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Behavioural research in road safety 2001
1 Forecasting older driver accidents and casualties

G. Maycock, Scientific and Allied Services, Bracknell RG12 9YH

Introduction

The increases in life expectancy that have taken place over the last few decades have meant that in percentage terms older groups in the population have been growing considerably faster than the population as a whole - a trend which is expected to continue. Moreover, the proportion of the older members of the population who hold driving licences has also been increasing over the years and is expected to continue to do so in the future. These trends, in combination with the higher accident liabilities of older drivers, are a cause of concern for road safety.

This paper summarises calculations aimed at estimating the trends in the numbers of older drivers (over 60) by sex and age group over the next 20 years or so, the numbers of accidents in which they will be involved, and the numbers of casualties resulting.

The prediction method

The method of predicting the numbers of drivers, the accidents they will have and the casualties resulting from these accidents can be summarised as follows:

| Predicted number of drivers = Predicted numbers of people in the relevant sector of the population (by age and sex) x predicted proportion of drivers in this sector. |
| Predicted number of accident involvements = Predicted number of drivers x predicted accident liability of the drivers. |
| Number of casualties involved in accidents = Number of accident involvements x the number of casualties per accident. |

The number of accident involvements is the number of accidents in a year in which drivers of a particular sex and age group are expected to experience as drivers. In the case of both accidents and casualties two severities will be considered - fatal and serious combined (KSI - killed and seriously injured), and slight accidents.

The principles involved in the estimation of the proportion of drivers in each age and sex group are illustrated by means of the matrix shown in Figure 1. All the calculations are performed in relation to five-year age groups and five-year periods of time (the nominal time being taken as the mid-point of each five-year period). The rows in Figure 1 correspond to 11 five-year age groups used in the study ranging from 35-39 up to 85-89, the 90+ category forming the 12th group. The columns of the matrix correspond to the 11 five-year periods from 1970-74 through to 2020-24. The vertical solid line at the boundary between the 1995-99 period and the 2000-04 period represents the division between the data which can be obtained.
from current sources and the future which is to be estimated. The horizontal heavy broken line marks the boundary between the under 60s and the 'older driver' over 60 groups which are the target for the predictions included in this paper - thus in Figure 1, the region appropriate to the predictions is the bottom right quadrant of the figure (shaded).

**Figure 1: Illustrating the framework for the prediction of the proportion of drivers in the population**

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group</td>
<td>35-39</td>
<td>40-44</td>
<td>45-49</td>
<td>50-54</td>
<td>55-59</td>
<td>60-64</td>
<td>65-69</td>
<td>70-74</td>
<td>75-79</td>
<td>80-84</td>
</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Superimposed on the cells in Figure 1 are two sets of arrows - a horizontal set (solid lines) and a diagonal set (broken lines). The horizontal arrows represent the way the proportion of drivers in a particular five-year age group changes over time. The relationship between the proportion of drivers and time is assumed to be a logistic curve - illustrated in Figure 2. The equation for the logistic growth curve (shown in Figure 2) indicates that the upper limit of the proportion of drivers in each age group is determined by the parameter 'k', and the rate at which the growth curve rises is determined (at the point of inflexion) by the parameter 'a' in the exponential term. The parameter 'b' is a scaling factor.

**Figure 2: Illustrating the assumed growth of the proportion of drivers over time**
The diagonal arrows in Figure 1 represent cohorts of drivers moving through time and a plot of the proportion of drivers in a cohort as both time and age increased is illustrated in Figure 3.

**Figure 3: Illustrating the changes in the proportion of drivers in a cohort as age changes over time**

The initial rise in Figure 3 represents the rapid increase in the number (and proportion) of drivers obtaining their licences after age 17. This rate of increase slows as the drivers in the cohort become older, until the rate of addition of new drivers balances the rate at which drivers give up driving - at which time, the proportion of drivers in the population reaches a maximum ($P_{\text{Max}}$). Thereafter, the proportion of drivers declines at a rate determined by the rate at which drivers give up driving. The equation shown in Figure 3 is the equation which has been used to represent the falling part of the curve. It will be seen that the decline in the proportion of drivers is assumed to be represented by a curve in which $1-P/P_{\text{Max}}$ increases exponentially (called subsequently the 'driving decrement function'). $A_0$ represents the age at which the decline in the proportion of drivers is taken to begin - 65 will turn out to be a
reasonable value for \(A_0\) - and 'c' determines the rate of decline; 'd' is a scaling factor.

Referring now to the matrix illustrated in Figure 1 it will be seen that the data in the cells to the left of the vertical thick line (data which in principle is available from existing sources) can be used to calibrate the parameters of the equations given in Figures 2 and 3 for each age and sex group. These equations can then in principle be used to predict the proportions of drivers in each of the shaded cells of Figure 1.

**Data sources and initial processing**

The data required to implement the process described above include population data (from the past), population predictions (for the future), data giving the numbers or proportions of currently licensed drivers, and data relating to accidents and casualties.

The population data for Great Britain by age group and sex used in the study were obtained from the Office for National Statistics, Fareham, Hampshire. National population projections for Great Britain were taken from those provided by the Government Actuary's Office based on information available in 1988.

The Driver and Vehicle Licensing Agency (DVLA) supplied data relating to the number of licensed drivers for each year from 1986 to 1997. This provided a 12-year sequence of licensing data for males and females separately, partially disaggregated by age - a suitable disaggregation by age was not available for the earlier years. For the purpose of estimating the proportions of licensed drivers in the five-year bands required by the prediction process, the DVLA data were used in conjunction with population data and National Travel Survey (NTS) data to provide estimates of the numbers of licensed drivers and the proportions of licensed drivers (P) for males and females for the five-year age bands shown in Figure 1. This was achieved by fitting a logistic equation (Figure 2) to the values of P obtained from DVLA/NTS data. The equation was fitted by regressing \((1/P)-1k\) against the year, and adjusting 'k' iteratively so as to optimise the data fit. These logistic regression equations were then used to estimate the mid-point values of the proportion of licensed drivers (P) in five-yearly intervals as required for the analysis.

**Predicting the proportion of licensed drivers**

The key step in predicting the proportion of drivers (P) over the next 20 years or so is the estimation of P in the target period (2020-24). Predicted values of P over the next 20 years may then be obtained from a family of logistic curves (one for each
age and sex group) which passes through the current value of \( P \) and the value of \( P \) in the target period. The estimate of the value of \( P \) in the target period is obtained from fitting the equation shown in Figure 3 to the cohort data represented by the diagonal dotted arrows in Figure 1. The process involves two steps - first, the value of \( P_{\text{Max}} \) has to be estimated for each cohort, then based on \( P_{\text{Max}} \), the parameters of the ‘giving up driving’ relation \( (A_0, c \text{ and } d) \) have to be determined.

Figure 4 shows, by way of illustration, the proportion of licensed drivers estimated as described in the previous section, plotted for the various cohorts of male drivers. Cohorts are labelled with the age group they fall into in the latest five-year period (1995-99).

Figure 4: The estimated proportion of licensed drivers by cohort - male drivers

Estimates of \( P_{\text{Max}} \) for all cohorts of male drivers were obtained from the data illustrated in Figure 4; corresponding values of \( P_{\text{Max}} \) were obtained in a similar way for female drivers. \( P_{\text{Max}} \) represents the maximum proportion of licensed drivers in each cohort assuming no one gives up driving. It is now necessary to address the question of the rate at which these drivers will give up driving as they get older - the driving decrement function.

Using the values of \( P_{\text{Max}} \), the ratio of \( P/P_{\text{Max}} \) was calculated for cohort 70-74 through to cohort 90+ for male and female drivers. The parameters of the driving decrement relation illustrated in Figure 3 were determined by plotting \( \ln(1-(P/P_{\text{Max}})) \) against the mid-point age of the cohort minus a suitable value for \( A_0 \), omitting those ratios which exceeded 1 as a result of random fluctuations in \( P \). A value for \( A_0 \) of 65 was chosen from the data by inspection as that age prior to which no reductions in \( P \) were observable. There was no statistically
significant difference between the driving decrement functions for male or female drivers and the data have therefore been combined. Figure 5 shows the resulting driving decrement function.

**Figure 5: The driving decrement function**

![Driving decrement function graph]

Rounding the combined values, the driving decrement function (Figure 5) becomes:

\[
P = P_{\text{Max}} (1 - 0.02e^{0.14(\text{AGE 65})})
\]

in which AGE is the mid-point of the age bands. This equation implies that the age at which there are no longer any licensed drivers (i.e., all have given up: \( P=0 \)) is 92.8, which seems reasonably realistic, though this figure is subject to considerable error. In order to allow for future changes in life expectancy, another term needs to be included in the driving decrement function to give:

\[
P = P_{\text{Max}} (1 - 0.02e^{0.14(\text{AGE 65-0.3N})})
\]

where \( N \) is the number of future five-year periods starting with \( N=0 \) at 1995-99. This modified decrement function means that at the mid-point of the target period (mid-year 2022) the age at which all drivers have given up driving becomes 95. Not surprisingly, the proportion and number of drivers in the oldest age groups are very sensitive to the coefficient of \( N \).

Table 1 (columns 2 and 3) shows the estimated values of \( P_{\text{Max}} \), from the analysis of the cohort data (illustrated for males in Figure 4). Combining these values with the driving decrement function generates the estimates of the proportion of licensed drivers in the target period shown in columns 4 and 5 of the
The values of $P$ for each age and sex group over the 25-year prediction period can now be obtained by fitting a logistic curve which passes though $P_{1995-99}$ (the current value) and through $P_{2020-25}$ (from Table 1). The resulting equations are given in Table 2. For convenience, the Table also includes the initial and final values of $P$.

Table 2: Predicted values of $P$ and parameters of the logistic curve

<table>
<thead>
<tr>
<th>Age group in 2020 2025</th>
<th>$P_{1995-99}$</th>
<th>Logistic curve parameters</th>
<th>Predicted $P_{2020-25}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$k$</td>
<td>$a$</td>
<td>$b$</td>
</tr>
<tr>
<td>Male licence holders</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60-64</td>
<td>0.854</td>
<td>1.022</td>
<td>-0.064</td>
</tr>
<tr>
<td>65-69</td>
<td>0.823</td>
<td>1.066</td>
<td>-0.091</td>
</tr>
<tr>
<td>70-74</td>
<td>0.717</td>
<td>1.083</td>
<td>-0.086</td>
</tr>
<tr>
<td>75-79</td>
<td>0.640</td>
<td>1.154</td>
<td>-0.094</td>
</tr>
<tr>
<td>80-84</td>
<td>0.511</td>
<td>1.309</td>
<td>-0.102</td>
</tr>
<tr>
<td>Age Group</td>
<td>Male</td>
<td>Mileage</td>
<td>Sex</td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
<td>---------</td>
<td>-----</td>
</tr>
<tr>
<td>85-89</td>
<td>0.379</td>
<td>1.760</td>
<td>-0.109</td>
</tr>
<tr>
<td>90+</td>
<td>0.155</td>
<td>5.012</td>
<td>-0.117</td>
</tr>
</tbody>
</table>

**Female licence holders**

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Male</th>
<th>Mileage</th>
<th>Sex</th>
<th>Liability</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-64</td>
<td>0.502</td>
<td>1.023</td>
<td>-0.087</td>
<td>7.82</td>
<td>0.883</td>
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<td>65-69</td>
<td>0.418</td>
<td>1.094</td>
<td>-0.096</td>
<td>12.94</td>
<td>0.826</td>
</tr>
<tr>
<td>70-74</td>
<td>0.276</td>
<td>1.169</td>
<td>-0.110</td>
<td>34.39</td>
<td>0.754</td>
</tr>
<tr>
<td>75-79</td>
<td>0.194</td>
<td>1.321</td>
<td>-0.116</td>
<td>62.04</td>
<td>0.653</td>
</tr>
<tr>
<td>80-84</td>
<td>0.117</td>
<td>1.617</td>
<td>-0.122</td>
<td>129.5</td>
<td>0.514</td>
</tr>
<tr>
<td>85-89</td>
<td>0.054</td>
<td>2.356</td>
<td>-0.128</td>
<td>348.9</td>
<td>0.332</td>
</tr>
<tr>
<td>90+</td>
<td>0.012</td>
<td>7.486</td>
<td>-0.135</td>
<td>1937</td>
<td>0.099</td>
</tr>
</tbody>
</table>

**Accident liability**

Injury accident data covering Great Britain were obtained from the Department of the Environment, Transport and the Regions (DETR STATS19) for each year from 1986 through to 1997 so as to match the NTS data on the numbers of licensed drivers.

Inevitably, some of the data in the STATS19 database relating to the age or sex of the drivers involved in accidents are unavailable; in the present study accident liabilities have been corrected for this missing data by multiplying the liabilities based on drivers with known age and sex by appropriate correction factors: 1.067 for KSI and 1.1 for slight accidents.

For purposes of predicting the accident rates for groups of drivers it is essential to be able to take into account the fact that the different groups have different levels of exposure to the risk of an accident, and that this exposure will change over the 25 years or so of the prediction period. In the present study annual mileage has been used as a proxy for exposure using a predictive model of annual mileage.

Estimates of annual mileage were available from the National Travel Surveys for male and female licence holders separately and for the various age groups. From these data, a model was developed which would enable annual mileage to be predicted from the survey years and the age of the drivers and extrapolated into the future. A number of different linear and non-linear models were tried, but the most satisfactory was:

Male licence holders: $\text{Annual mileage} = (32,014 - 564\text{Age} + 2.4\text{Age}^2) e^{0.000237\text{Age}\times\text{Yr}}$

Female licence holders: $\text{Annual mileage} = (9,557 - 129\text{Age} + 0.32\text{Age}^2) e^{0.000237\text{Age}\times\text{Yr}}$
where \( Yr \) is the actual year minus 1992. The SE of the exponential term is 0.000036.

Of course, the growth of annual mileage obtained by extrapolating current trends takes no account of changes in future policy regarding the use of the car, and ideally these projections should be brought into line with national road traffic forecasts. However, no allowance has been made in this analysis for changing policy on car use, though the coefficient of the exponential term in the above model can be regarded as a parameter of the model and adjusted to examine the effect of different rates of growth of mileage.

Accident liability is defined as the number of accidents per year a driver is expected to be involved in as a driver (expected, that is, in a statistical sense). In the present paper accident liabilities are presented as accidents (of a particular type) per 1,000 drivers. Accident liabilities have of course been changing over the years, so that it is necessary to model these changes. The simplest trend assumption would be that accidents have fallen by a constant multiplier each year resulting in a negative exponential decline over time. In addition, it is necessary to decide how to relate accident liability of a driver to their annual mileage. A number of studies of accident liability of individual drivers have shown that accidents are not directly proportional to annual mileage (Maycock et al, 1991, Forsyth et al, 1995).

Taking these factors into account suggests an accident model of the form:

\[
\text{Accident liability} = A(\text{Age, Sex}) M^a e^{-b \text{Year}}
\]

where ‘\( b \)’ is the fractional reduction in accident each year, Year is the year in which the accidents took place, \( A \) is a constant dependent on the age and sex group being considered and \( M \) is the average annual mileage raised to a power \( a \); both ‘\( b \)’ and ‘\( a \)’ are assumed to be common to all driver groups. Unfortunately, the data available in the present study do not allow the values of ‘\( b \)’ and ‘\( a \)’ to be determined independently, and in order to use this model the power of mileage has to be imported from other studies. In the present case, a value of 0.3 has been used (Maycock et al, 1991).

Table 3 gives estimates of the coefficients of the accident models for KSI and slight accidents. The table indicates that the statistical precision obtained for the older age group accident liabilities is rather poor because of the relatively small amount of data available for these groups, and this fact needs to be borne in mind when considering the accident predictions.

**Table 3:** Accident liabilities per 1,000 licence holders (1992) according to the equation given above
### Casualties

By definition, every injury accident results in one or more casualties. The number of casualties arising from the accidents in which drivers of a particular age group or sex are involved will, in the present study, be estimated by multiplying the predicted number of accidents by an estimate of the number of casualties per accident. It is therefore necessary to estimate the number of casualties per accident for both KSI and slight accidents and to determine whether this ratio is dependent on

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</table>
In order to do this, accident and casualty data for the five years 1979, 1983, 1987, 1992 and 1997 have been computed and analysed. Two ratios have been formed for both sexes and for each of the age groups from 60-64 through to 90+; these ratios are: KSI casualties/KSI accident, and slight casualties/all accidents. Multivariate analysis of these ratios showed that there was no significant difference between the sexes. In the case of KSI ratios, there was no trend over time and little practical age effect, so that an overall average value of 1.22 KSI casualties per KSI accident has been used in the prediction process. The SE of this average casualty rate is 0.008.

As far as slight accidents are concerned, there was a significant age effect and a trend over time - for convenience, 1992 has been used as the reference year to correspond with the accident models. The best fit equation describing the data was:

\[
\text{Slight casualties per accident} = 1.34 \exp[-0.002\text{Age} + 0.01(\text{Year} - 1992)]
\]

The SE of the age term is 0.001, and of the year term 0.0015.

**Accident and casualty predictions**

We are now in a position to predict the future number of accidents and the resulting casualties for the age groups 60-64 up to 90+. The process of prediction is that described at the beginning of the paper. The basic population projections for the years from 1998 to 2022 (mid-five-year values) are those provided by the Government Actuaries office. The proportion of licensed drivers (P) is then predicted using the logistic curves specified in Table 2. The number of licensed drivers is the product of these two numbers. An estimate of the annual mileage of drivers by age and sex is then derived from the mileage model, and the KSI and slight accident liabilities estimated from the models given in Table 3.

To correct for missing data in STATS19, KSI liabilities have been scaled by 1.067 and the number of KSI accidents for each age and sex group calculated by multiplying the number of drivers by their accident liability; the number of KSI casualties is the number of accidents multiplied by 1.22.

The number of slight accidents and casualties is calculated in the same way as are KSI accidents and casualties, except that the missing data correction is 1.1 and the number of slight casualties per accident is derived from the model given earlier.
Tables 4 and 5 summarise the predictions; the upper part of each table shows the predicted accidents and casualties by age group for male and female licence holders, and the lower part sums over the age groups to provide aggregate estimates for ages 60 and over, 65 and over etc up to 85 and over. The columns labelled D% in the tables are the equivalent annual percentage growth or decline of accidents or casualties over the 24 years of the prediction (1998 to 2022). As can be seen from the tables D% ranges from a decline of 4 per cent per year for the younger male groups - where the future growth in the number of drivers is limited - to an increase of 5-9 per cent per year for those groups of older female drivers who represent the fastest growing sector of the driving population.

The aggregate figures in the lower part of the tables have been corrected for the 'double counting' of accident and casualties implicit in the process of aggregating accident and casualties from smaller age groups.

### Table 4: Predicted fatal and serious accidents and casualties by age group for male and female drivers

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Table 5: Predicted slight accidents and casualties by age group for male and female drivers

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Aggregated totals - corrected for double counting

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Prediction accuracy

An attempt has been made to assess the accuracy of the above predictions. The statistical 'errors' involved fall into two categories - those which allow confidence intervals to be estimated from current parameter values, and those which extrapolate mileages, accident liabilities and casualties per accident into the future.

To give an indication of the errors of the first kind (ie assuming the trend effects are known without error), for male drivers aged 80-84, the number of KSI accidents in the final period (2020-25) together with an estimate of the 95 per cent confidence intervals turns out to be 176 ± 21 - a 12 per cent
margin. The corresponding values for slight accidents are estimated to be $2,082 \pm 211$ - a 10 per cent margin. The 95 per cent confidence intervals for casualties expressed in percentage terms are similar to those for accidents. For the younger age groups the 95 per cent confidence intervals are less; for 60-64-year-old males they are between 2 per cent and 3 per cent. For the older groups the 95 per cent confidence intervals are considerably larger; for the 85-89-year-old male drivers they rise to about 25-30 per cent, and for the 90+ group they are nearer 200 per cent.

Superimposed on these errors are errors resulting from the extrapolation of mileage, accident liability and, in the case of slight casualties, the casualty rate multiplier. If all the coefficients of time in these factors changed by their 95 per cent confidence intervals in such a way as to change the accident predictions in the same sense, the predictions for the target period for 80-84-year-old males would change by an average of $\pm 13$ per cent for KSI accidents and casualties. The corresponding effects for slight accidents or casualties are $\pm 11$ per cent for accidents and $\pm 21$ per cent for casualties (the change in casualties per accident for slight accidents producing this differential effect). Moreover, the effect of errors in the time-dependent trends is much the same for all groups so that when the two error types are combined the younger age groups will have confidence intervals of the order of $\pm 12$ per cent, increasing considerably for the older drivers - in particular, the predictions for the 90+ age group (both sexes) are poor because neither the estimates of $P_{2020-25}$ nor the accident liabilities for these groups have been determined with any degree of accuracy.

