1 if a driver is in speed band 5 and 0 if not.

Using HISPEED and LOSPEED as the dependent variables, the forward stepwise selection procedure available in SPSS for logistic regression was used to estimate how the probability of a driver's being in the two extreme speed groups depends on the variables obtained in the survey. As in the case of linear regression, the regression process was carried out in two stages. In the first stage, the only variables offered as explanatory variables were age, sex and the eight psychological variables. In the second stage, the other variables were allowed to enter should they prove to be statistically significant.

The first regression model for drivers in the high speed band is shown in Table 27. The terms are largely as expected. Age and stress have negative coefficients indicating that older drivers and drivers who experience stress when driving are less likely to be found in the high speed band. By contrast drivers who score highly on either the violation scale of the sensation seeking scale are more likely to feature in the high speed band. Men and women do not differ in the probability of their being in the high speed band. The surprise variable is the intolerance score - and its sign. It was pointed out in connection with the regression model for mean speed that the intolerance score was positively associated with mean speed, provided the other psychological terms - particularly violation score - were not also included in the model. Here however intolerance enters as a negative effect - the higher the intolerance score the less likely the driver is to be in the highest speed band. There is no obvious explanation for this effect, and it is possibly an artifact of the data or the model.

Table 27 Logistic regression model for drivers in the *high* speed band (Band 1)

Variable	*Coefficient (Z)*	*t-value*	*5-95%ile range*	*Probability range*
Constant	-1.115			
AGE	-0.029	8.8	23-71	0.30-0.10
VIOLATE	0.085	6.8	10-23	0.12-0.29
SENSAT	0.058	2.6	7-12	0.17-0.21
INTOL	-0.055	3.4	7-17	0.22-0.14
STRESS	-0.075	3.1	4-9	0.20-0.15

The final two columns of Table 27 - as in the case of the linear regressions given earlier - provide an indication of the size of the effect over the 5-95%ile range of the respective variables. For example, the probability that a 23 year old driver (the 5th %ile point of the age distribution) would be in the high speed band - all other terms in the equation being set at their mean values - would be 0.3. The corresponding probability for a 71 year old driver (the 95th %ile point of the age distribution) would be 0.1. It will be seen that age and violation score have similar 5-95%ile ranges, whereas the effect sizes of the other variables are rather smaller. Of course, taking variables in combination would produce considerably greater effect sizes than those shown in the table for individual variables. For example, the probability that a young driver with high violation and sensation seeking scores would appear in the high band would be about 0.48; the corresponding value for an older drivers with low violation and sensation seeking score would be 0.06.

In the second stage of the analysis for drivers in the high speed band, two other variables entered in addition to those given in Table 27 - engine capacity and whether the driver was carrying a passenger or not. As expected, the analysis showed that drivers in large cars are more likely to feature in the highest speed band, whilst drivers carrying passengers are less likely to be in this band.

Table 28 shows the equivalent STAGE 1 model for drivers in the lowest speed band - which because of the symmetry of the speed distributions, is to a large extent a mirror image of Table 27.

Table 28 Logistic regression model for drivers in the *lowest* speed band

Variable	Coefficient (Z)	t-value	5-95%ile range	Probability range
Constant	-1.494			
AGE	0.021	7.3	23-71	0.16-0.33
VIOLATE	-0.071	6.4	10-23	0.31-0.15
SEX	-0.219	2.6	1-M;2-F	0.23-0.27
STRESS	0.049	2.5	4-9	0.21-0.26

In the lowest speed band age and stress are positive terms, indicating that older drivers and drivers feeling more stress when driving are more likely to appear in this band, whilst violation score is a negative effect - high violators are less likely to be in the lowest speed band. In this case, sex was a significant term. Since the sex term is coded 1 for men and 2 for women, this negative coefficient means that male drivers are more likely than women to feature in the lowest speed band. This somewhat surprising result arises from the fact that the spread of speeds among male drivers is somewhat higher than it is among female drivers. The size of the effects of age, violations and stress in Table 28 for the low speed band are only slightly smaller than they are in Table 27 for the high speed band - emphasising the fundamentally symmetrical nature of the speed distribution for free flowing vehicles.

Once again, the second stage of the analysis showed that drivers of cars with large engine sizes are less likely to be in the lowest speed band, whilst drivers carrying passengers would be more likely to be found in the lowest speed band.

3.7 Accident analysis

3.7.1 Introduction

In the questionnaire survey, drivers were asked to report the number of accidents of all kinds in which they have been involved in the previous three years, or (if new drivers) for as long as they had been driving. Most of these accidents were damage only. This section examines the relationship between all reported accidents and the range of psychological and demographic variables collected in the study, and attempts to determine how these accidents are related to driver speed choice.

3.7.2 Accident tabulations

A total of 1239 accidents were reported from all drivers, whether or not they had been driving for more than three years. Table 29 shows that the majority of these accidents involved another vehicle, either moving or stationary. On average just over 13% of these accidents involved injury.

Table 29 Number and types of accident

Objects involved other than the driver's own car	All accidents: Numbers	All accidents: %
Moving vehicle	841	72
Stationary vehicle	220	19
Parked vehicle	41	3.5
Pedestrian	10	1
Cyclist/motorcyclist	29	2.5
Road furniture (bollards, signposts etc)	98	8.5

Previous studies have shown that there is a progressive memory loss effect for accidents over time, and that to avoid distortion in carrying out accident analyses, it is essential to use a common period for all subjects. In the present case, for those analyses (and tables) involving accident frequencies, drivers with less than three full years of driving have been omitted. Accordingly, Table 30 shows the average accident frequencies for only those drivers with three years or more experience by age group for male and female drivers and for all drivers combined. The table shows the expected fall in accident frequencies with increasing age.

Table 31 shows how accident frequencies are related to annual mileage for men and women drivers respectively and for both together. As in the case of other studies of this kind, it will be seen that accident frequencies do not increase in proportion to annual mileage; between the lowest and the highest mileage groups, although annual mileage has increased more than eight-fold (from an average of 3,400 to 28,400 in the two groups), accident frequency has increased by between a factor of 2 and 3 only.