When considering errors of the second kind (ie trend effects), it needs to be borne in mind that these trends are reflecting changes in the broader aspects of travel safety, and future trends will not necessarily be the same as they have been in the past. However, a comparison of the predictions for the 60-64-year-old group - the group which is the most likely to be similar to the population as a whole - with those of Broughton et al (2000) based on the population as a whole suggests that the predictions shown above are broadly in line with Broughton et al's more comprehensive assessment, at least for the next decade.

References


2 Predicting the on-road performance of older drivers

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Introduction

As reported in previous seminars, the Older Driver Project comprised three phases. In the first phase almost 2,000 drivers aged 50-90 completed a lengthy self-report questionnaire (the Ageing Driver Questionnaire, ADQ) covering a range of issues including their current driving behaviour and habits, areas of perceived strength and weakness, confidence and opinions about a range of possible road safety interventions. In Phase Two, 550 of those who had returned the ADQ went on to complete several hours' worth of laboratory testing, assessing a variety of cognitive and physiological abilities, and also measuring personality, intelligence, driving knowledge and general health. This paper reports on the relationships between the driving behaviour and performance measures collected in Phases One and Two of the programme, and a range of on-road driving performance measures collected during Phase Three.

Method

Participation was voluntary and offered, for ethical reasons, after a full account had been given of what the assessment would involve. Six hundred participants from the previous two phases were invited to take part and 436 volunteered to do so. The final 200 volunteers were selected using information obtained from the ADQ. Criteria used in the selection procedure included having taken no advanced driving qualifications or tuition and not having driven professionally. Further selection criteria aimed to ensure a good age range, in so far as this was possible, and an equal representation of both sexes.

Two assessment drives (route A and route B) were completed by each participant on two occasions, in the majority of cases one week apart. Order of route presentation was counterbalanced. Volunteers drove their own vehicle. One drive was completed in the morning, the other in the afternoon. ADIs, trained in the administration of the assessment, accompanied the volunteer in the passenger seat giving directional instructions and noting performance. Four ADIs worked on the assessment programme. Both routes were in suburban areas of Manchester and took approximately 35 minutes to drive, covering distances of 9.7 miles and 8.8 miles.

Prior to the assessment commencing, the ADI made a check of driving licence and insurance, noted details of the vehicle to be driven and made a short check of the vehicle condition. Before the drive commenced each participant was required to read successfully a licence plate at a distance of 20.5m (67ft).

Each assessment was structured in three parts. The first and third sections were alike and consisted of continuous assessment, scored in a manner identical to the UK driving test. Driver faults, serious faults and dangerous faults were recorded in relation to 35 items, grouped into 14 categories. The number of items in each category varied. The second section consisted of a series of assessed situations such as turning right at a crossroads or reversing for five metres. Eighteen manoeuvres/situations were assessed on Route A and 14 on Route B. A separate grade was awarded for each. Grades ranged from 1 to 6. A performance rating of '6' (very good) indicated that the driver had demonstrated no faults, '5' (good) that the driver had shown one driving fault, '4' (adequate) more than one driving fault, '3' (inadequate)
one serious error, '2' (poor) more than one serious error and '1' (dangerous) more than one dangerous error.

After the assessment was complete the ADI awarded a global score between 1 and 5. The global score, a subjective measure, was designed to reflect the personal opinion of the ADI concerning the volunteer's driving performance and was not a simple summary of the other measures.

The volunteer ended the assessment session by completing a second copy of the mood evaluation form and filling out a questionnaire rating their performance and answering a series of questions concerning their assessment experience.

**Measures**

Five indices of performance were calculated.

- Route A continuous performance: a measure of the number and seriousness of driving faults noted by the ADI. This was computed by scoring 1 point for each driver fault, 2 for serious faults and 3 for dangerous faults.
- Route B, continuous performance: assessed as for Route A.
- Overall score for performance on a total of 32 assessed manoeuvres. This score reflects performance on both drives as the manoeuvres/situations encountered on each were not the same.
- Global score, Route A: which reflects the ADI's overall impression of the driver on a five-point rating scale designed to measure driver safety.
- Global score, Route B: which reflects the ADI's overall impression of the driver on a five-point rating scale designed to measure driver safety.

**Inter-rater reliability among ADIs**

The on-road project design allowed for comparison between ADIs on all measures to ensure that a good degree of inter-rater reliability had been achieved. However, comparison of continuous assessment scores on all sections revealed that one of the four ADIs had scored significantly more faults than the others. Further, no correlation existed between this ADI's score and the score awarded to participants on their second assessment. Significant correlations existed between the other ADIs. Data collected by this ADI on the continuously assessed sections were therefore excluded from further analysis. This reduced the number of complete (two route) data sets to 113, the number of Route A data sets to 154 and the number of Route B data sets to 160.

**Results**

Overall, driving performance was good, although this may in part reflect the nature of the sample.

- Route A continuous performance: mean score was 9.17, range 1-21.
- Route B, continuous performance: mean score was 11.07, range 2-21.
• Overall score for performance on a total of 32 assessed manoeuvres: mean score was 5.2, indicating more than adequate performance on the manoeuvres and assessed situations. The range of scores obtained was 4.7-5.9.

• Global score, Route A: mean rating was 3.79, range 2-5.

• Global score, Route B: mean rating was 3.70, range 2-5. The mean global ratings given by ADIs for both routes indicated that they felt the older drivers were 'not bad'.

The next step was to consider the relationships between on-road performance and demographics, variables from the ADQ and laboratory test scores. In order to reduce the data to manageable proportions for such an analysis, simple bivariate correlations between each of the five on-road indices and a wide range of potential predictor variables were computed. Those with significant bivariate correlations were retained and subsequently entered into stepwise multiple regression analyses predicting scores on each of the five on-road indices. The regression equations were built up as follows: on the first step, age, sex and annual mileage were forced into the regression equation. On a second step, scores on the DBQ scales and on the 'theory test' were entered stepwise, and on the third step those laboratory variables significantly associated with four or five of the on-road measures were entered stepwise. This analysis strategy allowed for the influence of age, sex and mileage to be statistically removed from the analysis, so that the additional influence, if any, of the psychological variables could be assessed.

**Table 1: Predicting continuous assessment score, Route A**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Beta</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.06</td>
<td>0.64</td>
<td>NS</td>
</tr>
<tr>
<td>Mileage</td>
<td>0.04</td>
<td>0.38</td>
<td>NS</td>
</tr>
<tr>
<td>Sex</td>
<td>0.02</td>
<td>0.18</td>
<td>NS</td>
</tr>
<tr>
<td>'Theory test' score</td>
<td>-0.23</td>
<td>-2.55</td>
<td>0.01</td>
</tr>
<tr>
<td>Flexibility</td>
<td>-0.24</td>
<td>-2.72</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Adjusted R² = 0.079, F = 3.31, p < 0.01

Table 1 shows that the only significant predictors of continuous assessment scores for Route A were a relatively high 'theory test' score and good flexibility, which together accounted for almost 8 per cent of the variance in scores.

Table 2 shows that there were three independent and significant predictors of continuous assessment scores on Route B. These were DBQ lapses, 'theory test' score and height, which together accounted for 20 per cent of the variance in scores. Those who the ADIs marked relatively well tended to report fewer DBQ lapses, to score well on the 'theory test' and to be relatively tall.

**Table 2: Predicting continuous assessment score, Route B**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Beta</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
</table>

29
As shown in Table 3, scores on manoeuvres and assessed situations were predicted by being female, scoring relatively well on the 'theory test' and having a good respiratory capacity. Together these factors accounted for 14.4 per cent of the variance in scores.

**Table 3: Predicting performance on manoeuvres/assessed situations**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Beta</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.06</td>
<td>-0.71</td>
<td>NS</td>
</tr>
<tr>
<td>Mileage</td>
<td>0.60</td>
<td>0.77</td>
<td>NS</td>
</tr>
<tr>
<td>Sex</td>
<td>0.20</td>
<td>1.97</td>
<td>0.05</td>
</tr>
<tr>
<td>'Theory test'</td>
<td>0.21</td>
<td>2.70</td>
<td>0.01</td>
</tr>
<tr>
<td>Respiratory capacity</td>
<td>0.34</td>
<td>3.57</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Adjusted $R^2 = 0.144$, $F = 7.00$, $p < 0.001$

Table 4 shows that only respiratory capacity contributed significantly to prediction, accounting alone for 7 per cent of the variance in global scores on Route A.

**Table 4: Predicting global score, Route A**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Beta</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.13</td>
<td>-1.46</td>
<td>NS</td>
</tr>
<tr>
<td>Mileage</td>
<td>0.05</td>
<td>0.60</td>
<td>NS</td>
</tr>
<tr>
<td>Sex</td>
<td>0.12</td>
<td>1.11</td>
<td>NS</td>
</tr>
<tr>
<td>Respiratory capacity</td>
<td>0.28</td>
<td>2.83</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Adjusted $R^2 = 0.073$, $F = 4.55$, $p < 0.01$
As shown in Table 5, global ratings for Route B were predicted by a relatively high score on the 'theory test' and a relatively good respiratory capacity, which together accounted for 15 per cent of the variance in scores.

### Table 5: Predicting global score, Route B

<table>
<thead>
<tr>
<th>Variables</th>
<th>Beta</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.07</td>
<td>-0.85</td>
<td>NS</td>
</tr>
<tr>
<td>Mileage</td>
<td>0.11</td>
<td>1.37</td>
<td>NS</td>
</tr>
<tr>
<td>Sex</td>
<td>0.01</td>
<td>0.11</td>
<td>NS</td>
</tr>
<tr>
<td>'Theory test'</td>
<td>0.26</td>
<td>3.37</td>
<td>0.001</td>
</tr>
<tr>
<td>Respiratory capacity</td>
<td>0.18</td>
<td>1.90</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Adjusted $R^2 = 0.150$, $F = 7.31$, $p < 0.001$

To summarise:

- age and mileage were not significantly associated with any of the five on-road measures;
- gender was only marginally related to one of the five on-road measures;
- score on the 'theory test', administered as part of the ADQ, was significantly associated with four of the five on-road measures; in each case, those with higher scores on the 'theory test' performed relatively well in the on-road tests;
- a relatively strong respiratory capacity, as measured by spirometer, was significantly predictive of good scores on three of the five on-road measures;
- a high score on the DBQ lapse factor was significantly predictive of one of the five on-road indices;
- none of the cognitive tests was consistently predictive of any of the ADIs’ on-road assessments.

Discussion

The design of the on-road assessment allowed for several measures of driving performance to be made. All of these measures were significantly inter-correlated, indicating that continuous assessment scores, assessed manoeuvre/situation scores and global scores are related. It is difficult to determine which is the most 'useful' score. The continuous assessment score can highlight areas that the driver should pay attention to (such as taking care to signal correctly), whilst the assessed situation score can highlight the circumstances that an
individual finds problematic. The global score is perhaps least useful of the three types of assessment as it does not give specific details of performance which are useful in feedback to the driver. It is also noteworthy that the global scores were correlated with more demographic variables than were the other, more objective, measures. It is possible that the associations with factors such as sex and social class were due to personal bias or prejudice on the part of the ADIs. This is important to note, as an assessor can never be blinded to all information concerning the person being assessed, particularly when they drive their own car.

Performance on a surprise 'theory test' emerged as the most consistent predictor of on-road performance. This was a multiple-choice test using items taken from the bank of questions used in the current learner driver theory test. However, as the items used were chosen for their particular relevance to the older driver, this test cannot be considered as functionally equivalent to the actual learner driver theory test, which uses sets of items carefully balanced and validated for use together. Nevertheless, that theoretical and practical knowledge about driving is of significant importance in relation to actual performance is an interesting finding. The older drivers did not do especially well on the 'theory test', which currently has a pass mark of 32 correct of 35 items attempted. However, learner drivers are prepared for such a test, whereas the participants in this research had no warning and thus no time to prepare. In fact, the average length of time since participants last saw the Highway Code was reported at 17 years.

Taking this finding at face value it seems that knowledge of driving theory is important for actual on-road performance. If this is the case then it is possible that intervening to improve knowledge of driving theory would increase levels of safety and driver ability. This could be done relatively easily by sending appropriate literature to those aged 70 plus in the UK who are renewing their licenses. However, a cautious approach to these findings is necessary. It is possible that performance on the driving theory test may reflect, more generally, a continuing interest in and engagement with the task of driving. This suggestion is made all the more plausible by the association of DBQ lapse score with one of the continuous assessment measures. A relatively high score on DBQ lapses, which has been shown previously to be linked in this sample to accident involvement (Parker et al, 2001), may also reflect a lack of interest in and engagement with driving. Alternatively, both a high number of lapses and a poor performance on the 'theory test' may be acting as indices of general mental deterioration, a speculation strengthened by the significant correlation.
(R=0.31**) between DBQ lapse score and CMI score. At the same time, three of the five on-road measures were predicted by respiratory capacity, a measure that may be acting as a general measure of cardiovascular health. All of these tentative lines of evidence can be seen as pointing to the conclusion that mental alertness is the key to continuing proficient driving performance, although more research would clearly be necessary before this conclusion was established as reliable.

Of equal interest are those variables that might have been expected to explain a proportion of variation but did not. Neither age, gender nor mileage has consistent predictive relationships with on-road performance. This suggests that chronological age offers at best a crude indicator of likely competence and performance levels, and that those with an interest in road safety should consider using a more sensitive indicator. Within this sample at least, there were no gender differences in performance, with males and females equally likely to do well. Moreover there was no evidence of a practice or familiarity effect, in that reported annual mileage was not predictive of performance. Neither was general health, as measured by the Cornell Medical Index, predictive of on-road performance among this sample.

However, it must be noted that some of these slightly surprising findings may have been due to sampling effects in this study. The sample who took part in the on-road assessments were self-selected, a consequence not of poor methodology but of necessity. This will have had consequences, one being that the standard of driving in the group as a whole is likely to have been relatively high, as poor or nervous drivers will not have agreed to take part. This may also mean that drivers who demonstrated a low level of driving skill may have lacked insight (hence having agreed to take part), whilst those poor drivers who did have insight did not agree to take part.

Overall, the standard of driving ability demonstrated in this sample was fairly good. The emergence of 'theory test' score, respiratory capacity and DBQ lapse score as significant predictors of performance points to the possible benefits of self-administered diagnostic tests, maybe including the DBQ and a 'theory test' for older drivers seeking to assess their own abilities.

References
3 Driver sleepiness: Overview of recent findings from Loughborough Sleep Research Centre


Background

From accident surveys undertaken with many UK police forces we have found that sleepiness accounts for 15-20 per cent of accidents on monotonous roads, especially motorways1. Typically, these accidents involve running off the road or into the back of another vehicle, and are worsened by the high speed of impact (ie no braking beforehand). Many of these accidents are work-related (eg trucks, goods vehicles and company car drivers).

The body's natural biological clock has a major influence on sleepiness, as these accidents peak around 2am-7am and 2pm-4pm, when daily sleepiness is naturally higher2. Sleep-related vehicle accidents are more evident in young male drivers in the early morning and among older male drivers during the mid-afternoon, as the afternoon 'dip' tends to become more apparent as one gets older3. Of course, young men are more likely to be on the road in the early morning. However, as the effects of sleep loss and sleepiness are more profound in younger than in older people, which young men tend to deny, they are at a much greater risk when driving during the small hours.

Using a real-car simulator we have been undertaking laboratory studies of falling asleep at the wheel. In the earlier Phases 1 and 2 of this DTLR-sponsored research programme we examined the process of falling asleep at the wheel and the extent to which sleepy drivers are aware of their sleepiness. We also evaluated practical methods for the driver to overcome sleepiness. Our methodology has been validated on a real driving track4. We have shown that sleep does not occur spontaneously without warning, and is preceded by feelings of increasing sleepiness5 to the point that drivers who fall asleep would have reached the stage of 'fighting off' sleep when they will try and keep themselves awake, for example by winding down the window for cold air, turning up the radio, stretching at the wheel, etc. They must be aware of these acts and their sleepiness at the time. Nevertheless, after having fallen asleep at the wheel, drivers are unlikely to recollect having done so, and may even claim that it was an unforewarned 'sleep attack'. What many sleepy drivers do not appreciate is that sleep itself can ensue more rapidly than they imagine, and that their driving impairment is worse than they realise6. Sleepiness can also cause mild euphoria and increased confidence in one's driving ability7.

Continuing to drive whilst sleepy, and relying on cold air to the face and turning up the car radio, are of limited benefit8 - effective for only a matter of minutes - sufficient only to enable the driver to find a safe spot to take a break. The fact that drivers are aware of their sleepiness underlies the decision of the DTLR to instigate the erection of permanent signs on most motorways - 'Tiredness can kill - take a break'.

In taking a break (eg 30 minutes), what should the sleepy driver do? We have found that exercise (eg brisk walking) is of little use9. Short naps (less than 15 minutes) are very effective10, as is caffeine (150mg - as in about two cups of coffee or two cans of 'functional energy drinks'). Better still, take this caffeinated drink and then take the nap. Caffeine takes 20-30 minutes to be absorbed and act on the brain; hence there is the opportunity for a nap.
Caffeine (200mg) in the form of a beverage is particularly good for the early morning driver having had little sleep that night. These findings from Phases 1 and 2, concerning caffeine and naps, have been incorporated into the latest edition of the Highway Code.

Phase 3

Phase 3 of the research programme comprised five components.

1. Completion of the journal publication of research undertaken in Phase 2.
2. Further road accident audits to identify objectively the prevalence of sleep-related vehicle accidents.
3. A pilot study to examine the usefulness of tachograph charts for detecting sleep-related vehicle accidents.
4. Extension of the countermeasures research, to evaluate reaction time measures to detect driver sleepiness.
5. An investigation to ascertain whether 'naturally sleepier' individuals are more liable to show drowsy driving impairments.

Further road audits

Following the M40 road audit undertaken in Phase 2 and an earlier, initial pilot study on the A180/M180, we have conducted two further audits on a section of the M5 (between junctions 5 and 8) policed by West Mercia Constabulary, and on a larger scale, with North Yorkshire Police, involving four roads: the A1(T), A1(M), A19(T)/ A168(T) dual carriageway and A19(T) single carriageway. All the audits covered the period 1st January 1997 until 31 December 1998. Full reports are with the DTLR. We have developed criteria for determining whether an RTA is likely to be caused by sleepiness - ie a sleep-related vehicle accident (SRVA):

1. good weather conditions and clear visibility
2. breathalyser/blood alcohol levels below the legal driving limit
3. no mechanical defects to the vehicle
4. elimination of 'speeding' and 'driving too close to the vehicle in front'
5. driver had no known medical disorder to cause accident
6. vehicle either ran off the carriageway, or ran into another vehicle that was clearly visible for several seconds beforehand - ie the incident was easily avoidable, implying prolonged inattention
7. no signs of pre-impact emergency swerving or braking, eg no skid marks before the impact
8. the police officer at the scene suspected 'sleepiness'.

If all criteria 1-7 applied then the accident was a 'possible' SRVA. The inclusion of criterion 8 classified it as a 'probable' SRVA. The absence of this last criterion when criteria 1-7 applied does not imply that the investigating officer excluded sleepiness. It should be noted that SRVAs are particularly likely to occur between approximately 2am-7am, and 2pm-4pm, when people are naturally more sleepy.
M5

This 18.7 mile section is artificially lit. During the audit period there were 108 road traffic accidents (RTAs) involving slight injury, serious injury or death to which the Police were summoned. All accident data held by the police were scrutinised. We determined that six were 'possible' sleep-related vehicle accidents (SRVAs), and 16 were 'probable' SRVAs, making 22 in all, and comprising 20 per cent of the total RTAs. Although only 5 per cent of total daily traffic flow occurred during late night/early morning hours, almost one-third of the SRVAs occurred at that time. About half of these SRVAs were caused by cars. SRVAs were about twice as likely to result in death or serious injury compared with other RTAs on this road. Most (82 per cent) of the drivers in SRVAs were men, and half were aged 30 years and younger. Almost half (41 per cent) of these drivers came from skilled manual occupations.

NORTH YORKSHIRE

This audit consisted of:

- 44 miles of unlit A1(M) and A1(T) from Wetherby to the River Tees (Darlington); the A1 is the major north/south route east of the Pennines
- 24 miles of unlit A19(T)/A168(T) dual carriageway from Dishforth to Crathorne
- 19 miles of A19(T) single carriageway, from the A1237(T) York outer ring road to Sowerby, where the A19(T) branches off the main A19(T)/A168(T) dual carriageway. There is intermittent road lighting.