Table 32 shows the average accident frequencies of drivers in the five speed bands - uncorrected for either the effects of age or annual mileage. It will be seen that the faster drivers are involved in more accidents than the

Table 30 Accident frequencies by age and sex for drivers with more than three years driving experience

	Males		Females		Both	
Age group	Accident frequency	Number	Accident frequency	Number	Accident frequency	Number
Accident frequency over past 3 years						
17 - 29 years	0.395	294	0.378	302	0.385	597
30 - 39 years	0.324	478	0.262	696	0.287	1174
40 - 49 years	0.220	531	0.179	649	0.198	1180
50 - 59 years	0.193	487	0.164	372	0.180	861
60 + years	0.159	817	0.070	242	0.139	1060
All ages	0.235	2607	0.217	2261	0.226	4872

Table 31 Accident frequencies by annual mileage and sex for drivers with more than three years driving experience

	Males		*Females*		*Both*	
Annual mileage group	*Accident frequency*	*Number*	*Accident frequency*	*Number*	*Accident frequency*	*Number*
Accident frequency over past 3 years						
1,000 - 5,000	0.131	291	0.160	743	0.152	1034
5,001 - 10,000	0.177	730	0.204	876	0.192	1608
10,001 - 15,000	0.232	713	0.288	361	0.251	1076
Over 15,000	0.323	860	0.316	174	0.321	1036
All mileages	0.236	2594	0.212	2154	0.225	4754

Table 32 Accident frequencies by speed band and sex for drivers with more than three years driving experience

	Males		*Females*		*Both*	
Speed band	*Accident frequency*	*Number*	*Accident frequency*	*Number*	*Accident frequency*	*Number*
Accident frequency over past 3 years						
Band 1 (fast)	0.275	476	0.271	376	0.273	854
Band 2	0.243	465	0.244	479	0.243	945
Band 3	0.252	476	0.220	463	0.236	941
Band 4	0.250	536	0.163	447	0.210	984
Band 5 (slow)	0.179	661	0.195	503	0.187	1164
All bands	0.236	2614	0.217	2268	0.227	4888

slower drivers. However this effect may well be due to the fact that drivers in the faster speed bands are on average younger and drive higher mileages than those in the slower speed bands. Multivariate analysis is needed to assess whether these effects are still present when other covariables are taken into account.

3.7.3 Accident models

3.7.3.1 Introduction

In the following analysis a multivariate regression technique will be used to explore the relationship between accident frequency (the number of accidents reported in a three year period) and a range of explanatory variables. Since accident frequency approximates to a Poisson variable, Generalised Linear Modelling has been used, though some adjustment to the statistical assessment of the significance of terms included in the regression has been made to allow for some over-dispersion in the actual error distributions.

The form of the model fitted to the accident data is:

$$\mathbf{A} = k\,\mathbf{M}^{\alpha} \exp[b_1\mathbf{Age} + b_2(1/\mathbf{Experience})) + \Sigma\, b_i\mathbf{p_i}] \qquad (3)$$

where:

A is the expected number of accidents reported in three years (the individual driver's accident liability); no corrections have been made for accidents that may have been forgotten,

M is the annual mileage, and α an exponent to be determined,

Age is the respondent's age at the mid-point of the accident period, and **Experience** is the number of years the respondent has held a full driving licence; $\mathbf{b_1}$ and $\mathbf{b_2}$ are the coefficients to be determined. Because age and experience are usually quite highly correlated, there is always some trade off between the form of the age and experience terms in accident liability models, and often it is not possible to include both. However, in the present case, both terms were statistically useful, though a simple exponential for age combined with a more rapidly falling reciprocal function for experience was found to give the best fit to the data.

$\mathbf{p_i}$ represents the range of other variables fitted in the model - in particular the psychological variables - and the $\mathbf{b_i}$'s are the coefficients to be determined,

k is the constant.

Other studies of driver accident liability (Maycock *et al.*, 1991) have shown that road type effects are small. In the present survey, drivers were not asked to estimate the proportion of time they spent driving on different types of road and thus road type terms were not available for inclusion in the model. As in the case of speed, sex differences could not be statistically justified as a main term in the model. Sex interaction terms are noted when they prove to be statistically significant.

3.7.3.2 Model results

The accident models were fitted using the same 3-stage strategy as was used for the analysis of the speed data. First a model was fitted using the eight psychological variables only. This model provides an indication of the maximum variation in the accident data which could be attributed to these variables. In the second stage of the analysis, age, experience and annual mileage are added to the model. The final stage of the analysis explores the effects of the variables listed in Table 22 - vehicle ownership, journey purpose, engine capacity etc, on accidents once age, experience, mileage and the psychological variables have been taken into account.

Table 33 shows the results of the first stage model - using psychological variables only. The model has been fitted to 4058 drivers for whom there was no missing data for any of the variables included. Between them, the drivers had been involved in 923 accidents. It will be seen from Table 33 that five of the psychological variables contribute to ‘explaining’ the variation in accident liability reported by the drivers in the survey. Violation and hazard involvement scores contribute to accident prediction as they did to speed prediction. Drivers with a high violation score drive at higher speeds and are involved in more accidents. The size of the effect can be judged from the column headed ‘effect size’ in the table. This column indicates the 5th %ile to 95th %ile range of the effect of the variables taken in isolation from the rest. For example, in the case of violation score, a 5th %ile driver (score 10) has an accident liability (all other scores being set at their mean values) which is 21% lower (the minus sign) than the average driver; the 95th %ile driver (violation score 23) has a liability which is 31% higher than the average driver.

In the case of hazard involvement score, a driver scoring highly on this scale drives rather more slowly than other drivers, but as Table 33 shows, despite this, is involved in more accidents. The effect size is somewhat smaller than that of the violation score.