North Yorkshire Police attended 572 RTAs on these roads, of which 16 per cent were 'possible' or 'probable' SRVAs (except for the A19(T) single carriageway, which had a lower incidence of SRVAs). Compared with the daytime, about twice as many SRVAs occurred during the night/early hours of the morning (traffic flow was low) compared with the rest of the day. Put differently, half of all SRVAs happened then, compared with about 20 per cent of all RTAs. As one might expect, the overall incidence of RTAs generally rose with increasing traffic density. However, the A1(T) was particularly bad in this respect, in having an unusually high rate of RTAs. Nevertheless, the proportion of SRVAs on this road remained at approximately 16 per cent. Very few (less than 3 per cent) RTAs were associated with driver alcohol levels beyond the legal limit. Clusters of SRVAs were found on the A1(M); more so on the A1(T) and the A19(T)/A168(T). Road characteristics may facilitate this clustering. 65 per cent of SRVAs were caused by cars. Drivers in these SRVAs were more likely to:
  - sustain serious injuries than in RTAs as a whole
  - be men (91 per cent)
  - be aged 30 years and under (50 per cent)
  - be employed in skilled manual occupations (41 per cent).

Traffic Density

It is thought that road traffic density may affect driver sleepiness with, for example, a higher density providing greater stimulation for the driver and reducing the likelihood of sleepiness. Our findings from all our road audits do not support this assumption. For the types of non-
urban roads we have assessed, the propensity to fall asleep at the wheel is largely dependent on the inherent state of the driver and not on the road conditions.

**Tachographs and sleep-related HGV accidents**

When people fall asleep muscle tone relaxes throughout much of the body. In sleepy drivers this can be reflected in the relaxation of foot pressure on the accelerator and, depending on the extent to which the accelerator spring forces the foot up, the vehicle may slow down. If the driver then becomes more alert, muscle tone is restored, foot pressure returns and the vehicle may speed up. Very sleepy drivers can drift in and out of this state of sleepiness/alertness every few minutes for some time. In the case of vehicles equipped with tachometers, and when the driver is particularly sleepy, the possibility arises as to whether these devices reflect this periodicity, as well as a general slowing of speed. Of course this depends on a variety of other factors, such as traffic density, whether the vehicle is going uphill or downhill, the pressure required to depress the accelerator, and the presence of a speed limiter or use of a cruise control.

We analysed tachographs collected in the course of carrying out the road audits (above). All the tachographs were from HGVs having caused an RTA. Without knowing the accident causation (ie SRVA or non-SRVA), tachographs were studied 'blind', by examining the patterns of speed fluctuations and the time taken for changes in acceleration and deceleration in the final 15 minutes. The likely cause of the accident was then revealed. Findings were unclear, especially as most vehicles had speed limiters set at about 56mph. Given that many HGV drivers with speed limiters drive with their accelerator near to the floor, then relaxation of the foot, as with sleepiness, still leaves the accelerator depression beyond the level of cut-off for the speed limiter (ie no slowing). It was concluded that tachographs cannot be used as a reliable indicator for SRVAs. Whilst fluctuations in speed shown on tachographs may be the result of a sleepy driver losing and regaining muscle tones in the foot, these may be for other reasons. Also, the recent compulsory introduction of speed limiters further militates against this use of tachograph data for the purpose of detecting sleepiness.

**Reaction time measurements to detect driver sleepiness**

A driver's response time in braking in an emergency is generally thought to be impaired by sleepiness (although there is little good evidence to support this notion and reaction time (RT) used as an artificial task secondary to driving has been seen to be a good method for monitoring sleepiness. RT can be measured by means of the driver pushing a steering-wheel switch or a foot-operated button in response to stimuli generated from within the vehicle. However, laboratory studies indicate that a sleepy driver will either respond almost normally to an emergency or not at all (hence a collision). That is, response time becomes disrupted by sleepiness rather than reflects a gradual decline. This has been clearly demonstrated outside the field of driving, whereby deterioration in RT performance with sleepiness is reflected only in a portion of responses being impaired, often through momentary lapses. Thus, the majority of responses, even in sleepy people, usually remain within normal parameters.

In sum, little is known about what might be expected with RT as a secondary task in moderately sleepy drivers who otherwise show impaired driving (lane drifting) and declare themselves to be sleepy. Unfortunately, lapsing detected by these RT methods may be too late for a speeding driver to avoid a collision, as the vehicle may already be running off the road during the lapse. On the other hand, a RT response within normal parameters, even in a
sleepy driver, will be of little use in detecting sleepiness. Another issue concerning the application of RT as a secondary task during monotonous driving is that the very act of responding to the RT stimuli could have an arousing effect, particularly if the stimuli are frequent. Whilst this might seem to be advantageous, it masks underlying sleepiness and causes RT to be less sensitive to sleepiness.

With these viewpoints in mind we further evaluated simple RT as a secondary task to determine sleepiness in drivers and/or whether it otherwise affected driving behaviour in moderately sleepy people. They drove our real-car interactive simulator for two two-hour afternoon monotonous drives, with and without RT (counterbalanced). Lane wandering (driving 'incidents'), subjective and EEG measures of sleepiness were obtained. For both conditions all three of these latter measures worsened during the course of the afternoon circadian 'dip'. However, this was not reflected in RT, which remained relatively stable. In fact, RT did provide more 'stimulation' for the sleepy driver, and significantly reduced subjective sleepiness, with a trend for fewer incidents and a more alert EEG. We concluded that RT did not provide a useful guide to driver sleepiness; it was merely a mechanism for increasing task load and reducing monotony. That is, the more the sleepy driver has to keep him/herself occupied, the lesser the adverse effects of sleepiness. Also clear from the findings was that the drivers' own insight into their sleepiness was better than RT in this respect.

**TESTING OF A COMMERCIALLY AVAILABLE RT DEVICE**

Despite the doubtful validity of such RT devices, commercial products are coming on to the market. These may be problematic as they may simply encourage sleepy drivers to take further risks and continue to drive, with drivers believing that the device will alert them when necessary. We tested one such device that was claimed by the manufacturers to fulfil two functions to maintain/improve driver alertness by requiring immediate responses (via a foot switch) to frequent audio bleeps, and to monitor driver RT and, if responses slowed down, warn the driver by emitting a loud warning alarm. Utilising our driving simulator and standard driving protocol, sleepy drivers drove for two hours continuously on three occasions: twice using the device (to measure adaptation effects) and once as a control condition without the device. There was no clear evidence that the device reduced driving errors due to sleepiness. Instead, it caused more driving errors, as it seemed that during moderate sleepiness, responding to the frequent tone caused distraction and increased lane wandering.

**Driving ability in 'sleepier' or 'alert' people within normal limits of the Epworth Scale**

The Epworth Sleepiness Scale (ESS) is a commonly used self-assessment tool for assessing chronic (trait) levels of sleepiness. Scores of 10 or under are regarded to be within the normal range, and largely exclude those people with pathological, excessive daytime sleepiness, such as those suffering from obstructive sleep apnoea. In a large survey of UK car drivers, Maycock included the ESS, and reported that those respondents who did not snore, but had ESS scores higher in this range (ie more sleepy but probably without any serious sleep disorder), had a greater accident tendency than those with low ESS scores. Although Maycock could not establish whether this increased tendency was associated with sleep-related accidents rather than with accidents in general, it does suggest a link.

We were able to address this issue further using our database from our various driving simulator studies, as we administer the ESS routinely to all volunteers as part of the selection process, to include only those people within the 'normal' range of trait sleepiness. We have
data on 68 participants within the ESS range of 0-10. We selected the 10 most alert and 10 most sleepy within this range. They were studied during afternoon driving following a normal night's sleep and after a night of restricted sleep, which causes afternoon sleepiness to be increased. We found no differences in sleep-related lane drifting and subjective sleepiness between the 'more alert' and 'sleepier' groups, although there were trends with respect to the sleepier group showing more lane drifting following sleep restriction. However, of some concern was that the sleepier group tended to perceive themselves to be relatively less sleepy than the alert group following the sleep restriction. That is, unlike the alert group, they failed to realise the extent of their increased sleepiness, as perceived changes in sleepiness appear to depend on one's general (trait) frame of reference. This may become more evident in people having ESS scores beyond the norm.

**Key findings from Phase 3**

Our research has indicated that the following.

1. SRVAs are more likely to result in serious injury than the 'average' road accident.
2. Few accidents we investigated seemed to have alcohol as a contributory cause.
3. Men aged 30 years and under are more likely to have a SRVA, and seem to be at a higher risk.
4. Drivers from skilled manual occupations are also more likely to have a SRVA, probably because of a higher exposure to driving.
5. Driving between 2am and 7am presents a particular risk for SRVAs, as this is when one's 'body clock' is in a daily trough. There is another, smaller trough between about 2pm and 4pm.
6. Low traffic density is probably not a major risk factor for SRVAs. It is the associated factors, such as driving in the early morning, during the 'trough', when traffic density also happens to be low.
7. About 40 per cent of SRVAs are probably work-related, inasmuch as they involve commercial vehicles (HGVs, light goods vehicles and vans etc).
8. Sleepy drivers are aware of their sleepiness, particularly when they reach the stage of 'fighting sleep' (ie doing things to keep themselves awake, such as winding down the window).
9. Reaction time devices are of little practical use in detecting driver sleepiness.
10. Drivers already chronically mildly sleepy (eg due to chronic levels of sleep disturbance or insufficient sleep) are more vulnerable to any transient, additional sleep loss, and may not so easily perceive this increase in sleepiness.
11. Caffeine (150mg) is an effective countermeasure to sleepiness, as is a short (less than 15 minutes) nap or doze. The two combined together (caffeine in the form of a caffeinated drink, then a nap) are particularly effective. The efficacy of these treatments will depend on the magnitude of the sleepiness. Even 'relaxing with the eyes closed' is worthwhile.
12. Sleep-related accidents should no longer be viewed as 'accidents' but as road crashes due to easily preventable human error.
13. We feel strongly that driver education, linked to greater public awareness of the potential dangers of sleepiness and greater employer responsibility with regard to their employees' fitness to drive, present the best approaches for reducing sleep-related crashes.

Acknowledgements

We thank the DTLR for sponsoring this research programme.

References


2. Ibid.


6. Ibid.

7. Horne and Reyner, ref. 3 above.


13. Horne and Reyner, ref. 1 above.


Appendix

RECENT PAPERS


Summary - Falling asleep whilst driving accounts for a significant proportion of vehicle accidents under monotonous driving conditions. Many of these accidents are work-related (eg trucks, goods vehicles and company car drivers). Time of day (circadian) effects are profound, with sleepiness being particularly evident during night-shift work, and driving home afterwards. Circadian factors are as important in determining driver sleepiness as is the duration of the drive, but only the latter is built into legislation protecting professional drivers. Older drivers are also vulnerable to sleepiness in the mid-afternoon. Possible pathological causes of driver sleepiness are discussed, but there is little evidence that this factor contributes significantly to the accident statistics. Sleep does not occur spontaneously without warning. Drivers falling asleep are unlikely to recollect having done so, but will be aware of the precursory state of increasing sleepiness; probably reaching a state of fighting off sleep prior to an accident. Self-awareness of sleepiness is a better method for alerting the driver than in-vehicle automatic sleepiness detectors. None of the latter is of proven reliability and most have shortcomings. Putative countermeasures to sleepiness, adopted during continued driving (eg cold air, use of car radio) are only effective for a short while. The only safe countermeasure to driver sleepiness, particularly when the driver reaches the stage of fighting sleep, is to cease driving and, for example, take a 30-minute break encompassing a short (<15 min) nap and/or coffee (about 150mg caffeine), which are very effective particularly if taken together. Exercise is of little use.


Summary - Sleep-related vehicle accidents are prevalent in the early morning, especially in younger drivers. In two independent studies following a night of either restricted or nil sleep, young experienced drivers drove for two hours (6am-8am) continuously in an immobile car on an interactive, computer-generated dull and monotonous roadway. This followed ingestion (at 5.30am) of 200mg caffeine (= two to three cups coffee) compared with a placebo, counterbalanced, double blind. Driving incidents (lane drifting), subjective sleepiness, and 4-11Hz EEG activity were logged. Study 1 (sleeping from midnight to 5am): caffeine significantly reduced incidents and subjective sleepiness throughout the two-hour drive, and EEG power for the second 30-minute period. Study 2: (no sleep) sleepiness profoundly affected all measures, and driving was terminated after one hour. Nevertheless, caffeine significantly reduced incidents for the first 30-minutes and subjective sleepiness for the hour. This caffeine dose, feasibly taken via coffee, effectively reduces early-morning driver sleepiness for about 30-minutes following nil sleep, and for around two hours after sleep restriction.
4 The influence of cannabis and alcohol on driving

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Introduction

Results from a recent study of the incidence of alcohol and drugs in road accident fatalities have consistently shown a large increase in the incidence of drugs in fatal road casualties (drivers, riders, passengers and pedestrians) since the last comparable study in the mid-1980s. The latest results show that among all road users illicit drugs were present in 18 per cent of fatalities (Tunbridge et al, 2000). These figures represent a sixfold increase in illicit drug taking when compared with the previous study (Everest et al., 1989). Cannabis constitutes around two-thirds of the illegal drugs found.

Despite the increase in the incidence of drugs, it is not possible say that drugs caused these deaths. There may be an association, but presence cannot be taken as evidence of causation - there is no way of telling how much was consumed and how long before the fatal accident. So far as cannabis is concerned, the prevalence in drivers was not significantly different from that of passengers, which can be taken as a (albeit imperfect) measure of the prevalence in the population as a whole. However, cannabis remains detectable in the body for up to four weeks after use - long after any impairment of driving.

In most surveys reported in Europe cannabis is the most frequently detected drug (de Gier, 1998). In a range of accident-involved populations cannabis is found with an incidence between 2 and 12 per cent with a mode incidence around 5-8 per cent. This is certainly significantly above that of any other drug.

It is well known that cannabis is often used in conjunction with alcohol. The few studies that have been conducted combining the effects of cannabis and alcohol on driving performance have tended to use relatively high doses of alcohol, ie doses high enough to cause severe impairment alone. Psychopharmacological studies investigating the effects of alcohol and cannabis (Δ 9-THC) on psychomotor and cognitive performance have been inconsistent in terms of methodology, making comparisons difficult. There are considerable differences in drug preparations used, drug doses administered, routes of drug administration, drug consumption and absorption times, plasma analyses (if blood is taken), times of testing post-drug administration, and performance measurements. Furthermore, some studies administer alcohol and Δ 9-THC separately and compare the effects (comparative studies), while others examine the effects of the two drugs combined (combination studies).

Previous comparative studies have generally compared the effects of high doses of alcohol with those of medium-to-low doses of Δ 9-THC. It has been well established that alcohol has severe impairing effects at high blood alcohol concentrations, and performance decrements have been demonstrated at concentrations as low as 30mg/100ml (Moskowitz and Fiorentino, 2000). It has also been shown cannabis cigarettes containing 10mg Δ 9-THC are commensurate with a 'normal level' of cannabis intoxication, around 30 minutes post dosing (Robbe, 1994). If the alcohol doses were higher and the cannabis doses lower than this, in previous studies, it is not surprising that alcohol significantly impaired performance on most measures, whereas low doses of Δ 9-THC had a relatively small effect.
The combined effects of alcohol and Δ⁹-THC on performance skills related to driving tend to be cumulative. However, when drug doses were particularly low, no effects on performance were demonstrated. Anecdotal evidence suggests that regular cannabis users occasionally drink an amount of alcohol below the legal limit for safe driving, and then smoke cannabis before driving. It is therefore important to establish the degree of impairment caused by a low dose of alcohol in combination with cannabis.

The purpose of the research is to examine the effects of cannabis, alone and in combination with alcohol, on psychomotor and cognitive skills relevant to car driving. The overall research aims to identify specific aspects of cognitive/psychomotor behaviour that are affected by the two drugs, and to determine how individual differences might moderate the effects of the drugs on performance.

This report details the second phase of the research. The first phase of work addressed the effects of cannabis alone, this first trial took place in January and February 2000 and was reported in Sexton et al, 2000. The second phase of the study, reported here, took place in November/December 2000, when the effects of alcohol and cannabis in a controlled trial combination were studied.

**Study design**

Participants were asked to attend test sessions after consenting to the conditions outlined in an information sheet, sign a consent form and complete a questionnaire that assessed their drug use and driving histories. Each participant was required to perform cognitive and psychomotor tasks under different conditions of drug dose. The tests were designed to assess vigilance, selectivity of attention, working memory, and speed and accuracy of decision-making in response to different stimuli.

Participants were medically screened by a doctor for suitability and also completed a questionnaire about their cannabis smoking and alcohol drinking habits. Their identities were confidential during the trial and all identifying information was destroyed at the end of the trial.

Participants attended once for each treatment level, and had a week washout period between treatments. A urine sample was taken on arrival and their breath alcohol level was checked to make sure that they had not been drinking. Participants then took a refamiliarisation drive on the simulator and a short simulator drive to provide a baseline measure. They drank a pre-prepared drink and smoked a cannabis cigarette under controlled conditions 10 minutes later. They gave a saliva sample and were breath tested 30 minutes after dosing started, which is when the impairment testing started. They drove the simulator for about 25 minutes during which time they were assessed on a variety of driving-related measures. They also completed an adaptive tracking task. The total testing time was just under 45 minutes (allowing for transfers between tests). During the test session they also completed a questionnaire with visual analogue scales at different times. This was to investigate their 'mood' and subjective effects being experienced. A final saliva sample and breath test was taken after testing, which was about 70 minutes post dosing.

Medical cover for taking and handling blood samples was provided and was available for resuscitation if necessary. A registered medical practitioner covered these medical aspects.

The trial used two treatment levels of cannabis, zero THC and low THC (1.7 per cent of active compound), which were National Institute on Drug Abuse (NIDA) supplied 'grass'-
based cannabis cigarettes. They also were given a drink which was either a placebo or contained 10 per cent by volume of alcohol. The drinks were tonic water plus angustora bitters either with or without the alcohol (vodka). The volume of the drinks for each individual subject was always the same and the rims of the glasses were dipped in neat 40 per cent vodka to disguise the content. It was found that this drink combination effectively disguised the presence or absence of alcohol. Each participant was assigned to the four treatment combinations, in a fully randomised and balanced crossover design.

Each participant attended one test session for each treatment combination (at least one week apart), plus an initial screening interview. The test sessions were conducted from early evening until late evening, because most of the participants worked during the day, and also because this was a more natural time for them to be drinking and taking cannabis. Each test session was approximately two hours long. The results for the test session were recorded in a session case report form; this was very similar to that used in the cannabis study Sexton et al, 2000.

**EXPERIMENTAL DESIGN**

The study was designed for a crossover design analysis of variance with planned comparisons. The design was a crossover for two treatment levels of NIDA- supplied cannabis cigarettes, plus two alcoholic drink treatment levels.

### Table 1: Experimental design

<table>
<thead>
<tr>
<th>Group (5 participants per group)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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Dose levels: -A - placebo cannabis and placebo alcohol, B - cannabis dose plus placebo alcohol, C - placebo cannabis plus alcohol dose, D - cannabis dose plus alcohol dose

The design is shown in Table 1. Twenty participants were recruited for the trial, with five allocated at random to each of the treatment groups. The design was fully balanced across all four periods.

**ETHICS COMMITTEE**

The experimental design and methodology were presented via a protocol document to the local area ethics committee. The protocol included a subject information sheet and an example of the subject consent form that was signed by all subjects prior to being screened. The ethics committee approved the study.
SAMPLE SIZE

The sample size was determined from data on impairment in earlier studies and in particular from the study using different cannabis doses that took place in January/February 2000 (Sexton et al, 2000). The power calculation, on a reaction time pulling-out event, suggested that 20 participants should show a statistically significant effect at the 95 per cent confidence level on a one-sided test with 84 per cent power when comparing the difference in performance due to being impaired just below the legal alcohol limit. (In practice, two-sided tests were used for significance testing because it was not always clear in what direction cannabis changed the metric being evaluated.)

PARTICIPANTS

Participants were males over 18 years of age who had a driving licence and used cannabis and alcohol at least once per week. The sample was restricted to males because this avoided any possible complications that would have had to be considered in case females were already or became pregnant during the trial. It was thus more acceptable to the ethics committee. It may also be the situation that there are differences between males and females in terms of the effect on driving performance of smoking cannabis with or without alcohol, due to physiological differences and/or driving style differences. Four participants who had helped with the cannabis trial were recruited for this trial. This was to provide a check on the consistency of results between the two trials.

RECRUITING

Participants were recruited through people who were known to the project team and who knew regular cannabis users. It was found that once potential participants had been contacted they would know other cannabis users who also would be interested in helping with the trial. This recruiting technique is often referred to as a 'snowball' sampling approach.

Participants known to the 'link' people were invited to telephone the project team. The 'link' people were given a minimal amount of information about the trial, just the fact that male drivers who were regular cannabis and alcohol users were required and that complete confidentiality was assured. When participants phoned they were asked about their cannabis and alcohol use and their availability, and given some background information about the trial and the commitment being sought. If they were still interested, they were asked to attend a screening session.
SCREENING

Participants were given a full medical screen to ensure that they were fit and healthy, especially with respect to any respiratory problems or liver problems, past or current. They attended a pre-booked session at TRL and were examined by a doctor. Prior to being examined, they were asked to read a participant information sheet that informed them about the trial, and were asked to sign a consent form.