The other three psychological variables in Table 33 did not appear earlier as significant predictors of speeds. Driving style is however, a strong predictor of accidents, with drivers who consider themselves to be attentive, careful, placid, patient, safe and tolerant, having 27% fewer accident than the average driver, whilst those at the opposite end of this scale are involved in 37% more. Mild social deviance appears to be significant as a predictor of accident liability for female drivers only, whilst decision making style is significant for male drivers only; both have the same sense, with higher scores being associated with higher accident liabilities. There is no obvious explanation for these sex differences.

Table 34 shows the stage 2 model when age, experience and annual mileage are added.

A consideration of Table 34 shows that age, mileage and driving experience are all strongly significant when entered in the functional form shown in equation (3). All are relatively large effects, as seen in the ‘effect size’ column. Note that whereas the simple exponential terms tend to be reasonably symmetrical about the average, the power function used for mileage and the reciprocal function used for experience are asymmetrical. Both these functions are sharply non-linear. In both cases (though the sense of the effects is opposite) increasing mileage or the number of years of driving experience, has a much smaller effect on accident liability than decreasing mileage or the driving experience.

The effect of including age, experience, and mileage into the equation has halved the size of the violation term to the point where it is not significant at the 5% level. Mild social deviance (which is quite strongly correlated with violation score) has also been reduced considerably, though it still makes a significant contribution for female

Table 33 Accident model using the eight psychological variables only

	Coefficient (t-value)			*Effect size*	
Explanatory variables	*M*	*F*	*5-95% range*	*M*	*F*
Constant	0.0118				
VIOLATE	0.039 (4.0)		10-23	-21% to +31%	
HAZARD	0.035 (2.4)		9-16	-18% to +17%	
STYLE	0.039 (5.0)		6-22	-27% to +37%	
MSD	*0.019 (1.2)*	0.079 (4.8)	10-17	–	-18% to +43%
DECISION	0.056 (3.9)	*0.017 (1.2)*	14-23	-24% to +25%	–

Coefficients in italics are not statistically significant at the 5% level.

Table 34 Accident model including age, mileage and the psychological variables (Equation 3)

		Coefficient (t-value)			*Effect size*	
Explanatory terms		*M*	*F*	*5-95% range*	*M*	*F*
Constant	k	0.0054				
Age (Midpoint)	b_1	-0.013 (3.5)		23-71	+33% to -29%	
Mileage (M)	α	0.212 (4.1)		2K-33K	-58% to +23%	
(1/Experience)	b_2	1.73 (2.7)		4-47	+44% to -3%	
VIOLATE		*0.0173 (1.7)*		10-23	-8% to +13%	
HAZARD		0.047 (3.1)		9-16	-11% to +24%	
STYLE		0.030 (3.9)		6-22	-21% to +27%	
MSD		*-0.01 (0.6)*	0.053 (3.1)	10-17	–	-12% to +27%
DECISION		0.054 (3.8)	*0.013 (0.9)*	14-23	-24% to +24%	–

Coefficients in italics are not statistically significant at the 5% level drivers. However, driving style and decision making style have been affected only slightly, and the hazard involvement term has actually increased in size.

Stage 3 of the analysis consisted of adding the variables listed in Table 22 to the accident model shown in Table 34 to see whether the groups of drivers defined by these variables had significantly different accident liabilities. None of the following variables proved to be significant discriminators: vehicle ownership, journey purpose, engine capacity, whether the driver was carrying a passenger, occupational group, or the number of penalty points. However, drivers who had been warned by the police had an accident liability which was 18% higher than other drivers, and those who had been prosecuted by the police had an accident liability which was 28% higher.

3.7.4 Speed and accidents

On the basis of the full data set, Table 24 showed that the accident frequencies of drivers in the five speed bands varies systematically, such that the band 5 (slow) drivers have low accident frequencies and the band 1 (fast) drivers have high accident frequencies. The frequencies given in Table 32 were however uncorrected for difference in age, experience and mileage between the five speed groups.

Table 35 shows for the data sub-set used in generating the model shown in Table 34 (i.e. 4058 drivers), the average accident frequencies for the five speed groups under three conditions: column 2 shows the uncorrected averages for this sample of drivers, column 3 gives the averages adjusted to the mean age, experience and mileage of the sample as a whole, and column 4 give the average values adjusted for all the variables given in the model of Table 34.

Table 35 Average speeds (unadjusted and adjusted) of drivers in the five speed bands

	Accident frequencies (accidents per 3 years)		
Speed band	*Unadjusted*	*Adjusted for age, experience and annual mileage*	*Adjusted for the model of Table 34*
5 (Slow)	0.175	0.189	0.185
4	0.211	0.226	0.219
3	0.250	0.239	0.230
2	0.231	0.206	0.194
1 (Fast)	0.285	0.238	0.223

Table 35 shows that the difference in unadjusted accident frequencies between band 1 and band 5 drivers (0.11 accidents per three years), has been reduced to 0.048 when the accident frequencies have been adjusted for age, experience and annual mileage, and to 0.038 when the full model of Table 34 has been used to make adjustments. Thus a considerable part - but not all - of the variation in accident frequency between the five speed bands can be attributed to the differences in the characteristics of the drivers in each band.