MEDICAL CHECKS

The full range of medical checks is given in the screening document (Sexton et al, 2000). The participant was required to supply a urine sample which was checked to see that the participant had THC metabolites in his urine, and was thus a cannabis user. The urine sample was also used to check if the participant was a current poly-drug user (ie a user of other drugs in addition to cannabis). Participants also supplied a blood sample for a blood chemistry check and in particular liver function. Any participant who failed any of the screening checks was not included within the trial. This decision could not be made until the laboratory analysis of the blood samples had been processed.

QUESTIONNAIRE

A questionnaire regarding use of cannabis and other drugs had been developed by Kay Wright (University of Birmingham), who was part of the trial team. This questionnaire had been used to obtain a profile of the typical cannabis user and had been administered to a sample of 90 or so users. Participants who attended for screening were asked to complete this questionnaire. The questionnaire provided a further method of checking the suitability of potential participants.

ANALYSIS OF SAMPLES

Samples of blood taken for screening purposes were processed by the pathology laboratory in Frimley Park Hospital, Surrey. These were delivered to the laboratories within hours of being taken and the results were usually available within two to three days.

Samples of urine and saliva were analysed by Epsom Hospital Laboratories regional assay service. Samples of saliva were centrifuged to extract the saliva from a salivette and stored in a freezer. They were delivered to the laboratory on a weekly basis. The urine samples were also stored in a freezer on the evening of the trial and kept frozen ready for delivery.
The urine and saliva sample results took time to process. This is because the assaying of samples for relatively small quantities of cannabis metabolites is time consuming and will often require more than one analysis of the same sample in order to check the results.

CANNABIS DOSE

Participants were given two different cannabis doses, each one used twice. The two doses were pre-prepared 'grass'-based cannabis cigarettes supplied by NIDA, each of a different strength. The drinks were tonic water plus angustora bitters either with or without the alcohol (vodka). The volume of the drinks for each individual subject was always the same and the rims of the glasses were dipped in neat 40 per cent vodka to disguise the content. The drinks were pre-prepared and kept in a refrigerator until required, they were labelled for subjects and administered five minutes before smoking the cannabis.

CANNABIS SUPPLY

The NIDA cigarettes were leaf/bud/florets mixed and rolled to a tightly controlled standard. They were stored frozen and with a humidity of about 10 per cent. This needed to be increased to at least 14 per cent prior to smoking in order to avoid a dry smoke, which would not only be very harsh to participants but also would not convert the THC as required. Consequently, the cigarettes were humidified for 24-36 hours prior to smoking. The NIDA cigarettes weighed about 700mg and were supplied in two strengths:

- placebo containing about 0.005% ±0.002 of THC (active THC removed with a solvent).
- low dose - 1.70% ±0.14 THC.

CONTROL AND LICENSING

Cannabis is an illegal drug and so a licence to hold and administer for the purposes of this research had to be obtained from the Home Office. The control of the cannabis requires a drug book recording the supplier, quantities, when used etc. The cigarettes from NIDA were imported by the University of Birmingham under special licence conditions. The cigarettes were transferred to TRL and registered in the drugs control book.

CANNABIS ADMINISTRATION

Cannabis cigarettes for the required period were removed from storage by the project manager and signed out from the drugs control book. (Only he knew the dose required, although the
code-break was available if required.) The cannabis cigarettes were placed in a humidifier that had been clearly marked with the participant identifying code. The cigarettes were humidified for 24-36 hours. Prior to smoking the cannabis cigarette was taken from the humidifier by the drug administrator and placed in a sealed tube. The tubes were then made available to the drug administrator, who checked that the participant was given the correct cigarette to smoke.

Measures

OVERVIEW

On arrival, participants were checked for alcohol consumption using a Lion SD400 breathalyser. They then answered various questions to confirm their eligibility and proceeded with the trial.

A diversity of measures was obtained during the trial. The case report form showed the measure and the time when it was obtained. First, participants were refamiliarised with the simulator, and this included a baseline measurement of how they drove round a 'figure of eight' course. The simulator was used later in the trial session to assess their reactions to other vehicles, how they drove round the 'figure of eight' and their response to a long delay at traffic-light-controlled junctions.

Participants were asked to complete a mood questionnaire at various stages of their trial session. They also underwent sobriety tests that were administered by a forensic medical examiner (FME). They were assessed on an adaptive tracking task.

At different times during the experiment, participants gave samples of saliva and breath alcohol. The saliva was to obtain a measure of how much D9-THC was in their system and the breath alcohol to obtain a measure on their alcohol level. The initial urine sample was checked using Dade-Behring polydrug indicator strips that showed if the participant had recently been using cannabis, cocaine, amphetamines or opiates.

DRIVING SIMULATOR

A range of measures was derived for each participant when driving the simulator and these are summarised in Table 2. The measures were designed to assess different skills. The motorway driving section was mainly trying to assess reaction times to adverse events, the 'figure of eight' measures control skills in staying within a lane on a road with changing radius curve, and the traffic-light-controlled junction provided a measure of vigilance while waiting for the light to change.
Table 2: Simulated tasks and associated measures

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Performance measure</th>
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| Motorway section with vehicles pulling out in front | 1. Reaction times to pulling out events, averaged over several of the driven car events  
2. Minimum time headway during the event |
| Motorway section with vehicles braking in front of | 1. Reaction times to braking events, averaged over several the driven car events  
2. Minimum time headway during the event |
| Motorway section                              | Minimum, maximum and average speed                       |
| Following left-hand non-circular curve of about | Standard deviation of lane position from perfect path  
1km radius                                    |
| Following right-hand non-circular curve of about | Standard deviation of lane position from perfect path  
1km radius                                    |

Dual carriageway with traffic lights, the lights are Response time to lights changing to red/amber and the time triggered to red so the driven vehicle has to stop to crossing a point 15m from the stop line, averaged over and there is varying delay for green several replications with varying time delays

DESCRIPTION OF SIMULATOR

The TRL driving simulator is a real medium-sized saloon car (a Rover 414Sli) surrounded by three 3m x 4m screens to the front providing 210° front/side image and one rear screen providing normal rear vision using vehicle mirrors.

The 'VR world' is generated via the MultiGen 3-D modelling package and can be any driving scenario as required. Four projectors display the image on the screens: three linked to give continuous front/side image and a fourth at the rear of the car. The images are generated in 'real time' and refreshed 60 times per second. 'State of the art' Silicon Graphics reality engines generate the images. A further Silicon Graphics computer provides the simulator operator station with an interface to the experiment. The operator has a bird's-eye view of the road layout and the position of all vehicles in the driving scenario, also a continuous representation of the use of the vehicle controls and speed.

The system generates intelligent vehicles whose behaviour can relate to that of the simulator vehicle or behave as autonomous intelligent vehicles operating collision detection and avoidance with passive through 'normal' to aggressive driving styles.
The TRL driving simulator has been shown to be a valuable tool for measuring drug-induced impairment in drivers (Sexton, 1997).

**MOTORWAY DRIVE**

A section of motorway was modelled based on the M3. It was about 16.7km in length and ended by turning in to a two-lane road that was modelled on the TRL small loop. The motorway consisted of three lanes with a hard shoulder, there were some gentle bends, slopes and bridges and it had the appearance of a normal motorway road. There were two versions created with different traffic conditions. One version was used for screening/familiarising drivers and for their baseline drive. This consisted of traffic that behaved normally and created an impression of medium to light traffic flow.

The other version of the motor traffic used a combination of vehicle behaviours. Some vehicles were programmed to slow down and speed up as in the screening/baseline version. Other vehicles were pre-programmed to create a situation that the driver would have to react to. This was either by pulling out in front of the driver or braking for no apparent reason. The driver would therefore have to modify his driving behaviour in some way, and the time taken to do this provided a measure of his response latency. A computer program was developed to detect automatically this driving behaviour change.

The driving speed was continuously recorded during the motorway drive. The minimum, maximum and average speed was calculated over the whole motorway drive, excluding the first 1,000m and last 1,500m and any times when the driver stopped. The motorway section of the drive was about 16.7km in total length.

**PULLING OUT EVENTS**

Pulling out events are situations when a car pulls out in front of the driven car. The driver will normally have to take avoiding action that can be detected. A reaction time to the pulling out can thus be estimated. The events were designed such that they could not be easily anticipated, but also such that the driver had time and space to respond. There were five such pulling out events on the motorway drive. The average of the five events was taken as a measure of the driver's reaction time. The minimum time headway to the vehicle in front in the same lane was also calculated, and proved to be a more robust and easier to determine measure.
BRAKING EVENTS

Braking events were controlled in a similar way to pulling out events, except that the trigger vehicle braked at a distance of 50m from the driven vehicle. There were three braking events and the average of these was taken as a measure of the driver's reaction time. The minimum time headway to the vehicle in front in the same lane was also calculated and averaged over the three braking events.

FIGURE OF EIGHT

The 'figure of eight' loop is a 2km-long loop with constantly changing radius. Participants were asked to drive between 30mph and 40mph and stay in the middle of the road lane. Because the curve is of a changing radius, drivers have to make almost continuous steering wheel corrections in order to stay in the centre of the road lane. The measure of success in the task was the standard deviation of their lateral position in the lane (SDLP).

TRAFFIC-LIGHT-CONTROLLED JUNCTION

The final stage of the simulator drive was a dual carriageway. There were four-traffic-light controlled junctions. The lights were pre-determined to be on red when the driver approached. The driver stopped and was kept waiting for a time varying between 15 and 25 seconds before the red/amber-green sequence started. Two measures of interest were analysed: the time to start from the onset of the red/amber light; and the time that it took to pass a point 15m into the junction. It was hypothesised that cannabis may affect drivers' responses to the changing lights. The average of the times across all junctions was analysed.

ADAPTIVE TRACKING

The TRL adaptive tracking test is based on one used at the RAF Institute of Aviation Medicine in Farnborough and tests a subject's ability to coordinate eye and hand. The subject is asked to keep a 2mm dot within a 'randomly' moving circle (diameter 15mm). The circle moves according to weighted pseudo-random sequence which creates circle movement of a known frequency bandwidth. The subject moves the dot using a 2° of freedom joystick. When the dot is inside the circle the distance between the displayed points increases, creating the illusion that the circle is moving more quickly than when the dot is outside. This makes the tracking task more difficult.

The test is run for five-and-a-half minutes, during which the tracking speed is sampled every 300ms for a five-minute
period. The mean speed is used in the analysis the higher it is the better tracking task ability.

**MOOD QUESTIONNAIRE**

Visual analogue scales (VAS) were used to assess mood state and physical symptoms. Participants placed a mark on a 100mm scale labelled with a mood state adjective (eg friendly, confident, muddled) from 'not at all' to 'entirely', or a physical symptom adjective (eg anxiety, dizziness, tiredness) from 'absent' to 'severe'.

The cannabis scale was completed, requiring participants to respond 'true' or 'false' to statements such as: 'I have difficulty remembering'; 'I notice that my heart is beating faster'. An end-of-session (EOS) questionnaire was also presented requiring each participant to rate:

- the strength of the overall drug effect on a five-point scale from 'I felt no effect at all' to 'I felt a very strong effect'
- their willingness to drive on a five-point scale from 'I would not drive under any circumstances' to 'I would drive without any hesitation'
- how much they liked the drug effect on a 100mm VAS from 'disliked a lot' to 'liked a lot'.

**SOBRIETY TESTS**

The sobriety tests were conducted by a police surgeon who was very familiar with the usual procedures followed for subjects in police custody. They assembled the standard sobriety test measures as recommended by Fleming and Stewart (1998). The test measures used were as given in Sexton et al, (2000).

The standardised examination form used was taken from the Police Research Group report. This included impairment testing covering pupil size and reaction to light; present of lateral and vertical nystagmus and convergence; walk and turn test; one leg stand; finger-nose test; Romberg test (internal clock); and an example of writing.

The physical examination included comment on the general demeanour and behaviour of the individual and examination of speech, pulse, temperature, ears, eyes, heart, lungs, blood pressure and reflexes. The doctor was asked to conclude whether in their opinion the individual was impaired or whether there was a condition that might be due to the presence of a drug.
BIOCHEMISTRY

Participants gave samples of urine and saliva prior to smoking cannabis. These were required to provide a baseline measure which facilitated checking for other drug use. Samples of saliva were taken at 30 minutes after drinking and 20-25 minutes after smoking. A final saliva sample was taken about 70 minutes after drinking and 60-65 minutes after smoking.

The saliva samples were collected by participants chewing a salivette for five minutes. This was centrifuged in order to extract the saliva. The samples were dispatched to Epsom Hospital Laboratories regional assay service on a weekly basis having been kept frozen prior to transportation. The following substances were assayed in the analysis:

- \( \Delta 8\)-THC - delta-8-tetrahydrocannabinol - a minor but psychoactive constituent of cannabis
- \( \Delta 9\)-THC - delta-9-tetrahydrocannabinol - the major psychoactive constituent of cannabis
- THC-COOH-9-carboxy-THC - the most rapidly produced metabolite, not psychoactive
- CBD - cannabidiol, the second main constituent of cannabis but not psychoactive, although it may interact with THC to produce effects.

The main sample of interest was the quantity of \( \Delta 9\)-THC in saliva, because this is the major psychoactive constituent of cannabis. However, the levels of THC-COOH-9-carboxy-THC in the urine are an indicator of cannabis use. This is the use in terms of frequency over time as well as dose, hence high levels of THC-COOH suggest that the subject is a chronic user.

Subjects gave samples of urine, blood and saliva prior to smoking cannabis. These were required to provide a baseline measure which facilitated checking for other drug use. Samples of blood and saliva were taken 10 minutes after smoking and 25-35 minutes after smoking. A final saliva sample was taken 95 minutes after smoking.

Analysis

The data from the case report forms were entered into an SPSS (Statistical Package for the Social Sciences) file. The data from the simulator were processed on the SGI (Silicon Graphics) computers and a file suitable for input to SPSS was generated. The average response times for pulling out and braking events were based on just those events where a reaction could be determined. The minimum time headway measures were based
on just those events where a time could be determined; there were a few crashes and a few instances with no other vehicle in the same lane and so the time headway could not be calculated.

The actual THC levels at peak impairment (25-30 minutes after dosing) were determined from the analysis of the saliva samples. The analysis considered cannabis and alcohol as factors each with two levels (placebo dose and active dose).

**STATISTICAL MODEL**

The study design was a crossover experiment where participants attended four trial sessions. At each session they smoked either a placebo or active dose of cannabis and were given either a placebo or active alcoholic drink. The order of dosing was designed to be balanced such that the same number of participants took each dose level on each visit. Neither the participants nor the drug administrator knew what dose was being smoked or drunk, ie the administration was investigator blind.

The allocation of participant to order of dosing was randomised. Each participant was treated as his own control. For most of the analyses, a hierarchic analysis of variance model was used with participant as the first-level factor. The visit number (or period effect) was the next factor followed by the treatment factors (ie doses received). The analyses found carry-over effects for the maximum speed measure and the reaction time to braking events. However, there was no significant treatment effect for the braking reaction and although the maximum speed effect is significant with treatment, it has a similar effect as the average speed which does not have a carry-over effect. The analysis only found significant period effects for the adaptive tracking task. Only the significant probability levels have been reported.

Treatments were compared using the Tukey multiple range test option.

The analysis of the simulator and adaptive tracking measures used the SAS/GLM package module (Statistical Analysis System / General Linear Model). The mood questionnaire had measures over time as well as between trial sessions and was analysed using SPSS.

**Results**

**COMPARISON BETWEEN THE CANNABIS TRIAL AND THE CANNABIS AND ALCOHOL TRIAL**

The cannabis trial that took place in early 2000 and, as reported in Sexton et al, 2000, used the same simulation task as the current cannabis and alcohol trial; as such it is interesting to
compare average results from these two trials. The participants were recruited in similar ways, but those helping with the cannabis and alcohol trial were probably heavier users and none of them was much over 30 years of age, whereas in the cannabis trial there was a group of four to five subjects in their late 30s or early 40s. A summary of their overall characteristics is given in Table 3.

Table 3: Characteristics of trial subjects

<table>
<thead>
<tr>
<th>Mean and SD</th>
<th>Cannabis trial</th>
<th>Cannabis and alcohol trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of subjects</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>27.0 ±7.5</td>
<td>24.9 ±3.51</td>
</tr>
<tr>
<td>Units of alcohol per week</td>
<td>18.7 ±7.9</td>
<td>24.5 ±19.2</td>
</tr>
<tr>
<td>Age started using cannabis</td>
<td>16.7 ±1.7</td>
<td>15.5 ±1.3</td>
</tr>
<tr>
<td>Months driving</td>
<td>106.8 ±85.4</td>
<td>92.4 ±40.1</td>
</tr>
<tr>
<td>Use other drugs</td>
<td>47%</td>
<td>40%</td>
</tr>
<tr>
<td>Weekly use of cannabis</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Three or more cannabis cigarettes per occasion</td>
<td>73%</td>
<td>60%</td>
</tr>
</tbody>
</table>

Results from the cannabis trial and from the cannabis and alcohol trial have been plotted together in Figures 1 and 2. Respectively, they show the mean values with 95 per cent confidence interval for the average speed on the motorway section of the simulated drive and the SDLP measure on the right-hand loop.

The suffixes 1 or 2 refer to either the cannabis trial or the cannabis and alcohol trial. The figures show that a low dose of cannabis (ie 10mg) or more produces a change in these measures and this is consistent between the two studies. The replicate values for the placebo condition and the low dose of cannabis condition are also very similar between the two studies.

These results are encouraging for two reasons. Firstly, being able to replicate results across studies increases the confidence in the research. The sample subjects were different (apart from four subjects who took part in both), the average ages were different by >2 years and there is some evidence that one group had a sub-set of heavy cannabis users - and yet the findings were very similar. Secondly, plotting these eight values together provides a useful indication of the relative effects from different impairing substances and at different dose levels (in
the case of cannabis). For example, it can be seen that the performance on the placebo doses, the alcohol alone and the very low resin dose are similar, whereas a dose of cannabis >10mg THC with or without alcohol is also similar.

**Figure 1: Average speed on motorway**

![Average speed on motorway graph](image)

**Figure 2: Average SDLP on right-hand curve**

![Average SDLP on right hand curve graph](image)

The results of statistical analyses of the observations on driving performance tasks and driving-related laboratory tests are summarised in Table 4. There was a reduction in average speed on the motorway when participants had the active doses of cannabis. This confirms the results from many previous studies. It strongly suggests that the participants, as drivers, are aware of their impairment, but attempt to compensate for this.
impairment by driving more cautiously. A post-trial survey of participants showed that they were very good at guessing what dose combination they had received.

In the simulator trials where specific events involving other traffic were assessed, participants tended to have a bigger minimum time headway to pulling out events and braking events when they had taken the active dose of cannabis regardless of the alcohol dose. This suggests a compensatory action for the effects of cannabis impairment.

When considering the simulator tracking tasks, participants tended to drive less accurately on the right loops of the 'figure of eight' when they had been on the active cannabis dose. This suggests that they were unable to control their steering as well when under the influence of a cannabis dose. This again confirms previous observations that cannabis adversely affects drivers' tracking ability.

**Table 4: Summary of significant results (from comparison of adjusted means)**

<table>
<thead>
<tr>
<th></th>
<th>No active dose v cannabis</th>
<th>No active dose v alcohol</th>
<th>No active dose v cannabis and alcohol</th>
<th>Alcohol v cannabis and alcohol</th>
<th>Alcohol v cannabis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum speed on m'way (lower speed with cannabis)</td>
<td>p=0.046 ns ns</td>
<td>ns</td>
<td>ns</td>
<td>p=0.001 p=0.002</td>
<td></td>
</tr>
<tr>
<td>Average speed on m'way (lower speed with cannabis)</td>
<td>p=0.023 ns p=0.005</td>
<td>ns</td>
<td>p=0.005</td>
<td>p=0.025 p=0.005</td>
<td></td>
</tr>
<tr>
<td>Minimum time headway to pulling out events (longer headway with cannabis)</td>
<td>p=0.024 ns p=0.016</td>
<td>ns</td>
<td>p=0.002 ns</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Minimum time headway to braking events (longer headway with cannabis)</td>
<td>p=0.001 ns p=0.002</td>
<td>ns</td>
<td>p=0.003</td>
<td>p=0.006</td>
<td></td>
</tr>
<tr>
<td>SDLP on right loop (more 'wobbly' with cannabis)</td>
<td>p=0.027 ns p=0.023</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>
Adaptive tracking task (poorer performance with alcohol and worse with -cannabis plus alcohol) | ns | p=0.028 | p=0.002 | ns | ns

Note: -Only probabilities less than 5 per cent have been reported, ie 'ns' means that the probability of rejecting the null hypothesis is greater than 0.05, and there is at least a 5 per cent chance that there is no difference between the two dose levels being compared.

The mean tracking speed on the adaptive tracking task decreased with increasing level of dose, ie from no active dose, to cannabis, to alcohol, to cannabis and alcohol. Tracking was more accurate under the double placebo condition than under the either of the doses with alcohol involved.

In summary, the results of this study show a broad consistency with the effects of cannabis and low doses of alcohol on driver performance observed by previous researchers.

Conclusions

Overall, it is possible to conclude that cannabis has a measurable effect on psychomotor performance, particularly tracking ability. Drivers under the influence of cannabis seem to compensate to some extent for the impairment that they recognise, by reducing the difficulty of the driving task; eg by driving more slowly. This effect is not offset by the drinking of alcohol, albeit a dose just more than half the UK legal limit.

In terms of road safety, it cannot be concluded that driving under the influence of cannabis and/or alcohol is not a hazard, as there are effects on various aspects of driver performance and these are unpredictable. In comparison with high levels of alcohol, however, the effects found within this study on the higher cognitive processes of driving are not particular strong.

References


5 Crime and punishment - The 1991 Road Traffic Act

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Introduction

This paper is based on a research project which has been evaluating the working of the 1991 Road Traffic Act. The research has looked at the charging, prosecution and conviction of 'bad driving' offences.

The last review of motoring offences was reported on in 1988 in the Road Traffic Law Review Report (Department of Transport and Home Office, 1988), hereinafter referred to as the North Report, following recommendations advocating that measures to simplify the law should be investigated.

The Government response to the North Report, entitled The Road User and the Law (Home Office et al, 1989), agreed with the report that the reckless driving offence was not operating as it should in England and Wales, where emphasis was being placed on the driver's attitude (recklessness) rather than the objective quality of the driving (dangerousness). The response proposed to replace the offences with ones based more firmly on the actual standard of the driving.

The offences relating to bad driving were reformulated in the 1991 Road Traffic Act to more readily identify and punish dangerous drivers. Much of the Act was based on the recommendations of the North Report. The earlier offences of 'reckless driving' and 'causing death by reckless driving' were replaced by 'dangerous driving' and 'causing death by dangerous driving'. The offence of careless and inconsiderate driving remained unchanged.

The intention was that the determination of what amounts to driving dangerously would be by means of a test which concentrates upon the nature of the driving rather than the defendant's state of mind (Wallis, 1991). The research reported here examined whether such a test is appropriate in terms of culpability, and how this test is implemented in practice.

The study examined the extent to which the consequences of bad driving (death or injury) play a part in the decision-making process. Although there are separate offences of dangerous driving and causing death by dangerous driving, and a less serious offence of careless driving, there is no offence of causing death by careless driving (except where alcohol or drugs are involved). This, together with the much higher penalty for dangerous driving where a death results, has caused some debate on how far the system does (or should) focus on the standard of the driving alone, as opposed to the consequences.

Further argument centres on whether the 'deliberate' nature of some kinds of bad driving should attract the highest penalties, or whether the potential danger should be the key issue, regardless of the actual consequences.

Method

The objective was to gain an understanding of the current situation relating to the prosecution of those charged with bad driving offences, and to assess how current practice satisfies the intention behind the changes in legislation. This was done in a number of ways.

- Interviews with representatives from the Crown Office and the Crown Prosecution Service.
• Interviews with individual Crown Court judges, magistrates, sheriffs, police officers, lawyers, Crown Prosecutors and Procurators Fiscal.
• Interviews with victims' families and representatives from victim support organisations.
• A postal survey to assess agreement with views expressed in discussions with interviewees.
• Analysis of the prosecutions and convictions resulting from a sample of fatal accidents.
• Examining individual cases and their outcomes (case tracking).
• Analysis of conviction data held by the DVLA.
• Analysis of non-motoring conviction data held by the Home Office.

Results

DEFINITION OF DANGEROUS DRIVING

According to current legislation, a driver is guilty of dangerous driving if:

• the way he drives falls far below what would be expected of a competent and careful driver, and
• it would be obvious to a competent and careful driver that driving in that way would be dangerous.

The definition of dangerous driving hinges on an understanding of what a 'careful and competent' driver would be expected to do. This was felt by 70 per cent of the respondents to the survey to be a sufficiently clear standard. It has also been suggested, however, that virtually every driver, including members of juries and magistrates, considers themselves to be careful and competent. If this were true, it suggests that, in order to find a defendant guilty of dangerous driving, it would have to be shown that their driving was of a standard far below that of the members of the jury. Table 1 below shows how the respondents to the survey regarded the standards of the driving population.

Table 1: The percentage of the driving population regarded by the respondents as 'careful and competent'

<table>
<thead>
<tr>
<th>Respondents</th>
<th>CPS</th>
<th>Judges</th>
<th>Magistrates</th>
<th>Police</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=34 %</td>
<td>N=10 %</td>
<td>N=11 %</td>
<td>N=79 %</td>
</tr>
<tr>
<td>Less than 10%</td>
<td>0 0</td>
<td>1 10</td>
<td>0 0</td>
<td>4 5</td>
</tr>
<tr>
<td>11-25%</td>
<td>3 9</td>
<td>1 10</td>
<td>0 0</td>
<td>15 19</td>
</tr>
<tr>
<td>26-50%</td>
<td>5 15</td>
<td>1 10</td>
<td>4 36</td>
<td>19 24</td>
</tr>
<tr>
<td>51-75%</td>
<td>13 38</td>
<td>2 20</td>
<td>6 55</td>
<td>29 37</td>
</tr>
<tr>
<td>76-90%</td>
<td>5 15</td>
<td>3 30</td>
<td>0 0</td>
<td>2 3</td>
</tr>
<tr>
<td>Over 90%</td>
<td>2 6</td>
<td>0 0</td>
<td>1 9</td>
<td>4 5</td>
</tr>
</tbody>
</table>
Views about the general standard of driving on the road are likely to vary. Perceptions will be determined by a number of factors including the type of roads used most often and amount of driving experience. However, if the standard to which the driving of the defendant is to be compared is that of ‘a careful and competent driver’, which to one respondent is a standard achieved by less than 10 per cent of the population and to another is a standard achieved by more than 91 per cent of the population, it does call into question whether the same standards are being applied.

ANALYSIS OF FATAL ACCIDENTS

In order to examine what happens, in terms of convictions, after a fatal accident the police files for 5,943 fatal accidents in England and Wales were examined. These accidents occurred between 1989 and 1995, which covered the introduction of the 1991 Road Traffic Act. The majority of these files hold information on any offence for which a driver was reported, prosecuted or convicted. In many cases the sentence was also recorded. The files also record where the initial investigation found that the driver at fault was killed, or that a pedestrian fatality was deemed to have been caused primarily by the actions of the pedestrian. This information was collected and analysed as part of this research.

Of those fatal accidents where information on reported offences was available on the file (5,870):

- in 2,581 cases (44 per cent) the driver at fault was killed
- in 1,171 cases (20 per cent) a pedestrian at fault was killed
- in 10 per cent of cases a driver was reported for causing death by dangerous driving or causing death by reckless driving
- in 20 per cent of cases a driver was reported for careless driving
- in 1 per cent of cases a driver was reported for dangerous driving or reckless driving
- in 4 per cent of cases the file was simply marked as no prosecution.

There were a number of other offences for which drivers were reported, none individually accounting for more than 2 per cent of the total. In some cases these offences were unrelated to the accident, but will have been detected during the accident
investigation. The full report shows how these resulted in terms of prosecutions and convictions.

CASE TRACKING

A major part of the work carried out has been the identification and 'tracking' of a number of current cases where a charge of careless driving, dangerous driving or causing death by dangerous driving had been brought. This involved identifying potentially suitable cases, attending the trial and/or sentencing hearing, and, in some cases, conducting interviews with police, prosecutors, judges or magistrates. Eighty-four cases of causing death by dangerous driving, dangerous driving, and careless driving were analysed. Sixty-four of the trials were attended by TRL researchers.

A database was created to facilitate analysis of the cases. In creating the database a system of categorising cases was used in order to compare the treatment of different types of bad driving. The categories were based on the concept developed by Reason et al (1990). Cases were assessed on the basis of the description of the incident as being either a violation, error or lapse. An additional category of aggressiveness was added, as it was felt that violation itself as a category did not draw sufficient distinction, for the current purpose, between a simple contravention of a road traffic signal and a display of blatantly aggressive driving which may or may not include specific violations. It should be understood that these terms have been used in this research as a useful means of distinguishing between broad categories of driving behaviour. They are not necessarily being used as intended by the originators. Each case was examined and a judgement made on the basis of available facts. A rough definition of the categories follows.

- **Violation**: instances where traffic laws were breached, e.g. excessive speed, ignoring traffic signs.
- **Error**: instances where it appeared that the defendant made an error of judgement, e.g. pulled out of a junction having misjudged the speed of, or failing to see, oncoming traffic.
- **Lapse**: instances where the accident appeared to have been caused by inattention, whether momentary or prolonged.
- **Aggressiveness**: instances where the evidence suggested deliberate and blatantly 'hostile' driving.

Cases were examined to show the major elements of bad driving that were present. These descriptions were taken from the examples in the CPS Charging Standard. It is understood that the examples are not meant to be exhaustive or prescriptive. It is further understood that the CPS Charging Standard has no application in Scotland. Nevertheless they
provide a useful set of 'behaviours' against which to compare the cases in the study. It is difficult to 'rank' the cases objectively in terms of severity. This was an attempt to identify whether there were fundamental differences in the elements of an offence which contributed to the decision-making process.

**DANGEROUS AND CARELESS DRIVING ELEMENTS**

For the charge of causing death by dangerous driving, the most frequently found elements of bad driving were inappropriate speed and significant inattention.

For a charge of dangerous driving, inappropriate speed was also a common element, found in over half the cases, with aggressive driving as the second most common element, in nine of the cases.

When looking at the results of the trials, the most frequently found elements of bad driving across all verdicts were inappropriate speed and significant inattention, with unsafe overtaking also forming a significant part of the careless driving cases.

**LAPSES, VIOLATIONS, ERRORS AND AGGRESSIVENESS**

The cases were categorised further as one of four types of behaviour. The four categories used were lapse, violation, error and aggressiveness. Table 2 below shows the distribution of these categories through the cases overall.

**Table 2: Distribution of categories**

<table>
<thead>
<tr>
<th>Category of offence</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lapse</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>Violation</td>
<td>24</td>
<td>0.29</td>
</tr>
<tr>
<td>Error</td>
<td>24</td>
<td>29</td>
</tr>
<tr>
<td>Aggressiveness</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>84</td>
<td>100</td>
</tr>
</tbody>
</table>

It might be expected that lapses and errors, unless particularly severe, would be charged as careless driving. Similarly one would expect aggressiveness and violations, unless very minor, to be classed as dangerous driving. Table 3 shows the distribution of the categories by the offence the defendant was first charged with.

**Table 3: Distribution of categories by original charge**
The majority of causing death by dangerous driving and dangerous driving charges were caused by violations, followed by aggressiveness for dangerous driving, and lapses for causing death by dangerous driving. Over half of the careless driving cases were caused by an error in driving judgement and a third by a lapse in concentration. Further analyses described in Table 4 show how these categories are distributed by the final verdicts in each case.

Table 4: Distribution of categories by original charge and verdict (frequencies)

<table>
<thead>
<tr>
<th>Offence first charged with</th>
<th>Result of trial</th>
<th>Lapse in concentration</th>
<th>Violation of traffic regulation</th>
<th>Error in driving judgement</th>
<th>Aggressiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causing death by dangerous driving</td>
<td>N=23</td>
<td>N=24</td>
<td>N=24</td>
<td>N=13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Causing death by dangerous driving</td>
<td>3</td>
<td>9</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Dangerous driving</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Careless driving</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Not guilty</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Dangerous driving</td>
<td>Dangerous driving</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Careless driving</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Not guilty</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cause of incident</th>
<th>Causing death by dangerous driving</th>
<th>Dangerous driving</th>
<th>Careless driving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=27</td>
<td>%</td>
<td>N=24</td>
</tr>
<tr>
<td>Lapse</td>
<td>7</td>
<td>26</td>
<td>4</td>
</tr>
<tr>
<td>Violation</td>
<td>12</td>
<td>44</td>
<td>11</td>
</tr>
<tr>
<td>Error</td>
<td>3</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Aggressiveness</td>
<td>5</td>
<td>19</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>27</td>
<td>100</td>
<td>24</td>
</tr>
</tbody>
</table>
Those cases that did not follow the assumptions made above, ie that dangerous driving would be made up of violations and aggressiveness and careless driving of lapses and errors were examined further.

LAPSE IN CONCENTRATION AMONGST DANGEROUS DRIVING OFFENCES

Seven cases classified as a lapse were originally charged as causing death by dangerous driving. As it might be expected that lapses would be treated as careless rather than dangerous driving the individual cases were examined. Three resulted in careless driving convictions. All three of these cases were the result of a jury decision. One resulted in a dangerous driving conviction after the prosecution accepted a plea.

Three 'lapses' resulted in convictions for causing death by dangerous driving. They involved the use of a mobile phone in one case and an HGV driver exceeding work hours in another. The third case involved a failure to observe that traffic ahead was stopping, and was treated severely compared to similar cases.

ERRORS AMONGST DANGEROUS DRIVING OFFENCES

There were three cases originally charged as causing death by dangerous driving, and one as dangerous driving, which were classified as errors. All four resulted in convictions for careless driving.

VIOLATIONS AMONGST CARELESS DRIVING OFFENCES

Only one offence originally charged as careless driving had been classed as a violation. In that case, which involved a minor damage-only accident, it had been decided to drop the careless driving charge after the defendant pleaded guilty to the offence of failing to report an accident.

Amongst those dangerous driving charges which resulted in convictions for careless driving, six had been classed as violations. There were two fatal cases. The decision in one was affected by the reluctance of the family of the deceased to
pursue the more serious charge. In the second case the jury decided that the defendant was guilty only of the lesser charge, despite being at nearly twice the speed limit in a town centre. All of the non-fatal cases involved speed.

AGGRESSIVENESS AMONGST CARELESS DRIVING OFFENCES

No cases classed as aggressive were originally charged as careless. There were five cases, none involving fatalities, which resulted in careless driving convictions. Two cases were decided by a jury in Crown Court, who found the defendants not guilty of the more serious charge, but guilty of careless driving, possibly on the basis of insufficient proof of what took place. In one the absence of an accident appears to have been a key deciding factor. In one there was some doubt about the seriousness of an incident described as 'larking about'. In the final case the prosecution accepted a plea to the lesser charge because a key witness was unavailable.

ANALYSIS OF MOTORING CONVICTION DATA

This section of the paper is based on information from the Driver and Vehicle Licensing Agency (DVLA).

Just over a third of people convicted of dangerous driving in 1999 were first offenders (ie they had no previous valid motoring violations recorded on their licence). Two-thirds of offenders had at least one valid endorsement for a previous motoring offence.

Reoffending behaviour of offenders sentenced for a first dangerous driving offence between January 1995 and December 1998 was examined. Only 3.4 per cent of these offenders were women, and 24 months after they were sentenced only three had committed a further dangerous driving offence.

Five groups of male offenders were examined:

- those not sentenced to a retest
- those sentenced to an ordinary retest who had not passed the test by the end of 1999
- those sentenced to an ordinary retest who had passed it
- those sentenced to an extended retest who had not passed it by the end of 1999
- those sentenced to an extended retest who had passed it.
Around a third of male offenders sentenced to either an ordinary or an extended retest in 1995 and 1996 had passed the retest by the end of 1999.

REOFFENDING WITH A FURTHER DANGEROUS DRIVING OFFENCE

Between 3 and 4 per cent of men who had been sentenced to either retest and had not passed it, or who had not been sentenced to a retest, had committed a further dangerous driving offence within 24 months. Fewer than 0.5 per cent of offenders who had passed a retest had reoffended in this way. For comparison, men convicted of a careless driving offence during the same period were very unlikely to go on to commit a dangerous driving offence, and only 1.3 per cent went on to commit a further careless driving offence.

The effects of a prison sentence and different lengths of disqualification period were examined. Men who were not imprisoned and who had not passed a retest started reoffending soon after conviction, regardless of the length of their disqualification period.

Once they have been released, offenders sentenced to prison who have not passed a retest reoffend as much as those who have not been in prison. Men sentenced to 24 months' disqualification who have not passed a retest reoffend more than those sentenced to 12 months' disqualification. Offenders who pass a retest reoffend very little, regardless of prison sentence or length of disqualification.

Offenders from higher social groups reoffend less than those from lower social groups. Regardless of social group, less than 1 per cent of men who pass either retest are sentenced for a further dangerous driving offence within 24 months.

Older men reoffend less than younger men. If they have not passed a retest, around 6 per cent of men under 20 were sentenced for a further dangerous driving offence within 24 months. Less than 1 per cent of offenders who passed either retest had reoffended in this way, regardless of age group.

Male offenders with between nil and four previous motoring offences are very unlikely to reoffend whether they have passed a retest or not. Offenders who have between five and nine previous motoring offences reoffend significantly less if they have passed either retest.

Very few offenders with 10 or more offences pass a retest. As might be expected, reoffending rates are very high for this group of 3,800 men; between 8.6 and 10.9 per cent have
between sentenced for a further dangerous driving offence within 24 months.

**REOFFENDING WITH ANY MOTORING OFFENCE**

Around a third of all offenders (men and women) convicted of a first dangerous driving offence between 1995 and 1998 have been sentenced for a further motoring offence by December 1999. The most common offence committed was driving while disqualified.

Around 12 per cent of the small number of dangerous drivers who are women have been sentenced for a further motoring offence within 24 months.

Around 30 per cent of men who have not passed a retest have been sentenced for a further motoring offence within 24 months. Offenders who have passed a retest reoffend less, but a significant number do reoffend in this way (about 13 per cent). For comparison, about 19 per cent of offenders who were sentenced to a first careless driving offence reoffended in this way.

Twenty-four months after conviction, men sentenced to either six or 12 months in prison had reoffended as much as those not imprisoned. Men who had been in prison and had passed a retest reoffended less than those who had not.

Offenders who go on to pass a retest appear to refrain from committing a further motoring offence (or possibly from being caught committing such an offence) until after the end of their disqualification period. Offenders who do not go on to pass a retest (either because they were not sentenced to one, or because they have failed to do so even if thus sentenced) start to reoffend immediately after being sentenced.

Although reoffending rates calculated by looking at any further motoring offences are, inevitably, higher than rates calculated by looking at a further dangerous driving offence, the patterns of reoffending are similar when social groups and age groups are examined. Men from lower social groups reoffended more than those from higher social groups, and younger men reoffended more than older ones. Men who passed either retest reoffended less than those who did not. The highest rates of reoffending were for young men under 20. Over 40 per cent of these young men had been sentenced to a further motoring offence within 24 months. Between 15 and 19 per cent of this group who passed a retest reoffended in this way.

Reoffending rates for male offenders with 10 or more earlier offences are extremely high. About 60 per cent of these offenders had been sentenced for a further motoring offence
within two years of their first dangerous driving offence. Offenders with between nil and four offences reoffend considerably less (11 to 13 per cent), and those who pass either retest reoffend at the same rate as those who do not. For offenders with between five and nine previous offences, there is a significant difference in reoffending rates between those who pass an extended retest and those who do not (29 per cent for those who pass, between 36 and 43 per cent for those who do not). Men passing an ordinary retest appear to reoffend as much as those who do not.

THE EFFECT OF RETESTING

The effects of passing an ordinary retest and of passing an extended retest are very similar. Offenders who pass either retest appear to reoffend less than those who do not. However, this could be because they are a self-selected group. The majority of offenders sentenced to a retest have not passed one three years after being sentenced. This suggests (as do the large numbers convicted of driving while disqualified) that large numbers continue driving without a licence. Offenders who decide not to take a retest could be from a group who are less likely to obey the law generally. This is indicated by the fact that offenders who pass a retest appear to refrain from reoffending during their disqualification period, while those who do not pass (or are not sentenced to a retest) do not. The results from examining previous offending history also show that offenders who have fewer motoring offences generally reoffend very little whether they have passed a retest or not.

ANALYSIS OF NON-MOTORING CONVICTION DATA HELD BY THE HOME OFFICE

This section of the paper is based on information from the Offenders Index. The index, held by the Home Office, is one of the largest criminal databases in Europe and holds the criminal histories of all those people convicted of a standard list offence in England and Wales from 1963 onwards (standard list offences are all indictable or triable offences plus a few of the more serious summary offences, ie Crown Court cases plus the more serious magistrates' court cases).

The sample consisted of offenders convicted on 30 particular days in 1996 (1-15 March 1996 and 1-15 November 1996), 42,879 offenders in total, which is equivalent to around 14 per cent of all offenders convicted of an indictable offence in 1996. Of these offenders, 541 were convicted of a dangerous driving offence during the 30-day period, equivalent to around 9 per cent of all convictions for dangerous driving in 1996.
Thirty-eight per cent of offenders convicted of dangerous driving in 1996 were first offenders (ie had no criminal history), while 46 per cent had been convicted in court on three or more previous occasions of standard list offences. For the remainder of this paper those with three or more previous court appearances will be referred to as multiple offenders. These compare with 34 per cent of offenders convicted of other standard list offences in 1996 being first offenders and 43 per cent being multiple. These differences were statistically significant at the 5 per cent level.