Another way of looking at basically the same interaction between accidents, speed and the common variables such as age and annual mileage which influence both, is to use the predicted speed ratio from the speed model as an 'explanatory' variable in the accident model. This has been done by applying the full speed model represented by Table 25 to the accident data set used in the accident model of Table 34. For this purpose the small proportion of missing data for the variables in the lower half of Table 25 were substituted as follows: engine capacity set to category 2 (1000-1499cc), passengers set to 2 (not carrying a passenger) and journey to work was set to 2 (other). Two equally good equations were generated relating accidents to predicted speed:

$$A = 0.215\ S^{7.8} \text{ and } A = 9.9\ 10^{-5}\ e^{7.75S} \qquad (4)$$

It is clear that because the range of the speed ratio S is quite small, the functional form of the accident-speed relation is not critical. The exponents in both these equations are massively significant (t-value of 10 or more) and both explain a large part of the variation in accident frequencies. However, even when all the variation in accident frequencies that can be 'explained' by the speed ratio has been removed by fitting equation (4), there is still a significant amount of residual variation which can be attributed to differences in driving experience and annual mileage - but not age effects which appear to have been accounted for by equation (4). The exponential form of equation (4) lends itself readily to estimating a elasticity of accident frequencies in relation to speed. Differentiating with respect to speed and remembering that $S=V/V_{mean}$ gives:

$$\frac{dA}{A} / \frac{dV}{V_{mean}} = 7.75$$

This implies that a 1% change in an individual driver's choice of speed (as predicted from the speed model) is associated with a 7.75% change in that individual's accident liability. Such an elasticity is far higher than that usually associated with mean speed changes and accident changes on a specific section of road. The usual figure quoted is that a 1 mph change in mean speed results in 5% change in accidents - an effect size probably corresponding to an elasticity of between 1 and 2. Of course, the fact that there is a strong 'cross-sectional' association between speed and accidents does not necessarily imply a causal link between the two, and it cannot be assumed that reductions in speed by particular drivers (a 'within driver' effect) will necessarily result in accident reductions of a size predicted by this association. It seems more likely that the association arises from the fact that both speed and accidents are related in similar ways to the same variables - particularly age, experience and annual mileage. Further structural modelling of the data might help to illuminate this critical issue.

4 Summary and conclusions

4.1 Introduction

The speed at which drivers choose to drive is a crucially important aspect of their behaviour on the road, and also plays a major role in the frequency and severity of accidents. This project has used on-road observation of speeds followed by a postal questionnaire survey to explore associations between the characteristics of individual drivers and their driving speeds. A follow-up phase will investigate the speed choice behaviour of a sub-sample of these drivers in more detail by using laboratory tests and drives around a test route.

Before summarising the findings, it is appropriate to draw attention to the fact that the drivers in this study do not represent a ‘random’ sample of UK drivers. Because the study was of speed choice, only drivers with more than a three second headway between themselves and the car in front were sampled; moreover, to maximise the number of free flowing vehicles in the traffic stream, the speed surveys were carried out mainly during off-peak periods. Within the free flow distribution thus sampled, drivers were differentially selected within five speed bands - all drivers in the upper and lower 15%ile bands and in the upper and lower 15 - 30%ile bands were included in the study, whereas drivers in the 40%ile range about the mean speed were sampled to give approximately the same numbers of drivers in this band as in the other four 15%ile bands. To facilitate the reading and recording of number plates, the surveys were only carried out in daylight.

The sample of sites used in the study excluded higher speed roads (such as motorways), and because some drivers were to be invited to take part in experimental studies, the sites were local to the Transport Research Laboratory. Differences in weather conditions were not part of the experimental design, so the effects of weather on speed could not be evaluated during the analysis independently of the permanent geometric and design features of the sites.

A further non-random element is introduced into the sampling through the use of a postal questionnaire to collect personal data, since this technique will inevitably introduce some bias arising from the self-selecting nature of the respondents who completed and returned the questionnaires. Nevertheless, despite these limitations, the sample obtained represents a significant section of the driving public. The age distribution of the drivers ranged from 17 to 89 years, and annual mileages from a few hundred to over 100,000 miles per year. 53% of the drivers were male and 47% were female - a much higher proportion of women than would be obtained in a random sample of drivers on the roads.

4.2 Driver speeds

The results of this study show that there are a variety of interacting factors which determine an individual driver’s choice of speed. These factors are likely to vary from time to time and from trip to trip depending on a range of personal and trip related factors. The fact that in this study only one speed measurement was made for one driver at one point in a single trip means that many of the subtleties of speed choice will be lost. As a result this survey will only be able to identify the broad correlates of speed choice.

The analysis has shown that in relation to the sample of drivers obtained for this study, the faster drivers tend to be younger rather than older, driving high annual mileages in large cars; they also tend to be travelling alone to or from work. In terms of their own reported driving behaviour, they reflect their tendency to fast driving by scoring highly on the violation scale, and there are also indications that sensation seeking is an element in the choice of high driving speeds for male drivers. By contrast, drivers who find driving stressful or who tend to become over-involved in hazardous situations tend to drive marginally slower.

The main results relating to the sources of speed variation can be summarised as follows:

i *Site effects*. The largest influence on driver speed are the site characteristics. The mean speeds for the sites in this sample varied from 29 to 57 mph, and in all, 55% of the variation in speed arises from these site to site differences.

Because of the dominance of the site to site variations, there are no meaningful relationships between *absolute* speeds and individual driver characteristics. In order to detect associations between speed choice and individual characteristics it is essential to use *relative* speed as the dependent variable. In the present case this was achieved by using the ratio of the individual driver’s speed to the geometric mean speed for the site at which he or she was observed (S) as the dependent variable in the analysis; for statistical reasons the equation fitted related the natural logarithm of S to a weighted sum of the explanatory variables.

ii *Driver effects: age, sex and exposure.* The regression analysis of individual driver speeds relative to the site mean speed (without other explanatory variables added), showed that the variables which best predicted the speeds of drivers (size of the effect in brackets) were age (11%) and annual mileage (2.7%). Overall, the difference between the sexes was not statistically significant, though in examining some of the psychological variables interactions between some of them (such as sensation seeking) and sex emerge from the analysis. In the discriminant and logistic regression approaches used, age remains a very strong predictor of relative speed, whereas the relatively small effect of annual mileage becomes non-significant when other variables are included in the models.

iii *Psychological variables*. When the psychological variables are used on their own to predict speed, the largest positive association arises from the violation scale (an 8% effect) - the more that drivers report themselves as engaging in violations, the higher their relative speed is predicted to be. Mild social deviance (which is highly correlated with violation score) is also a positive speed predictor, and provides some additional explanatory power (1.4% effect size), though social deviance ceases to be significant when age and other explanatory variables are added to the model. The sensation seeking scale is a significant positive correlate of speed for male drivers only.