Dangerous drivers were more likely to be first offenders rather than having one or two previous sentencing occasions compared with those convicted of other standard list offences, but just as likely to be multiple offenders. These results could suggest that there are two distinct groups of dangerous drivers, those that do not have a previous criminal history (38 per cent) and those that are multiple offenders (46 per cent).

One-third of those convicted of dangerous driving in the 30 particular days in 1996 went on to be convicted of a subsequent offence in 1997. This proportion varied depending on whether the offender had a previous criminal history. Fourteen per cent of offenders with no criminal history prior to 1996 committed a subsequent offence in 1997, compared to 56 per cent for offenders with three or more previous court appearances prior to 1996. Theft and motoring offences accounted for almost two-thirds of the subsequent offences.

The length of the criminal career is measured by the number of years between an offender's first and last conviction. 38 per cent of dangerous drivers have had a short criminal career of less than one year, with the majority of these being convicted only once. However, a quarter of the dangerous driver offenders have had a criminal career of at least 10 years in length and one in 13 has had a criminal career of 20 or more years. On average those with a criminal career of at least 20 years had around one court appearance every two years (0.5 appearances per year). This compares with an average of two court appearances per year for those with a criminal career of between one and five years.

**Discussion**

There are a number of key questions which must be answered in order to make sound decisions on the definition of bad driving offences.

- What kind of driving behaviour is to be seen as blameworthy?
• What emphasis is to be put on the duty of care a driver must carry?

• Is there a level of culpability that must be reached before a driver can be held responsible for the consequences of his actions?

• If the answer to the above is yes, where is that level to be set?

• What regard, if any, should be paid to the intentions of a driver?

• What is the purpose of the prosecution and sentencing?

If it is reasonable to assume that driving a car demands a duty of care on the part of the driver, then careless driving is clearly a failure to exercise the required degree of care. It might be assumed that dangerous driving is a quite different type of behaviour; not a failure to exercise care but a planned behaviour - one where the driver intentionally drives in a certain way without regard to the safety of other road users, whilst being aware of the danger that driving in such a way poses. Although this appears to provide a quite clear distinction between the two offences, it is evident from the research that, in practice, the distinction is not clear. In many ways they are not regarded as distinct offences, but as an arbitrary distinction between the most 'serious' bad driving and the rest, with a significant grey area covering offences which could be interpreted one way or another.

The earlier offences of reckless driving and causing death by reckless driving were problematic to the courts primarily because it was held to be necessary to prove the state of mind of the driver. This requirement to show mens rea, generally held to be central to the concept of criminal liability, involves a subjective enquiry into the actual state of mind of the accused at the time of the offence. The rejection of this principle is, perhaps, an indication of the separation of motoring offences from the rest of criminal law.

The changes in legislation brought about by the 1991 Road Traffic Act were intended to focus attention on the standard of driving rather than the mental state of the driver.

This, taken at face value, seems to imply that a manoeuvre which poses a danger to other road users should attract equal punishment regardless of whether the driver carried out that manoeuvre deliberately (in order to make speedier progress for example) and was aware of the risk, or by mistake. In reality, consideration is given, when deciding the appropriate charge and in debates in court, as to whether the driver was aware of the risks he or she was taking. If the defendant was driving the
wrong way up a one-way road, which is clearly dangerous per se, it is natural to ask whether he or she was aware that they were entering a one-way road. If in fact a driver intentionally drove up a one-way road it seems likely that the verdict would be that he or she was guilty of dangerous driving. The difference here is one of intention. How much the intentions of the defendant should direct the charge is a key issue. In examining intentions there is a need to be clear about whether it is intention to harm, intention to violate or intention to take risks which is in question.

In modern law, if A injures B, the legal consequences will depend on A's state of mind at the time. If it was A's intention to injure B, they may be liable to criminal prosecution and punishment (Jacobs, 1971). Jacobs holds that recklessness equates here with intention. If accepted, this would give the same weight to an intention to take risk as an intention to harm. If there was no intention to injure they will not be criminally liable, but B may succeed in a civil action against A if he or she can show that A was negligent. If this were accepted as the basis for defining the bad driving offences it would follow that 'reckless' driving would be a criminal offence requiring proof of the state of mind of the driver, and 'careless' driving would not be a criminal offence but would be a matter of civil liability. Clearly this is not the case. Elsewhere arguments can be found for the inclusion of various degrees of negligence in criminal liability.

Attempts to grasp the underlying legal principles are confused further by the semantics used in describing both the actions and consequences of bad driving. It is common practice to refer to 'accidents', even where there is no doubt that the collision was caused entirely by the bad driving of another driver. Furthermore, the term 'careless' is generally used to refer to minor omissions with no serious consequences, whereas 'careless driving' may result in a death. It is one of the common complaints from those who lobby for changes in the law that 'carelessness' is not an appropriate description for a failure to drive in a responsible and safe fashion.

Another key issue, tackled by the North Report but still causing debate, is the extent to which the consequences of driving in a certain way should be taken into account. There are conflicting schools of thought on this. What is clear, however, is that two similar pieces of driving can result in a collision in one instance and have no consequences in another. Similarly, whether a fatality results from a collision depends upon a number of circumstances, some of which are unrelated to the blameworthiness of the driver.
The research found differing views regarding how much the consequences should be taken into account in sentencing. It was suggested that, as there already is a much higher sentencing potential for causing death by dangerous driving than exists for dangerous driving, the system already recognises that serious consequences should attract a more severe penalty.

Legal precedents in England and Wales have recently diverged from those in Scotland on this issue. Since the Simmons appeal English courts may now take the fact of a death into account when sentencing for careless driving. This appeal case held that the fact that a death has occurred can and should be taken into account in sentencing for careless driving, and that the fact that a death has occurred ought to be mentioned in court.

Scottish law does not currently permit this. It is a feature of the different legal systems which was commented on during the research that, although the 1991 Road Traffic Act applies equally to Scotland as to England and Wales, the way in which the law is interpreted by the courts is largely guided by case law and legal precedents. These precedents are not shared, and hence the way in which Scottish courts interpret road traffic law can differ from the interpretation of English courts, as indeed was the case prior to the 1991 Act in the interpretation of 'recklessness'.

A recent decision in the Supreme Court stated:

'It is often a matter of chance whether death or serious injury results from even a serious breach. Generally where death is the consequence of a criminal act it is regarded as an aggravating feature of the offence. The penalty should reflect public disquiet at the unnecessary loss of life.'

The research has examined the use of different penalties for bad driving offences, and has examined the relationship between some of those penalties and reoffending. Whilst deterrence is one function of a penalty there are other functions. This is a subject outside the scope of this research, but cannot be ignored in looking at the wider picture of offences and penalties. The North Report provides a clear and thoughtful explanation of the four objectives of punishment, namely deterrence, retribution, restraint and reform.

Conclusions

OFFENDERS

Analyses of convictions found the following facts:
Those convicted of dangerous driving are mainly young males, with three-quarters of the dangerous driver offenders in 1996 being males aged under 30 years.

A higher proportion of those convicted of dangerous driving fall into the younger age categories than those convicted of other serious non-motorising offences.

It was found that 38 per cent of offenders convicted of dangerous driving in 1996 had no recorded criminal history and 46 per cent had been convicted in court on at least three occasions.

A third of those convicted of dangerous driving in 1996 went on to commit a subsequent criminal offence in 1997. This proportion varied depending on whether the offender had a previous criminal history. Fourteen per cent of offenders with no criminal history prior to 1996 committed a subsequent offence in 1997, compared to 56 per cent for offenders with three or more previous court appearances prior to 1996.

It was found that around one offender in 20 convicted of dangerous driving in 1996 was convicted of a further dangerous driving offence in 1997.

**OFFENCES**

The majority of those surveyed, 74 per cent, felt that it should not be necessary to prove that an action was deliberate in order to prove a charge of dangerous driving.

A significantly smaller number, 55 to 58 per cent, felt that it was not currently necessary to prove that specific actions were deliberate in order to prove a charge of dangerous driving.

The use of the 'careful and competent' driver as the standard to which the defendant's driving should be compared was felt to be sufficiently clear to 70 per cent of respondents to the survey.

There was, however, significant variation in the percentage of the driving population the respondents thought could be described as 'careful and competent'. This suggests that the term is being interpreted differently.

From the cases examined it was found that the majority of offences described as violations or aggressiveness were brought as dangerous, rather than careless, driving.

The extent to which the consequences of the driving, rather than the driving itself, are taken into account appears to vary in terms of both offence and penalty.
Excessive speed was the most common element amongst the dangerous driving cases followed in the research. However, there is a lack of consistency in the way in which speed is taken as an indication of dangerous driving.

Penalties for convictions for careless driving were significantly higher in those cases involving a fatality.

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References and further reading


6 Research into unlicensed drivers

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Introduction

In October 1999 the Department of the Environment, Transport and the Regions (DETR) Road Safety Division commissioned Ross Silcock (a member of the Babtie Group) and Social Research Associates to conduct research into unlicensed drivers. The main objectives of the two-and-a-half-year project are to:

• estimate the extent of unlicensed driving, ie the proportion of drivers who drive unlicensed, the frequency and circumstances of unlicensed driving and the miles driven;

• consider the road safety implications of unlicensed driving with reference to accident reports and self-reported accident involvement;

• determine the characteristics of unlicensed drivers;

• identify the motivations for unlicensed driving and the beliefs and attitudes associated with the behaviour (including consideration of possible consequences and the effectiveness of existing and possible deterrents); and

• make recommendations for countermeasures.

Several surveys and strands of research are being completed. These include the following:

• a national postal survey of potential unlicensed drivers

• analysis of prosecutions and crashes of unlicensed drivers

• in-depth local area and focal point face-to-face and telephone interviews.

At the time of writing, preliminary analyses of the results from the national postal survey and prosecutions and crashes of unlicensed drivers have been completed. It would be premature to present any initial findings before the analyses have been subjected to various checks and validations. Indeed, further research and sensitivity analysis is planned in order to assess the validity of the preliminary findings in depth.

With many research projects a number of assumptions are necessary in order to assess the findings from surveys and reach conclusions. The findings should only be considered with respect to the assumptions made as part of the research. To present the findings without reference to the acknowledged limitations of the results would be misleading and could result in ineffective recommendations being developed.

For these reasons therefore, this paper will concern itself only with a description of the methodologies used and the assumptions necessary to reach conclusions. No details of preliminary results will be provided.
National postal survey of potential unlicensed drivers

METHOD

There are several categories of person who are in a position to commit the offence of unlicensed driving, whose details can be identified from the DVLA database of driving licences. The project steering group agreed that three main categories should be surveyed:

- provisional licence holders (who may drive otherwise than in accordance with the restrictions of the provisional licence);
- drivers who may drive after being disqualified from driving for
  - a drink-driving offence
  - some other single offence
  - the totting up of penalty points
- drivers whose licence was revoked under the provisions of the Road Traffic (New Drivers Act) 1995 (who may drive before reapplying for a provisional licence, and may also drive otherwise than in accordance with the restrictions of the provisional licence if they decide to reapply for one).

These are people who at some stage have applied for a licence and have 'entered the system' and may or may not have driven unlicensed. The category of provisional licence holders was also subdivided into a sample of those drivers who applied for a provisional driving licence approximately a year previously but had not yet passed the practical driving test, and a sample of drivers who had only very recently passed the practical driving test. These two samples would include drivers varying in the amount of time taken between obtaining a provisional licence and obtaining a full driving licence, and would therefore allow an investigation as to how this and the number of L-test failures may affect the decision to drive unlicensed.

A further category on the DVLA database system are those who have been caught driving but have never held a licence (NELIs). These records are maintained in case any such driver subsequently applies for a licence to which endorsements or a period of disqualification would then be applied accordingly. The national postal survey reported here did not include those unlicensed drivers who have never applied for a driving licence.

Hence the names and addresses of people targeted for survey were requested and supplied from a random selection of DVLA database records to the specifications shown in Table 1.

It can be seen from Table 1 that the names and addresses supplied are for people who have been issued with a provisional licence or received a disqualification or revocation order within a defined time period. The time periods were carefully chosen to ensure that the person receiving the questionnaire would have recently had the opportunity to drive unlicensed. The time periods specified also had to be long enough in duration for sufficient people of that type to exist within the DVLA records from which 5,000 could then be randomly selected. Questionnaires were posted to the sample during the months of May and June 2000.

Table 1: Specifications for contact lists supplied from DVLA database records
A separate (but similar) questionnaire was designed and sent to each of the three main categories of driver. To encourage a good response rate to a questionnaire that is, after all, asking about illegal behaviour, the recipient was advised that the returned questionnaires were anonymous unless the respondent was willing to discuss their views, in which case they were asked to provide their telephone number. The questionnaires also incorporated a return postage pre-paid address and therefore could be returned by simply folding and posting them. The respondents were also advised that the questionnaire gave them an opportunity to tell us what they thought of the current system in the hope that this may encourage even more people to respond. The different sub-categories within the overall sample were sent questionnaires on different coloured paper so that they could be identified, anonymously, upon return.

Because of the different legal system in Scotland it was also thought that it would prove useful for the survey to provide a comparison of unlicensed driving in Scotland with England/Wales. Therefore, those questionnaires within the sample that were sent to Scottish addresses were uniquely marked to allow identification as being Scottish when returned.

Table 2 shows the categories and numbers of drivers surveyed. Although it was initially intended that 5,000 questionnaires would be sent to each category, a slightly reduced number were eventually sent due to printing or packing errors.

Table 2: Numbers of drivers surveyed

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-category</th>
<th>Total issued</th>
<th>Total returned</th>
<th>Response rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5,000 names and addresses of people who first applied for a provisional driving licence for a motor car during March 1999 and who had not yet passed the practical driving test by May 14th, 2000.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5,000 names and addresses of people who have recently passed the practical driving test (5,000 drawn from full licences issued during February or March 2000).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5,000 names and addresses of those disqualified beginning during the two-month period March 1st, 1999 to April 30th, 1999 for drinking and driving.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5,000 names and addresses of those disqualified beginning during the two-month period March 1st, 1999 to April 30th, 1999 for a single offence other than drinking and driving.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5,000 names and addresses of those disqualified beginning during the two-month period March 1st, 1999 to April 30th, 1999 as a result of the 'totting up' of penalty points.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>5,000 names and addresses of those whose licence was revoked under the New Drivers Act during the nine-month period December 1st, 1998 to August 31st, 1999.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
As can be seen, the response rate to the survey varied for the different categories of drivers surveyed. It can only be speculated as to why this should be, though it may be partly because of some categories' disaffection with authorities. Overall 3,425 valid questionnaires were returned, giving an overall response rate of 11.5 per cent.

CAVEATS

Respondents to survey may be self-selecting

The national postal survey relies upon a sufficient number of potential unlicensed drivers responding to the anonymous questionnaire asking about unlicensed driving. It is unclear as to whether people who do drive unlicensed are more likely or less likely to return the questionnaire. However, a telephone audit of non-responses suggests that those who did not respond were of a similar socio-economic profile to those who did.

USE OF DVLA RECORDS

Out-of-date address details

Questionnaires were sent to potential unlicensed drivers whose names and addresses were taken from the DVLA database of driving licence holders. DVLA rely upon members of the general public to inform them of any changes to personal details such as name and address. It is thought that many records may be out of date due to members of the public not bothering to inform DVLA of such changes. It is possible that people with a more criminal inclination are less likely to inform DVLA of such changes to their details.
Large number of provisional licence holders according to DVLA records

The 'grossing up' to estimate the national extent of unlicensed driving will be based upon the proportion of respondents to our survey who admit to unlicensed driving, multiplied by the total number of potential unlicensed drivers (such as provisional licence holders obtained from DVLA records), multiplied by the amount that our survey respondents said they did it. However, there are a number of concerns over the apparently large number of provisional licence holders who may be potential unlicensed drivers, according to the DVLA database.

It is thought that there could be a large number of provisional licence holders on the DVLA database that are not valid. This is because the provisional licence, once obtained, is valid until the age of 70. Some people may mislay their licence and then apply for another licence inadvertently using a slightly different name or initials, which would generate a new record. Others may reapply for a provisional licence with a new name, for example after marrying, without reference to their old licence. A number of records may relate to people who have died.

This is of particular concern regarding the total number of provisional licence holders on the DVLA database (thought to be about 5.5 million). It is thought that this group contributes a large proportion of unlicensed driving. They have a much larger population compared to the many other groups of potential unlicensed drivers surveyed, although on average the reported hours driven illegally is generally lower.

Upon further investigation it was ascertained that some informal DVLA research completed four years ago found that around 20 per cent of those applying for a provisional licence had already done so previously. However, it was not known how the proportions applying for a second provisional licence had changed over time, or how many such licences had subsequently been identified and removed by DVLA.

DVLA also advised that it was thought that relatives informed DVLA of the death of a licence holder in only about 12 per cent of cases. However, again it was unclear as to how this proportion had changed over time, or how many records DVLA may have identified through other means and removed from their database.

SURVEY SAMPLE DIFFERENT TO POPULATION

In order to achieve a sufficiently large response rate to our postal survey the questionnaires were sent to potential unlicensed drivers whose DVLA records may be more likely to contain an up-to-date postal address (ie those who would have
recently been in contact with DVLA). For this reason questionnaires were sent to provisional licence holders who had recently passed their test, and provisional licence holders who, a year previously, had applied for the provisional licence.

However, this sample is not necessarily representative of provisional licence holders as a whole. Although we have obtained data from DVLA as to the number of provisional licence applications each year from 1980 to 1999 that are still valid, and have applied this information to our estimates of the extent of unlicensed driving, a problem remains. This is that our respondents are perhaps more likely to have been recently driving in some form because they had recently passed the test, or recently applied for the provisional licence. This is in comparison to the general population of provisional licence holders, many of whom may have obtained a provisional licence several years previously, but may not have driven for several years. Conversely, they may be driving regularly with no intention of taking a test.

COMPARATIVELY SMALL NUMBER OF SURVEY RESPONSES COMPARED TO THE POPULATION

Within the resources available it was possible to issue almost 30,000 postal questionnaires to potential unlicensed drivers. Around 3,400 questionnaires were returned - a response rate of 11.5 per cent. Of these a proportion admitted to unlicensed driving. This is a small number compared to the total number of potential unlicensed drivers according to DVLA records (in excess of 5 million people).

Analysis of prosecutions and accidents of unlicensed drivers

INTRODUCTION

A primary objective of this research project defined within the terms of reference is as follows:

'to consider the road safety implications of unlicensed driving with reference to accident reports and self-reported accident involvement.'

The strategy adopted by the research team to complete this task, with regard to accident reports, has been to analyse data held by various police forces on prosecutions for unlicensed driving that have derived from involvement in motor vehicle crashes. The relevant prosecution data have then been matched with the associated STATS19 accident records, which have then been compared with the STATS19 records for the police force area as a whole.
DATA COLLECTION

Although a straightforward task in principle, there have been found to be several hurdles to be overcome to obtain the complete data required. After obtaining cooperation and support from a number of police forces, to whom we are grateful, our initial enquiries have focused upon establishing a link between the prosecution and crash databases. For historic reasons each police force contacted has collected and stored their data in a different manner, and in every case the prosecution and crash records are stored separately. In no cases have the two sets of data been electronically linked. At best the only link that has been found to exist for some cases is the use of a common reference number (such as an accident reference number) stored on both computer databases. In these cases it has been possible to obtain prosecution data for various categories of unlicensed driving which include an accident reference number, and to then use the accident reference numbers to extract the associated crash data from the separate STATS19 database.

It has been found to be more usually the case in most police forces contacted that there is no common reference number stored electronically on the two databases. Any linking reference number exists upon paper records only. To complete a manual match of paper prosecution and STATS19 crash records would be extremely laborious and time consuming, and would be beyond the reasonable resources of the project and of the police forces involved.

The decision as to which police forces to approach was made based upon an initial desire to choose four locations that were also targeted as part of the local area interview surveys. It was also intended that the police forces contacted would be representative of a range of urban and rural situations. Due to the problems encountered in finding suitable data, the number of police forces approached was expanded. Further police forces were approached based upon research team and DETR staff knowledge as to which police forces were most likely to compile and store data in a way that would be useful to us.

Eventually data for three police force areas (Leicestershire, Northumbria, and Avon and Somerset) were analysed, and it is considered that these areas, with their diverse mixture of rural and urban roads, may be considered fairly representative of other districts throughout Great Britain.

CAVEATS

The police forces for which analysis of data was possible have been issued with copies of the report of the analysis. They have been invited to comment and suggest reasons for the identified
differences between some of the police forces in the types of prosecutions made. We have also enquired as to the individual police force policy on unlicensed driver prosecution. It is hoped that any information received may provide some reassurance or explanations that would address some of the following concerns about the data.