The other two significant psychological variables proved to be negatively associated with speed. The size of the effect predicted by the stress scale was small (1.1%); it suggested that drivers who find driving stressful drive slightly slower than those who do not. In addition, male drivers who are relatively frequently involved in hazardous situations (the hazard scale) drive rather more slowly than those who do not experience frequent involvement in hazards - though this is not an effect which reaches statistical significance for women drivers.

Of these psychological measures, the violation, sensation seeking and stress scales appear to be reasonably robust in all the analyses attempted in this study. They feature in the discriminant analysis as variables which significantly distinguish between drivers in the five speed groups, and feature strongly in the logistic regressions as predictors of the probability that drivers will be found in the highest or the lowest speed groups.

iv *Other driver effects*. Once age, annual mileage and trip frequency effects had been allowed for, the following driving conditions influenced speed (again, with the size of the effect in relation to other drivers given in brackets): driving to or from work (+3%), driving without a passenger (+3%), driving a large car (up to +4%), occupational group (senior managers drive 1.4% faster than junior managers or manual workers, and 2.8% faster than housewives/house husbands or students).

Drivers who had been warned by the police or prosecuted for a motoring offence drive some 3 to 3.5% faster than those who have not. Drivers with 3-5 penalty points on their licence drive 2.3% faster than drivers with less than 3 points on their licences, and those with 6 penalty points or over drive 5.7% faster. These associations are unlikely to be causal; more probably the faster drivers are more likely to be the subject of enforcement action and as a result incur more penalty points on their licences.

4.3 Accident frequencies

Drivers reported the number of accidents in which they had been involved in the last three years (or since they started driving). The results are very much in line with those from other recent accident studies. The main findings may be summarised as follows:

i *Accident types*. The majority of the accidents reported by drivers were damage only; 13% involved injury. Of the accidents reported, 72% involved another moving vehicle, whilst a further 19% involved a stationary vehicle. It is characteristic of self-reported accidents that relatively few involve pedestrians or cyclists, since the majority of those that do are injury accidents.

ii *Age and experience effects*. Accident frequencies are strongly dependent on age and driving experience. Although in the earlier accident liability studies age and driving experience were fitted using a reciprocal relation, in the present case, a simple negative exponential proved to be an adequate descriptor of the age effect. As expected, both age and experience are very significant correlates of accident liability, with liability falling by a factor of about 2.8 with increasing age and experience.

iii *Exposure effects*. Accident frequencies increase with the number of miles travelled each year. However, accident frequency does not increase in proportion to annual mileage, but tends to ‘flatten off’ at high levels of exposure. In the present data, accident liability was proportional to annual mileage raised to a power of just over 0.2. Again, this result is similar to that previously found.

iv *Psychological variables*. Of the psychological variables included in this study, hazard involvement, driving style, and violation score related to accidents for both male and female drivers. Driving style exerted the largest effect, with drivers who classified themselves as attentive, careful, placid, patient, safe, and tolerant having 27% fewer accident than the average driver, and those at the opposite end of this scale having 37% more accidents. Drivers who report being involved in relatively few hazardous situations have 18% fewer accident than the average, whilst those whose involvement in these incidents is near the upper end of the scale have an accident liability which is 17% higher than the average. Without the inclusion of age, experience and annual mileage in the regression equation, violation score is also a strong predictor of accidents; low violators are involved in 21% fewer accidents than the average driver whilst high violators are involved in 31% more accidents. However, when the age, experience and annual mileage terms are added to the model, the predictive power of violation score (which is strongly correlated with age) is significantly diminished, whereas the coefficients of the other psychological variables remain reasonably robust.

Mild social deviance appears to be significant as a predictor of accident liability only for female drivers, whilst decision making style is significant only for male drivers. Both have the same sense - higher scores on these scales are associated with higher accident liabilities, and the size of the effects is quite large. There is no obvious explanation for these sex differences.

v *Other determinants of accidents*. The following variables did not prove to be significant predictors of accidents: vehicle ownership, journey purpose, engine capacity, whether the driver was carrying a passenger, occupational group, or the number of penalty points. However, drivers who had been warned by the police had an accident liability which was 18% higher than drivers who had not received a warning, and those who had been prosecuted by the police had an accident liability which was 28% higher than those who had not been prosecuted.

4.4 Speed and accidents

By using predicted speeds as an explanatory variable in the model of accident involvement it is possible to obtain an apparent relationship between speed and accidents. This relationship suggested that a 1% change in an individual driver’s choice of speed is associated with a 7.75% change in that individual’s accident liability. This ‘elasticity’ is much greater than that observed between changes in mean speed and accident change on a specific section of road (Finch *et al.*, 1994). Of course, the fact that there is an apparent strong ‘cross-sectional’ association between speed and accidents does not necessarily imply a causal link between the two, and it cannot be assumed that reductions in speed by particular drivers (a ‘within driver’ effect) will necessarily result in accident reductions of a size predicted by this association. It seems more likely that the association arises from the fact that both speed and accidents are related in similar ways to the same variables - particularly age, experience and exposure.

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Appendix: The questionnaire

TRANSPORT RESEARCH LABORATORY

(Ref: TRL/S&E/ARQ/95)

DRIVER BEHAVIOUR AND SAFETY QUESTIONNAIRE

Please would you complete the following questionnaire by either ticking one of the boxes or writing in the space provided.

TO START WITH, A FEW QUESTIONS ABOUT YOUR JOURNEY ON THE DAY YOUR VEHICLE WAS OBSERVED.

Q 1. What was the reason for that particular journey?

Driving to or from work	☐
Driving as part of your work	☐
Leisure, or shopping	☐
Can't remember	☐
Other (please specify)	☐

Q 2. Is the vehicle you were driving?