EACH POLICE FORCE IS DIFFERENT

Recording prosecution data

There is not a requirement or need for a police force to collect prosecution and STATS19 data together. Collection of accident statistics for the later research and analysis must not be confused with evidence for any later prosecution or litigation, and for this reason many collect information separately early in the process which makes any later comparison between the date difficult.

With regard to the STATS19 data this does not present this research with a problem because the STATS19 form is used to record data about personal injury road crashes and their consequent casualties, to a consistent national format. However, with the prosecution data, there is not a national requirement for a consistent method of recording data. For example some forces have recorded the number of proceedings, whereas others have recorded whether there was a prosecution, caution or whether no further action was taken. This has caused collection difficulties for the research and so for consistency we have analysed prosecutions only.

Different offence codes

To try to ensure reasonable consistency, data were obtained for a number of offences directly related to unlicensed driving with reference to Home Office and local police force codes for these offences. However, it was apparent that the police forces varied in the way that the offences were categorised and coded.

Police force policy on unlicensed driving offences

This analysis has not been examined or analysed individual police forces’ policies on unlicensed driving, and therefore it is unclear how this may have influenced our analysis. It may be that different police forces place a higher degree of importance on such offences, compared to others in any case every police officer has discretion and may decide not to instigate proceedings. This may influence our results when we try to scale our findings up to the national level.
NO RECORD OF FINDINGS OF GUILT

The police do not undertake the administration task of updating the file record with the court outcome, to inquire as to the result of the prosecution would be very time consuming for the police force involved. This has made researching whether each prosecution resulted in a finding of guilt somewhat impossible, and to 'gross up' to the national total number of STATS19 records in which a guilty unlicensed driver was involved we are applying national proportions of findings of guilt from Home Office national statistics.

It is known that in some cases, relatively less serious offences (such as unlicensed driving) are dropped when a number of charges are laid, before they reach the courts. Such cases will not result in a finding of guilt, even though the driver was unlicensed. Therefore the adjusted figures for findings of guilt discussed above will be an underestimate of all crashes involving a guilty unlicensed driver.

UNDER-REPORTING OF UNLICENSED DRIVER CRASHES

Other factors could lead to an underestimation of crashes. These include undetected unlicensed drivers (particularly where the police did not attend at the scene), errors of omission during the manual search of records by the police, and cases where the unlicensed driver was killed and so no prosecution was made.

ARE OUR POLICE FORCES REPRESENTATIVE OF THE NATION?

Originally we hoped to obtain data for at least four police forces whose locations would coincide with local area interview surveys of unlicensed drivers. The four locations were intended to provide a range of urban and rural situations. In the event it was necessary to collect data from any force that had data in a suitably electronic format as otherwise the research would have been to onerous and not have met our timeplan. For reasons mentioned already it is unclear as to how representative the three police forces areas from where useful data were eventually obtained are of the nation as a whole, with respect to unlicensed driving.

SMALL AMOUNT OF DATA ANALYSED

Given the constraints on the collection of data caused by the lack of electronic or manual tie between accident data and prosecution outcome, the number of crashes that could be linked to a prosecution for unlicensed driving and were analysed within the resources available is a relatively small number compared to the total number of potential unlicensed
driving crashes throughout the country. It is unclear how representative the crashes involving unlicensed driving analysed are of such crashes as a whole.

ATTRIBUTING BLAME

Within the STATS19 data analysed, there is no requirement to record of who was to blame for each of the records involving an unlicensed driver. For this reason it could be argued that some crashes may have occurred anyway, regardless that an unlicensed driver was involved. However, it could also be argued that had the unlicensed driver not been on the road at the time of the crash, then it would not have happened.

Conclusions

After further analysis and additional research it is expected that a reliable estimate will be made as to the proportion of car driving completed by unlicensed drivers nationally. This information will then be combined with the analysis of police prosecution and STATS19 accident records to assess if unlicensed drivers are over-represented in road accidents for the amount of driving that they complete.

Further strands of research that are currently being completed include in-depth telephone and face-to-face interview surveys of potential unlicensed drivers in four geographical areas, whose details have also been taken from the DVLA database of driving licences. Similar surveys of drivers identified from focal points (locations frequented by possible unlicensed drivers) are also being completed, to include those who may never have held a licence and therefore do not appear on the DVLA database. It is intended that these surveys will provide important additional information on the characteristics of unlicensed drivers as well as new information on the motivations, beliefs and attitudes associated with their behaviour. This information will be most valuable when considering the effectiveness of deterrents to unlicensed driving.

The final stage of the research will be the identification of possible deterrents and recommendations for countermeasures. This will involve a Delphi survey and workshop involving decision-makers and stakeholders, and those involved in administering potential measures for the reduction of unlicensed driving.
7 Mission impossible? A retrospective of the effectiveness of a high-intensity enforcement campaign

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Introduction

In July 1997 a trial high enforcement campaign, named Operation Lifesaver (OL), was implemented in one police divisional area of the Republic of Ireland. Comparing accident data for this area for the last full year before high enforcement (1996) with the first full year after it was introduced (1998) there was found to be a 39 per cent drop in fatalities, a 24 per cent drop in serious injuries and a 26 per cent increase in minor injuries. One might be tempted to conclude, on the basis of this evidence, that the high enforcement intervention was at least successful in reducing the severity of injuries, represented by the decline in numbers of fatalities and serious injuries. However, before reaching such a conclusion we need to ask a number of questions of the data, in particular how these results compare with a control area; whether the findings are simply an expression of ongoing trends in casualty profiles; how representative they are of the true accident picture; and whether there is evidence of a reduction in the contribution to casualty figures of the behaviours actually targeted by the enforcement intervention.

Effects of Operation Lifesaver on casualties

COMPARISON WITH A CONTROL AREA

The local high enforcement intervention was situated in an historical and ongoing stream of national media campaigns directed towards increased road safety. For example, in the year prior to OL, national campaigns by the National Safety Council had targeted speeding, drink-driving, the wearing of seat-belts and the vulnerability of elderly pedestrians. To control for any possible effects of such campaigns and other contributory factors at a national level it is of course useful to have a non-intervention sample. This was obtained from a second police divisional area, matched on mix of rural and urban areas, profile of road types (national routes, other main trunk roads, rural roads and urban streets), proximity to the capital Dublin and accident profile prior to OL. Casualty data comparing the years 1996 and 1998 for the treatment and control areas are presented in Figures 1 to 3. Considering numbers of fatalities and injuries in this way assumes, of course, that differences in totals over the three-year period are not simply due to proportionally different changes in the two areas sampled in population, vehicle registrations or kilometres driven. The data for new car registrations for 1997 and 1998 are at least consistent with this assumption, with an increase of 10 per cent and 9.5 per cent in the control and treatment areas respectively (Revenue Commissioners, 2000).

Figure 1: Fatalities for treatment and control areas, 1996-98
For fatalities, it may be seen that there was a drop from 1996 to 1998 in both treatment and control areas. The 'k' test value for these data is 1.0, indicating that the decrease in fatalities in the treatment area was the same as that in the control area. Not surprisingly the associated $c^2$ value was less than unity ($\chi^2 < 1.0$, df = 1, ns). For serious injuries, there was a reduction in the treatment area from 229 to 189, compared with a very slight increase in the control area. For these data, $k = 0.82$, indicating a reduction of 18 per cent in the treatment area compared with the control. However the associated $c^2$ value was not statistically significant ($\chi^2 = 1.44$, df = 1, ns). For minor injuries, there was an increase in both the treatment and the control areas, although the increase was 9 per cent more in the control area ($k = 0.91$). The
\( \chi^2 \) value here was also not significant (\( \chi^2 = 1.36, \text{df} = 1, \text{ns} \)). Thus the proportional changes over time seen in both the treatment and control areas for the different categories of casualty are not reliably different.

**ARE OBSERVED CHANGES EXPRESSIONS OF ONGOING TRENDS IN EACH AREA?**

The possibility exists that the observed changes in the treatment and control areas may be expressions of continuing trends or indeed of regression to the mean from extreme levels. However, it was not possible to carry out a meaningful analysis of these possibilities because new accident reporting procedures were introduced in 1996, enabling a higher proportion of road accidents to be documented by the police (estimated as an increase of about 17 per cent by Bacon, 1999).

**REPRESENTATIVENESS OF THE DATA**

Because only a certain proportion of injury accidents are represented in the national statistics compiled from police reports, an attempt was made to estimate the effects of OL on the numbers of traffic accident victims presenting to the accident and emergency (A&E) departments in a representative major hospital in each of the treatment and control areas. Comparisons between the two hospitals turned out to be somewhat restricted, however, because records from each hospital varied in detail and also availability. In particular, only aggregated annual data were available from the control area hospital and detailed recording of road and traffic accidents (RTAs) in the A&E department of the treatment area hospital did not commence until 21 October 1996. Despite these limitations, one comparison may be made using estimates of the annual data for the treatment area hospital for 1996. Estimates for this hospital are possible because the relationship between accident victim numbers in the last two months of the year are related to the total numbers of victims for the year (mean percentage = 17.1; range in available sample of three years 1997-99 = 2.8 per cent). Looking at the numbers of RTA victims retained or transferred revealed a significant difference between areas (\( \chi^2 = 10.21, \text{df} = 3, p < .02 \)), with the numbers reducing over time in the treatment area, but initially increasing and then decreasing in the control area (see Figure 4).

**Figure 4: RTA victims retained in hospital or transferred**

![Graph showing RTA victims retained in hospital or transferred](image)

**EVIDENCE OF CHANGE IN THE CONTRIBUTION TO CASUALTY FIGURES OF THE BEHAVIOUR TARGETED BY THE ENFORCEMENT INTERVENTION**

Operation Lifesaver targeted speeding, drink-driving and seat-belt wearing. One further way of examining the effects of OL is to examine the proportion of accidents that were attributed to the targeted behaviours of the campaign. If the campaign were effective, then one would
expect the contribution of targeted behaviours to accidents to decrease. However, only one of
the three targeted behaviours was amenable to this level of analysis, because first of all
alcohol as a contributing factor has not been routinely assessed in injury accidents in Ireland;
and secondly because, although seat-belt wearing can contribute to reducing the severity of
an accident, failure to wear one cannot reasonably be considered as a contributing cause.
Hence the results below are concerned specifically with the effects of OL on the proportion
of accidents where 'exceeded safe speed' was a contributing factor from one (or more)
drivers.

For fatal accidents, the percentage involving one or more drivers exceeding a safe speed is
presented in Figure 5 for the years 1996 and 1998. The whole-year data show both treatment
and control areas with similar proportions of speed-related accidents in 1998, but with each
coming from a rather different baseline in 1996, when the difference in percentages was
statistically significant (  \chi^2 = 9.61, \text{df} = 1, p < .01). The notable change, however, is that we
are seeing an increase in the proportion of speed-related fatal accidents in the treatment area
and the opposite effect in the control area. For serious accidents, the percentage involving one
or more drivers exceeding a safe speed is presented in Figure 6. There is an increase in the
proportion of speed-related accidents from 1996 to 1998 in both treatment and control areas,
with a larger increase in the treatment area. This difference was not significant, however (  \chi^2
= 0.35, \text{df} = 1, \text{ns}).

Figure 5: Percentage speeding in fatal accidents: 1996 v 1998

Figure 6: Percentage speeding in serious injury accidents

Figure 7: Percentage speeding in minor injury accidents
Finally, for minor accidents, the percentage involving one or more drivers exceeding a safe speed is presented in Figure 7. The proportion of minor accidents involving excessive speed decreases in the treatment area from 1996 to 1998 and shows a slight rise in the control area over the same period. These differences, however, are not statistically reliable ($\chi^2 = 1.73$, df = 1, ns).

The analysis above is only meaningful if we assume that there is no systematic bias in the reporting of contributing factors, either over years or between the treatment and control areas. For example, it is a plausible hypothesis that in the treatment area those involved in completing the accident report forms may have been sensitised to 'exceeding safe speed' as a contributory factor. Nevertheless, the picture from this analysis is not especially heartening: apart from a (non-significant) decrease in the treatment area in the proportion of minor accidents involving unsafe speed, the only treatment versus group significant difference is in the wrong direction.

CONCLUSIONS FROM THE CASUALTY EVIDENCE

So what can we conclude about the effects of OL on casualties? Despite apparent decreases in serious injury numbers and a smaller increase in minor injury numbers in the treatment area, these gains are not reliably different from the control area. Changes in police reporting procedures pre-empt the possibility of a useful trend or regression analysis. The hospital data, although providing an additional and positive picture of the effects of OL, cannot contribute to an evaluation of the representativeness of the national accident data because of lack of consistency or equivalence in recording procedures. Finally, where we do have a chance to examine the contribution of speeding to casualty figures, we find either no reliable difference between treatment and control areas or a shift, as for fatal accidents, in the 'wrong' direction. Effects of Operation Lifesaver on expectations and compliance

EXPECTATIONS

For an enhanced enforcement campaign such as OL to be effective, road users must perceive an increased probability of detection and penalty if committing a violation (Mäkinen et al, 1999). To assist in this process and to change attitudes towards the targeted offences of speeding, drink-driving and non-wearing of seat-belts, the NSC undertook a specific media campaign in the treatment area to coincide with the onset of OL. The primary medium used in the OL campaign was that of sheet poster, employed as a 'point-of-danger' medium. Forty-eight-sheet posters were located at various points along main roads in the treatment area, depicting a police officer using a speed camera with the caption 'IT'S THE END OF THE
ROAD FOR SPEEDERS'. Twenty-five such posters were used during August and 23 during September and October 1997. A supplementary radio campaign using a 30-second message was also run over two-week periods during the months of July and August 1997 with an estimated 30 spots per week, and both national and local print press reported the campaign on a regular basis during the first six months of its implementation.

To determine if there were measurable differences in knowledge and perceptions between drivers from the treatment and control areas, we obtained two convenience samples of drivers who agreed to participate and answer a series of questions posed to them on entry to a supermarket car park. One sample came from two towns in the treatment area, and the other from two similar towns in the control area. Overall 240 drivers were interviewed, 123 in the treatment area and 117 in the control area, with roughly equivalent distributions of participants by age and sex.

Figure 8 presents the percentage of participants from each area who indicated a greater likelihood of being detected if committing various offences after Operation Lifesaver.

![Figure 8: Percentage from treatment and control areas indicated a greater likelihood of being caught if committing various offences after OL](image)

Proportionally more drivers in the treatment area felt they were more likely to be caught speeding and not wearing seat belts (speeding $\chi^2 = 8.84, df = 1, p < .01$; seat-belts $\chi^2 = 4.53, df = 1, p < .05$). For drink-driving, proportionally more control area drivers felt they were more likely to be caught once OL was introduced ($\chi^2 = 13.82, df = 1, p < .001$).

How are we to interpret these results? Notwithstanding questions regarding the representativeness of the samples and the reliability of recall, there is of course the important
issue of the relationship between reported and actual behaviour. Does increased perception of enforcement translate into increased compliance?

**COMPLIANCE**

This being a retrospective study, the only data on compliance with speed limits prior to the onset of OL and with a follow-up in October 1997 are for the treatment area (An Garda Síochána Management Journal, 1997). In the initial sample 16,235 vehicles were monitored and 5,203 offences were recorded, indicating a non-compliance rate of 32.0 per cent. The follow-up sample, which examined exactly the same routes, monitored 16,249 vehicles and found 4,463 offences, gave a non-compliance rate of 27.5 per cent. A chi square analysis reveals that there is a statistically reliable difference between the pre- and post-samples in the proportion of drivers who are non-compliant ($\chi^2 = 81.52$, df = 1, $p < .001$). Thus the 4.5 per cent increase in compliance detected after the implementation of OL was a significant one.

In an attempt to compare compliance rates between the treatment and control areas, we have been restricted to an analysis of speeding behaviour on motorways taken in 1999. This is partly because of restricted availability of data from the relevant divisions and also because of the difficulty of obtaining comparable data, the incidence of speeding behaviour being in part a function of the design characteristics of the roadway.

The percentages of drivers complying with the speed limit (70mph), exceeding it in the range 71-80mph and at a speed greater than 80mph, are presented in Figure 9.

**Figure 9: The percentage of drivers within and exceeding the speed limit on motorways, 1999 data**

Although these percentages for the treatment and control areas are remarkably similar, statistical analysis reveals that proportionately more drivers in the treatment area sample exceeded 80mph on motorways (7.7 per cent and 3.3 per cent for the treatment and control areas respectively; $\chi^2 = 14.47$, df = 2, $p < .001$). Of course, it needs to be remembered that perhaps a large proportion of vehicles using motorways may be through traffic rather than local road users. Nevertheless, data for compliance on dual carriageways and regional two-lane roads are not heartening for the treatment area in 1999, with 83 per cent compliance on the latter but only 25 per cent compliance on the former (assuming random sampling of vehicles).

We do not have roadside observations of seat-belt compliance in the treatment and control areas, but it is possible to gain an estimate of compliance through accident records for the years 1996 through to 1998. Although something like 65 per cent of injury accident records are not complete in this regard, and there may also be an interaction between seat-belt
wearing and accident involvement (for example, culpable accident-involved persons may be less likely to wear seat-belts), it may be noted that although there were no significant differences between areas for any year sampled, a treatment area advantage seen in 1996, which slipped in 1997, had recovered by 1998, with a compliance rate of 87 per cent (see Figure 10).

**Figure 10: Percentage of drivers involved in all injury accidents not wearing a seat-belt**

Thus in summary there is evidence to indicate that Operation Lifesaver did indeed increase driver perceptions of the likelihood of being detected for two of the three targeted offences, speeding and non-wearing of seat-belts. This perception reliably, but only weakly, translates into compliance with speed limits, a conclusion qualified by the fact that we have no control data for comparison and later results on compliance with speed limits on motorways do not support this observation. Similarly, there is no evidence here to suggest an increased compliance with seat-belt wearing in the treatment area. Given these results, and those for accident casualties, it seems worth determining more precisely what was involved in the implementation of Operation Lifesaver.

**The meaning of high-intensity enforcement**

With the introduction of OL, there was an increase in the permanent staff of the divisional traffic corps in the treatment area who were used exclusively in the enforcement of road traffic legislation (RTL) (O'Brien, 2000). As a result, the number of hours of RTL enforcement in the treatment area was approximately 7 per cent greater than in the control area (Mangan, 2000). This increase is also reflected in the number of traffic offences for which proceedings were taken over the years 1996 to 1998 (see Figure 11) (An Garda Síochána Annual Report, 1997, 1998). These numbers are of course in part a function of the rate of violation as well as intensity of surveillance and enforcement. However, looking specifically at the enforcement levels of targeted behaviours, the percentage change in the number of speeding detections (with 1996 as 100) is presented in Figure 12 for treatment and control areas for the years 1996 through to 1998 (note that data for 1996 and 1998 for the control area are extrapolated from six-month data). It may be seen that there is some difference between areas in the amount of change, although this is not statistically significant ($\chi^2 = 5.54$, df = 2, ns). However, in addition to the above detections, there were 7,953 fixed penalty notices issued in the treatment area in 1997 (when they were introduced for the first time) and a further 11,843 were issued in 1998 (Mangan, 2000). Comparative data are not available from the control area.

**Figure 11: Number of traffic offences for which proceedings taken**
Figure 12: Percentage change in speeding detections

Figure 13: Percentage change in prosecutions for non-wearing of seat-belts

Figure 13 shows the percentage change in the number of prosecutions for non-seat-belt wearing (with 1996 as 100) for both areas for the years 1996 through to 1998 (note again that data for 1996 and 1998 for the control area are extrapolated from six-month data). It is very obvious from these data that there was a massive increase in the number of prosecutions for non-wearing of seat-belts in the treatment area in 1997, compared with the previous year (from 265 in 1996 to 1,984 in 1997) and compared with the control area (749 per cent increase compared with 105 per cent) and that although this size of increase was not sustained in 1998, nevertheless the rate of prosecution in that year in the treatment area was still more than twice the rate for 1996. Not surprisingly, the proportional differences between areas observed here are statistically highly reliable ($\chi^2 = 464.0$, df = 2, $p < .001$).
Finally, there was no difference whatsoever between the treatment and control areas in the percentage change in the number of detections for drunk-driving over the years 1996 to 1998 (both increased by 50 per cent). From all of this evidence regarding the levels of enforcement of targeted behaviours in the treatment and control areas, we have to conclude that the main difference in the treatment area has been in the enforcement of seat-belt regulations and to a lesser extent speeding. These differences should, of course, be considered in conjunction with the coordinated enforcement media campaign.