Privately owned	☐
Company owned	☐
Owned by a hire company	☐
Other (please specify)	☐

Q 3. What is the engine capacity of this car?

up to 999cc	☐
1000 - 1499 cc	☐
1500 - 1999 cc	☐
2000 cc or over	☐

Q 4. Were there any passengers with you at the time?

Yes	☐
No (if no go to Q 6.)	☐

Q 5. May we have a few details about your passengers?

	Sex: Male	Sex: Female	Approximate age (years)
Passenger 1	☐	☐	....
Passenger 2	☐	☐	....
Passenger 3	☐	☐	....

NOW SOME GENERAL QUESTIONS ABOUT ROAD SAFETY AND DRIVER BEHAVIOUR.

Q 6. How often do you think that <u>other</u> drivers do each of the following?

	Never/ Very rarely 1	Occasionally 2	Sometimes 3	Often 4	Very often/ Always 5
Drive faster than the speed limit	☐	☐	☐	☐	☐
Follow another car too closely	☐	☐	☐	☐	☐
Drive too slowly	☐	☐	☐	☐	☐
Drive aggressively	☐	☐	☐	☐	☐
Overtake dangerously	☐	☐	☐	☐	☐
Drive too fast for the conditions	☐	☐	☐	☐	☐
Drive when over the legal limit for alcohol	☐	☐	☐	☐	☐

Q 7. Consider driving in a *residential* area where the speed limit is 30 mph. How serious an offence is driving at each of the following speeds?

	Very serious	Serious	Neither serious nor minor	Minor	Very minor
35 mph	☐	☐	☐	☐	☐
40 mph	☐	☐	☐	☐	☐
50 mph	☐	☐	☐	☐	☐

Q 8. Consider driving on a motorway with a speed limit of 70 mph. How serious an offence is driving at each of the following speeds?

	Very serious	Serious	Neither serious nor minor	Minor	Very minor
75 mph	☐	☐	☐	☐	☐
80 mph	☐	☐	☐	☐	☐
90 mph	☐	☐	☐	☐	☐

Q 9. Realistically, how likely do you think it is that someone would be stopped by the police for speeding in the following situations?

	Extremely unlikely	Unlikely	Neither likely nor unlikely	Likely	Extremely likely
If they drive at 40 mph in a built-up town centre where the speed limit is 30 mph	☐	☐	☐	☐	☐
If they drive at 85 mph on a motorway where the speed limit is 70 mph	☐	☐	☐	☐	☐

NOW SOME QUESTIONS ABOUT <u>YOUR</u> DRIVING.

Q 10. Comparing the speed at which you drive with that of other drivers, would you say that, in general, you drive faster or slower than them?

Much faster	☐
A little faster	☐
About the same	☐
A little slower	☐
Much slower	☐

Q 11. How often, when given the opportunity, would you say <u>you</u> drive faster than the speed limit?

Never/very rarely	☐
Occasionally	☐
Sometimes	☐
Often	☐
Very often/always	☐

Q 12. On those occasions when you find yourself exceeding the speed limit, how likely is it that it would be for each of the following reasons?

	Extremely unlikely 1	Unlikely 2	Neither likely nor unlikely 3	Likely 4	Extremely likely 5
You don't know what the speed limit is	❑	❑	❑	❑	❑
You are unaware of your speed	❑	❑	❑	❑	❑
You deliberately set your own safe speed which is higher than the speed limit	❑	❑	❑	❑	❑
You are in a hurry and deliberately drive faster than the limit	❑	❑	❑	❑	❑
You feel pressurised by other drivers to increase your speed	❑	❑	❑	❑	❑
You are simply keeping up with the speed set by other drivers	❑	❑	❑	❑	❑

Q 13. How likely is it that each of the following measures would cause <u>you</u> to drive more slowly?

	Extremely unlikely	Unlikely	Neither likely nor unlikely	Likely	Extremely likely
Greater enforcement of speed limits (using "speed traps") by the police	❑	❑	❑	❑	❑
More use of automatic speed cameras	❑	❑	❑	❑	❑
More road humps (or other traffic "calming" devices used to slow traffic down)	❑	❑	❑	❑	❑
More publicity campaigns (like "Kill your speed not a child")	❑	❑	❑	❑	❑
Introducing lower speed limits	❑	❑	❑	❑	❑

Q 14. Please indicate your agreement or disagreement with the following statements.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Decreasing the speed limit on motorways is a good idea	❑	❑	❑	❑	❑
Even at night-time on quiet roads, it is important to keep within the speed limit	❑	❑	❑	❑	❑
Drivers who cause accidents by reckless driving should be banned from driving for life	❑	❑	❑	❑	❑
People should drive slower than the speed limit when it is raining	❑	❑	❑	❑	❑
Cars should never overtake on the inside lane even if a slow driver is blocking the outside lane	❑	❑	❑	❑	❑
In towns where there are a lot of pedestrians the speed limit should be 20mph	❑	❑	❑	❑	❑
Penalties for speeding should be more severe	❑	❑	❑	❑	❑

NOW SOME QUESTIONS ABOUT THINGS OTHER THAN HOW YOU DRIVE.

Q 15. The following questions examine the way in which you make decisions. In general, how often do you do each the following things?

	Never/ Very rarely 1	Occasionally 2	Sometimes 3	Often 4	Very often/ Always 5
Plan well ahead	❑	❑	❑	❑	❑
Make decisions without considering all of the implications	❑	❑	❑	❑	❑
Make decisions using a deliberate, logical process	❑	❑	❑	❑	❑
Find you change your mind, having already made your decision	❑	❑	❑	❑	❑
Remain calm when you have to make decisions quickly	❑	❑	❑	❑	❑

Q 16. How likely is it that you would engage in each of the following activities if you could be sure of getting away with it?

	Not at all likely	Quite likely	Very likely
Riding on public transport without paying a fare	❑	❑	❑
Parking on double yellow lines	❑	❑	❑
Earning cash payments without paying income tax that is owed	❑	❑	❑
Leaving a shop with goods that have not been paid for	❑	❑	❑
Making a fraudulent insurance claim	❑	❑	❑
Keeping a £20 note found in the street	❑	❑	❑
Hitting someone who has annoyed or upset you	❑	❑	❑
Owning and watching a TV without having a licence	❑	❑	❑
Taking time off work "sick" when you have something more interesting to do	❑	❑	❑
Driving down the hard shoulder of a motorway when all the other lanes are jammed	❑	❑	❑

NOW SOME MORE GENERAL QUESTIONS ABOUT YOUR DRIVING.

Q 17. Do you think that you overtake other cars more often than you are overtaken?

Yes ❑
No ❑

Q 18. Could you tell us what kind of driver you are by putting a tick on each of the lines below. At either end of each line there is a word which describes a way of driving, and these words are opposites. Put your tick nearer to the word which best describes your driving; the closer a tick is to a word, the more you agree with this description of your driving.

PLEASE PLACE ONE TICK FOR EACH PAIR OF ADJECTIVES.

	1	2	3	4	5	6	7	
Attentive								Inattentive
Careful								Careless
Irritable								Placid
Patient								Impatient
Safe								Risky
Tolerant								Intolerant

Q 19. When driving, how often do you do each of the following?

	Never/ Very rarely 1	Occasionally 2	Sometimes 3	Often 4	Very often/ Always 5
Drive too close to the car in front	☐	☐	☐	☐	☐
Drive through a traffic light after it has turned amber	☐	☐	☐	☐	☐
Drive through a traffic light after it has turned red	☐	☐	☐	☐	☐
Get into a skid when cornering or braking	☐	☐	☐	☐	☐
Knowingly exceed the 30 mph speed limit in built-up areas	☐	☐	☐	☐	☐
Knowingly exceed the speed limit on motorways	☐	☐	☐	☐	☐
Pull out onto a main road knowing you will force other traffic to slow down	☐	☐	☐	☐	☐
Speed up when being overtaken	☐	☐	☐	☐	☐

And the following?

	Never/ Very rarely	Occasionally	Sometimes	Often	Very often/ Always
Have to brake sharply to avoid a collision with the vehicle ahead of you because it has slowed	☐	☐	☐	☐	☐
Misjudge the speed of an oncoming vehicle when overtaking	☐	☐	☐	☐	☐
Pull out to overtake or turn right not initially noticing another vehicle in your "blind spot"	☐	☐	☐	☐	☐
Fail to notice someone waiting to cross at a pedestrian crossing until it is too late to stop	☐	☐	☐	☐	☐
Misjudge the gaps in the main road traffic when pulling out of a side road	☐	☐	☐	☐	☐
Find you are travelling too fast to negotiate the bend safely, when cornering, and have to brake sharply	☐	☐	☐	☐	☐
Fail to give way when entering a roundabout to a vehicle already on the roundabout	☐	☐	☐	☐	☐
Have to brake or swerve suddenly to avoid an accident	☐	☐	☐	☐	☐

And the following?

	Never/ Very rarely	Occasionally	Sometimes	Often	Very often/ Always
Generally feel calm and in control of things	☐	☐	☐	☐	☐
Get flustered because too much is going on at once	☐	☐	☐	☐	☐
Get into situations in which you find it hard to cope	☐	☐	☐	☐	☐
Let your mood influence how you drive	☐	☐	☐	☐	☐

	Never/ Very rarely 1	Occasionally 2	Sometimes 3	Often 4	Very often/ Always 5
Feel afraid when driving	☐	☐	☐	☐	☐
Feel tense when overtaking another vehicle	☐	☐	☐	☐	☐
Make rude gestures to other road users	☐	☐	☐	☐	☐
Feel aggressive towards other drivers	☐	☐	☐	☐	☐

And the following?

	Never/ Very rarely	Occasionally	Sometimes	Often	Very often/ Always
Get involved in unofficial 'races' with other drivers	☐	☐	☐	☐	☐
Try to beat other drivers away from traffic lights	☐	☐	☐	☐	☐
Do things when driving which you know are dangerous	☐	☐	☐	☐	☐
Drive fast for enjoyment	☐	☐	☐	☐	☐
Get annoyed at being behind other vehicles	☐	☐	☐	☐	☐
Get frustrated when you try but fail to overtake	☐	☐	☐	☐	☐
Get annoyed when traffic lights change to red as you approach them	☐	☐	☐	☐	☐
Become impatient with slower drivers and overtake dangerously	☐	☐	☐	☐	☐
Drive after drinking a small amount of alcohol	☐	☐	☐	☐	☐
Drive fast to impress your friends	☐	☐	☐	☐	☐
Drive to express your personality	☐	☐	☐	☐	☐
Take chances because it is fun	☐	☐	☐	☐	☐

TO FINISH OFF, SOME QUESTIONS ABOUT YOUR DRIVING HISTORY.

Q 20. For how many years have you held a full driving licence? (Please write in)

.... years

Q 21. Approximately how many miles have you driven (in a car or light van) in the last 12 months? (Please write in)

.... thousand miles

Q 22. Have you been stopped and warned (but not prosecuted) by the police for any motoring offence (other than parking offences) in the last five years?

No (If no go to Q 24.) ☐
Yes ☐

Q 23. If yes, please tick the box below to indicate the category of offence.

Speeding ☐
Not wearing a seat belt ☐
Condition of vehicle (e.g. tyres, lights, brakes) ☐
Traffic signs or signals offences ☐
Other (Please specify) .... ☐

Q 24. Have you been prosecuted for any motoring offences (other than parking) in the last five years?

- No (If no go to Q 26.) ❑
- Yes ❑

Q 25. If yes, please tick the box below to indicate the category of offence.

- Speeding ❑
- Condition of vehicle (e.g. tyres, lights, brakes) ❑
- Traffic signs and signals offences ❑
- Document offence (e.g. road tax, test certificate, insurance) ❑
- Other (please specify) .... ❑

Q 26. How many penalty points do you currently have on your licence? (Please write in)

.... points

We are interested in the types of road accident you have been involved in as a driver, over the last three years.

By "accident" we mean any incident which involved injury to another person or yourself, damage to property, damage to another vehicle, or damage to the vehicle that you were driving. Please mention only those accidents which occurred on public roads (not on private property), and in which you were involved as a driver, not as a passenger. Please include all accidents, regardless of how they were caused or how slight they were.

Q 27. How many accidents have you been involved in during the last three years <u>whilst driving a car or van?</u> (please write in)

.... (If none go to Q 33.)

We would now like you to give us further details of up to your last three accidents whilst driving a car or van during this period using the following table.

	Most recent	Next most recent	One before that
Date (day, month, year)	/ /19_	/ /19_	/ /19_
Q 28. Did the accident occur during...			
Daylight	❑	❑	❑
Hours of darkness	❑	❑	❑
Dawn/Dusk	❑	❑	❑
Q 29. What type of vehicle were you driving?			
Private car / van	❑	❑	❑
Company owned car / van	❑	❑	❑
Owned by a hire company	❑	❑	❑
Other (please specify)	❑	❑	❑
Q 30. What type of road were you driving on?			
Motorway	❑	❑	❑
Road in a built up area	❑	❑	❑
Road in a non-built up area	❑	❑	❑
Q 31. Apart from your vehicle what else was involved? (You may tick more than one box).			
Moving vehicle(s)	❑	❑	❑
Stationary vehicle(s)	❑	❑	❑
Parked vehicle(s)	❑	❑	❑
Pedestrian(s)	❑	❑	❑
(Motor) cyclist(s)	❑	❑	❑
Other (e.g. lamp-post, road sign, kerb, traffic bollard, tree)	❑	❑	❑
Q 32. Were there any injuries (either to yourself or others)?			
None	❑	❑	❑
Slight (e.g. cuts/bruises)	❑	❑	❑
Serious injuries (needing hospital care)	❑	❑	❑
Fatal	❑	❑	❑

Q 33. Which of the following educational qualifications do you have? (Tick as many boxes as necessary)

- CSE ❑
- School certificate / O level ❑
- GCSE ❑
- HSC / A level ❑
- OND / B Tech ❑
- HND / City & Guilds ❑
- Degree ❑
- None of the above ❑
- Other (please specify) .... ❑

Q 34. What age were you last birthday? (Please write in)

.... years

Q 35. Are you

female ❑ male ❑

Q 36. Are you:

- Married? ❑
- Living with someone? ❑
- Single? ❑
- Divorced? ❑
- Widowed? ❑

Q 37. How many dependents (children) do you have living with you? (Please write in)

.... dependents

Q 38. Please tick the box which best describes your situation/work. If you have retired, please tick the box that best describes your position before you retired.

- Senior managerial, administrative, or professional ❑
- Junior managerial, administrative or professional, supervisory and clerical ❑
- Skilled manual worker ❑
- Semi-skilled or unskilled manual worker ❑
- Student, housewife/househusband, unemployed ❑

The Transport Research Laboratory (TRL), which is situated in Crowthorne (between Bracknell and Camberley), is a Department of Transport Agency that is continuously engaged in a programme of road safety research. As part of this, people (who live in the area) are occasionally invited to attend the Laboratory to take part in experimental trials. These can cover a wide range of topics, including studies of driver behaviour, evaluations of new in-car technology, and studies on the effects of alcohol. TRL has recently developed a new driving simulator (the most advanced in Europe) based on computer generated images, for which research participants are also required on a regular basis.

Participants are paid for taking part, and also receive travel expenses. If you are prepared to assist TRL researchers in the future, please fill in your name, address and (if possible) a contact telephone number below.

Filling in your name and address at this stage will not commit you in any way to attending the Laboratory, but may mean we will contact you and give you details of what would be involved.

Name: ....

Address: ....

....

Telephone (work) .... (home) ....

NOW PLEASE RETURN THE QUESTIONNAIRE IN THE PRE-PAID ENVELOPE PROVIDED.

Abstract

This study sets out to identify and quantify those factors which influence a driver's choice of speed. The factors investigated included demographic variables, driving habits, accident histories, and a range of psychological variables. The speeds and registration numbers of free-flowing vehicles were recorded on video. Using the registration number information, self-completion questionnaires were sent to the relevant drivers in order to collect detailed information on the variables under investigation, and to relate this to the speeds at which the drivers were travelling when filmed. Information was collected from over 5000 drivers at 24 different sites. Of those observed, the faster drivers tended to be young, driving high annual mileage in large cars, and to be travelling alone to and from work. A variety of interacting factors were found to influence a driver's choice of speed, but the largest single influence was from site characteristics, which accounted for over half of the variation in speed. Because of this, the analysis concentrated on speed relative to the mean for each site, rather than the absolute speed. Multivariate techniques were used to analyse the speed data and to explore the contribution of the demographic and psychological variables. Of the former, age proved to be the strongest predictor, and some of the psychological variables turned out to be reasonably robust. The modelling of the accident data confirmed results from recent studies, and the analysis suggests that a 1% change in the speed choice of an individual driver is associated with a 7.75% change in accident liability.

Related publications

TRL332 *Road layout design standards and driver behaviour* by G Maycock, P J Brocklebank and R D Hall. 1998 (price £30, code H)

TRL326 *Drivers' speed choice: an in-depth study* by A R Quimby, G Maycock, C Palmer and G B Grayson. 1999 (price £25, code E)

RR315 *The accident liability of car drivers* by G Maycock, C R Lockwood and J F Lester. 1991 (Price £20, code C)

PR58 *Speed, speed limits and accidents* by D J Finch, P Kompfner and G Maycock, 1994 (price £25, code E)

CR253 *The social and cognitive determinants of aberrant driving behaviour* by J T Reason et al. 1991 (price £25, code E)

CT84.1 Speed and road accidents (1994-98). (*Current topics in Transport: selected abstracts from TRL's Library's database*) (price £20)

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