**Conclusions**

Operation Lifesaver was described and promoted publicly as a high-intensity enforcement campaign targeting speeding, drink-driving and seat-belt wearing. However, the evidence suggests that in comparison with a control area, its implementation has only involved a 7 per cent increase in enforcement activity and has been mainly applied to seat-belt wearing, to a lesser extent to speeding and not at all to drink-driving. Driver perceptions were in a way consistent with this, in that in the treatment area they reported they felt more likely to be caught if speeding or not wearing seat-belts, but drivers in the control area felt more likely to be caught if drink-driving. Despite these mixed perceptions, the available evidence does not in general support the idea that increased enforcement has translated into higher levels of compliance or a reduction in the contribution of speeding to injury accidents in the treatment area. Apparent reductions in serious and minor injury casualties in the treatment area are not statistically reliable, and even the more positive hospital data are based in part on estimated pre-intervention values for the treatment area.

As an intervention, Operation Lifesaver was situated in the context of ongoing national media campaigns and a regular national end-of-year drink-driving enforcement 'blitz' campaign around Christmas and the New Year. These events may have served to reduce the specific effects of OL in the treatment area compared to the control. It must also be remembered that only a proportion of crashes have as a contributory factor some violation of traffic regulations, thus limiting the possible effects of an enforcement campaign on accident rates.

It is also worth raising the point that estimates of the reliability of differences over time are necessarily based on comparisons with variability in previous samples. Can we count non-significant decreases in casualties as random variation or may they be the start of a trend? There is perhaps room here for the development of some form of conditional statistic that evaluates the significance of an observed value conditional on the next value (yet to be obtained) being equal to or greater than some criterion. Such a statistic may be of help to policy-makers in deciding on the continuation of interventions and help counter the tendency to accept any positive change as being a policy outcome.

Despite these rather pessimistic conclusions regarding the effects of OL, it must be stressed that they must be treated only as an approximation and with considerable caution. For a proper scientific evaluation of the effects of an intervention such as OL, it is paramount that comparable, reliable and valid data are available for both treatment and control areas. As described earlier, it has proven difficult to satisfy this criterion in many elements of this study, making it almost an impossible mission. The strong implication is that for future evaluative exercises it will be important to plan the evaluation prior to the intervention, decide on what will count as evidence and take appropriate measures in real time.
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References


8 The general deterrent effect of speed camera housings

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Abstract

A scheme for hypothecation of fine revenue from additional speed cameras is currently being piloted in eight UK police force areas. Such schemes change the whole fiscal basis of road traffic enforcement activities such that they are no longer a net cost to the police and the courts. On the basis of preliminary results from the pilot areas a decision has already been made to roll out the scheme nationwide, beginning late 2001. This paper summarises international and UK evidence on the effects and effectiveness of speed camera enforcement, briefly reviews the UK pilot scheme, describes the criteria for camera site selection, and presents some preliminary data from the six sites in the Strathclyde Police/Glasgow City Council/Glasgow District Court area, showing the effects on mean speed, number of speeders and number of offenders of partial installation of site furniture.

Introduction

Speed kills by increasing crash severity. The laws of physics dictate that the higher the speed at impact the more kinetic energy must be absorbed by hard metal, soft flesh and brittle bones. Finch et al (1994) reported that every 1mph increase in mean traffic speed elevated accidents by about 5 per cent on UK roads. Stradling et al (2000) showed that English drivers who speed, who violate other rules of the road, and who seek thrill when driving pose greater risks to themselves and to other road users. They argued that speeders should be constrained because 35 per cent of the car drivers in their study who had been penalised for speeding in the previous three years reported also having been accident involved in that period, compared to 22 per cent of those who had not been penalised, indicating that the kind of drivers recently caught for speeding are 59 per cent more likely to have also been recently crash involved. However, there was no data in that study to demonstrate that such drivers had their crashes while speeding, only that speeders were more likely to have crashes. Cooper (1997) reported that US drivers with four or more excessive speed convictions had double the crash rate of other drivers, and that drivers with more than the average number of general traffic violations were more likely to be involved in crashes and in crashes caused by excessive speed.

Holland and Conner (1996) studied the effects of police intervention on exceeding the posted speed limit and on intentions to speed in one UK location. They found that an anti-speeding campaign of enhanced enforcement was effective in reducing the numbers breaking the speed limits, with a small effect still evident nine weeks after a three-week police presence. This intervention involved a time-limited police presence on the roads, and thus differs from studies examining the effect of speed cameras that have a permanent presence at the roadside. Holland and Conner (1996) found that warning signs had a significant effect, even in the absence of any recent police enforcement. They suggested that drivers' intentions to speed in future are more likely to be altered by continuous enforcement devices such as fixed-site speed cameras.

Speed cameras - or safety cameras as they have recently been re-badged - are intended to reduce casualties by reducing accidents by reducing speeds at specific high-risk locations. Bourne and Cooke (1993) reported that, in the state of Victoria, Australia, a mobile Speed Camera Program, running since 1989 in conjunction with tougher drink-driving enforcement
and advertising campaigns, had lowered traffic crashes by 25 per cent and decreased injuries by 45 per cent. However, three treatment variables are here confounded and it is not clear how much of the crash and injury reduction may be attributed to the camera campaign. Sixty mobile speed cameras were introduced over eight months. These cameras were used to check vehicle speeds at over 1,000 sites between 1990 and 1993. In December 1989 23 per cent of vehicles were recorded as being over the camera trigger speed. By June 1990, this figure was 11 per cent and by August 1992 less than 5 per cent of vehicles were travelling over the camera trigger speed. Bourne and Cooke (1993) claimed that the programme had 'led to a major change in driver speeding, and has established a base whereby speeding can become socially unacceptable given continued publicity and sustained enforcement' (p. 191).

Hooke et al (1996) looked at the effectiveness of almost 500 speed camera sites in 10 UK police forces and found the installation of fixed-site speed cameras reduced accidents by 28 per cent and lowered speeds by an average of 4.2mph. Corbett and Simon (1999) collected self-report information from drivers in four police force areas (Thames Valley, Northumbria, West Midlands and Surrey) where speed cameras had been installed. They found that installing speed cameras produced a reduction in self-reported speeds for up to eight months, with the drivers' speed choice and concern at being detected strongest at the initial installation of the camera. Before camera installation 63 per cent of drivers reported that they drove at above 31mph. Two months after camera installation 35 per cent of drivers said did. After six months this figure reduced further to 30 per cent. But eight months after camera installation they found 34 per cent of drivers reporting driving above 31mph, suggesting that the effect had peaked. In a fifth area (Hampshire) they found that 'speed camera' warning signs alone produced a significant reduction in speed for the six months of the survey.

System Three (1997) research in Scotland found penalties did encourage drivers to adhere to the 'unofficial' speed limit, especially around speed camera sites. They also reported a general perception that drivers would not be prosecuted unless they drove at speeds at least 10mph over the posted speed limit.

In 1999 it was estimated that 'about 75 countries around the world rely on cameras to enforce speed limits' (Insurance Institute for Highway Safety, 1999) but DETR (2000) cautioned that speed cameras cannot be viewed as the single answer to speeding problems. DETR (2000) report that breaking the speed limit is not perceived by many as a criminal act. These opinions on speeding were in contrast with those of drunk-driving and of dangerous driving, both of which the respondents viewed as serious crimes. The punishments for these crimes were a strong deterrent to the respondents, who also saw these crimes as morally wrong.

Scottish Executive (2000) statistics show that 35 per cent of motor vehicle offences recorded by the police in Scotland were speeding offences, and that speeding offences make up the largest single category of motor vehicle offences in Scotland and are increasing. This may be partly due to the advances in the technology now available to the police to detect these offences, though the police are only able to detect a large number of speeding offences if there are many motorists driving above the posted speed limits.

Use of speed cameras to supply an evidential basis for prosecution was made possible by Section 23 of the Road Traffic Act 1991, which provided that photographs from an approved automated speed camera may be used as evidence without the corroboration of a police officer in prosecuting drivers for exceeding speed limits. The Association of British Drivers, keen to alert its members to the location of speed and red-light cameras, currently lists
approaching 2,000 fixed and mobile camera locations on its website, with just below 100 in Wales, just above 100 in Scotland, and the rest in England.

The Strathclyde hypothecation project

The first speed cameras in the Strathclyde police area were introduced in 1993. Location decisions regarding where these cameras should be placed were made by examining accident and speed data held by the police and the local authority to find concentrations of fatal and serious accidents. The director of roads and transport for Glasgow City Council set out criteria for speed camera installations. The revised criteria, formulated in 1997, are based primarily on site suitability and injury accident statistics. The candidate site must provide up to 500m of suitable road conditions, where no other engineering measures would be appropriate for slowing traffic. On this stretch of road there must have been at least six injury accidents in a three-year period. Either three or more of the accidents must have had excessive speed as a major contributory factor (eg loss of control on a bend or a vehicle overturning) or four or more of the accidents must have involved fatal or serious casualties. And the 85th percentile speed for the site must be 10mph or more over the speed limit (the 85th percentile speed is that at or below which 85 per cent of the traffic is travelling).

There are currently 19 red-light camera sites in Glasgow and 23 fixed speed camera sites, including six new hypothecation speed camera sites installed in fiscal year 2000/01, the first year of the two-year hypothecation project period. Year 2 of the hypothecation project will see the installation of a further six speed cameras and two more red-light cameras in Glasgow.

The most recent development in speed camera usage in Glasgow has been the implementation of the hypothecation pilot project that began on 1 April 2000. Strathclyde is one of eight UK regions taking part and each region was required to introduce additional speed cameras, over and above their previous level of automated speed enforcement. The other seven regions are Cleveland, Essex, Lincolnshire, Nottingham, Northampton, South Wales and Thames Valley. Locally the project is run as a partnership between Strathclyde Police, Glasgow City Council and Glasgow District Court. In the Glasgow area of the Strathclyde Police region an additional six sites were identified which met the criteria, and a new speed camera was purchased to serve these new sites. The six sites are Ballater Street, Barrhead Road, Berryknowes Road, Edinburgh Road, Sandwood Road and Titwood Road, all four-lane or dual-carriageway feeder roads providing access to the Glasgow city centre area. Five have a speed limit of 30mph, one of 40mph.

HYPOTHECATION

The hypothecation pilot project differs markedly from past speed camera policy in financial terms. Previously revenue from court fines and fixed penalties went directly to the Consolidated Fund of the Exchequer. Neither the local traffic authorities, which purchase and house the cameras, nor the police, who operate them, nor the courts, which administer the collection of fines and fixed penalty notices, were able to cover their costs from fine revenue. Glasgow City Council retained 10 per cent of court fines as a contribution towards Glasgow District Court administration costs. Now, in the eight pilot projects, the money from their additional cameras will go to the local authorities, the court and the police and will be reserved (‘hypothecated’) for investment in road safety measures. During the hypothecation pilot project, once an agreed baseline number of tickets have been processed, all finances raised by the project sites have the costs of the project deducted, though the remainder is still
remitted to the Exchequer. The project partners were required to outline their anticipated income and outgoings in a business plan. The two situations are contrasted in Table 1.

Table 1: Distribution of revenue raised by speed camera detection

<table>
<thead>
<tr>
<th></th>
<th>To police</th>
<th>To court/council</th>
<th>To exchequer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original scheme</td>
<td>nil</td>
<td>10%</td>
<td>90%</td>
</tr>
<tr>
<td>Hypothecation scheme</td>
<td>costs</td>
<td>costs</td>
<td>any remaining funds</td>
</tr>
</tbody>
</table>

NU-METRIC SURVEYS

Nu-metric equipment has been used to compile traffic statistics for each of the six sites once every three months, beginning in April 2000. This equipment records the number of vehicles, the speed each vehicle travelled at, type of vehicle (passenger car, small goods vehicle, large goods vehicle), and distance ('headway') between vehicles passing the unit, over a 24-hour period. Nu-metric surveys are conducted for 24 hours from noon until noon the following day. All surveys are conducted on a weekday, with surveys at different sites on different days. Research access to this data was made possible by Strathclyde Police Traffic Department, which conducts the Nu-metric surveys.

For each measurement occasion from April 2000, through July 2000, to October 2000 the current stage of camera installation was recorded.

April 2000

At this time the six new sites had been identified for speed camera installation. Nu-metric surveys were carried out with no camera casings, cameras, road markings or warning signs present. When this survey was conducted the sites had been chosen for the cameras but the camera casings had not been erected. Therefore the study was able to record the baseline traffic speeds before any deterrents were introduced. There was nothing at any of the locations to indicate to passing drivers that these were chosen speed camera sites. Speed camera warning signs must be present within one mile of any fixed automatic speed camera. No new speed camera warning signs were erected in respect of the six new camera sites as all were within the statutory distance of existing signs.

- Sites chosen.
- No camera housings.
- No white line road markings.
- No cameras in operation.
July 2000

By this time when the Nu-metric survey was conducted the camera casings were in place, consisting of a grey metal pole with grey metal box on top. No white line calibration road markings were present on the road and no new warning signs had been erected. There were no cameras in any of the new sites, therefore there were no camera flashes to indicate to drivers that a camera might be present (neither active cameras nor 'dummy' cameras which flash when speeding vehicles pass but take no photograph to record the offence).

- Camera housings (grey pole with box on top) in place.
- No white line road markings.
- No cameras in operation.
- No new camera warning signs.

October 2000

At this time camera casings and white line road markings were in place at all six new sites. No new warning signs had been erected. Live cameras had been in four of the sites for between one and 15 days before the Nu-metric surveys were conducted. This means that speeding drivers would have experienced the camera flashing as they passed, but due to the length of the process for issuing prosecution letters, few notices of intention to prosecute - specific deterrents - would have reached offending drivers by the time of this Nu-metric survey.

- Camera housings (grey pole with box on top) in place.
- White line road markings in place.
- Four sites recently operational with active flashing camera.
- Two sites still without a camera.
- No new camera warning signs.

Traffic flow

Speeding behaviour is driven by the interaction of opportunity, obligation and inclination (Stradling et al, 1999) and traffic flow constrains drivers' opportunities for speeding. It was thus necessary in comparing speed distributions at the three measurement times to determine that the traffic flows were not materially different. The number of cars travelling at each hour of the survey day was recorded for each site. When these results are combined across sites, the resulting plot, Figure 1,
shows that there was little alteration in the number of vehicles travelling on these roads at each measurement occasion. Traffic flow at the six Year 1 hypothecation pilot project sites had remained relatively stable.

Between April 2000 and October 2000 the level and pattern of use of these roads had not significantly altered, save for a small diminution in morning and evening peak flows from the first to the latter two measurement times. Much the same numbers of vehicles were travelling on these roads at the same times of day as prior to the camera installation. Thus the opportunities to speed would have remained effectively constant. Collection of data for Year 2 of the hypothecation project, commencing April 2001, may yield some clues as to whether this diminution in peak volumes is a seasonal effect.

**Figure 1: Traffic flow as number of vehicles by time of day for all six new camera sites**

Reduction of speed over time

Analysis of the Nu-metric data for the three quarterly surveys at the five 30mph sites, shown in Figure 2, gives a clear indication of the effects of the stages of speed camera installation on the speed distribution at the sites.

Figure 2 shows, for the five sites with a 30mph speed limit, the decrease in the speed of traffic on these roads. From April to July the modal speed was moved from above 35mph to close to 30mph and the number of drivers substantially in excess of the posted speed limit was cut. From July to October the shoulder of the distribution between 35mph and 50mph was further reduced. The mean speed for these sites reduced from 34.2mph in April 2000 to 31.1mph in October 2000, a reduction of
3.1mph or 9 per cent. The mean 85th percentile speed for April 2000 was 38.5mph, decreasing to 32.9mph in October 2000, a reduction of 5.6mph or 15 per cent. The average speed reduction across the eight UK pilot schemes in this period has been computed at 5.2mph (Gains, 2000).

**Figure 2: Number of vehicles by speed travelled for five 30mph sites**

![Graph showing speed distribution](image)

The proportion of drivers over the posted speed limit at each of the three times is given in Table 2, while Table 3 expresses these figures as percentage reductions from Time 1 to Time 2 and from Time 1 to Time 3.

**Table 2: Percentage of vehicles travelling over posted speed limit**

<table>
<thead>
<tr>
<th>Site</th>
<th>April 2000</th>
<th>July 2000</th>
<th>October 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Ballater Street</td>
<td>71.9</td>
<td>51.8</td>
<td>29.8</td>
</tr>
<tr>
<td>Berryknowes Road</td>
<td>52.4</td>
<td>32.5</td>
<td>20.2</td>
</tr>
<tr>
<td>Edinburgh Road</td>
<td>65.4</td>
<td>34.2</td>
<td>23.6</td>
</tr>
<tr>
<td>Sandwood Road</td>
<td>70.7</td>
<td>38.4</td>
<td>Not available</td>
</tr>
<tr>
<td>Titwood Road</td>
<td>58.6</td>
<td>29.4</td>
<td>17.6</td>
</tr>
<tr>
<td><strong>Average across five sites:</strong></td>
<td><strong>63.8</strong></td>
<td><strong>37.3</strong></td>
<td><strong>22.8</strong></td>
</tr>
<tr>
<td><strong>Range:</strong></td>
<td><strong>52-72</strong></td>
<td><strong>29-52</strong></td>
<td><strong>18-30</strong></td>
</tr>
<tr>
<td>Barrhead Road (40mph)</td>
<td>39.7</td>
<td>Not available</td>
<td>7.9</td>
</tr>
</tbody>
</table>

Table 2 shows that, at baseline measurement, April 2000, an average of 64 per cent of drivers were exceeding the speed limit at the five 30mph sites. Proportions varied across the sites
from a half (52 per cent: Berryknowes Road) to three-quarters (72 per cent: Ballater Street). Forty per cent were exceeding the posted limit at the 40mph limit site. By July, with only the speed camera housings in place, an average of 37 per cent of drivers were exceeding the limit at the 30mph sites, with proportions varying from three in 10 (29 per cent: Titwood Road)) to one-half (52 per cent: Ballater Street). By October, with painted on-road gridlines added and some cameras flashing at some sites, below one-quarter (23 per cent) were exceeding the limit at the 30mph sites, and only one in 12 (8 per cent) at the 40mph site.

Table 3: Percentage reduction in vehicles travelling over posted speed limit

<table>
<thead>
<tr>
<th>Site</th>
<th>April 2000 - July 2000</th>
<th>April 2000 - October 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ballater Street</td>
<td>20.1</td>
<td>42.1</td>
</tr>
<tr>
<td>Berryknowes Road</td>
<td>19.9</td>
<td>32.2</td>
</tr>
<tr>
<td>Edinburgh Road</td>
<td>31.2</td>
<td>41.8</td>
</tr>
<tr>
<td>Sandwood Road</td>
<td>32.3</td>
<td>Not available</td>
</tr>
<tr>
<td>Titwood Road</td>
<td>29.2</td>
<td>41.0</td>
</tr>
<tr>
<td><strong>Average across five sites:</strong></td>
<td><strong>26.5</strong></td>
<td><strong>39.3</strong></td>
</tr>
<tr>
<td><strong>Range:</strong></td>
<td><strong>20-32</strong></td>
<td><strong>32-42</strong></td>
</tr>
<tr>
<td>Barrhead Road (40mph)</td>
<td>Not available</td>
<td>31.9%</td>
</tr>
</tbody>
</table>

Table 3 shows from April to July an average of 27 per cent reduction in the number of speeding drivers, varying between 20 per cent (Berryknowes Road) and 32 per cent (Sandwood Road), and an average reduction of 39 per cent between April and October, ranging from 32 per cent at Berryknowes Road to 42 per cent on Ballater Street and Edinburgh Road. Barrhead Road, the 40mph site, registered a 32 per cent reduction between April and October.

**SPEEDERS AND OFFENDERS**

Figure 2 and Tables 2 and 3 show substantial reduction in the number of speeders - drivers exceeding the local speed limit - with the gradual installation of site furniture. The number of offenders - those exceeding the camera trigger speed (42mph for 30mph sites; 52mph for 40mph sites) who would have received a warning letter or a notice of intended prosecution, and subsequently a summons in the case of excessive speeders, or a conditional offer of a fixed penalty notice (now £60 plus
licence endorsement of three penalty points) had the cameras been active - also fell.

Figures 3 and 4 contrast the distributions for these two groups. (Figure 4 plots numbers travelling above 45mph, not 42mph, as the Nu-metric machinery had been set to 45mph for the April data collection and this setting was retained to facilitate comparison over time. The figures thus slightly underestimate the numbers of ‘offenders’.)

Figure 3 shows that at the time of the baseline measure many drivers were exceeding the 30mph speed limit during the morning peak period, and many more were during the evening peak period. Figure 1, traffic flow by time of day, shows the evening peak with more traffic and over a longer duration. This pattern is broadly mirrored in Figure 3. Installation of the speed camera casings - the July distribution - shows substantial flattening of the morning and afternoon peaks, with that for the late peak being more remarkable because of the greater reduction achieved. By Time 3, October, both ‘speeding peaks’ had been removed and the greatest number of speeding drivers were now to be found in the lower traffic flow period between the peaks.

**Figure 3: Number of vehicles exceeding speed limit (speeders) at all 30mph site**

Figure 4 is plotted to a different scale to Figure 3 because of the much lower number of ‘offenders’ - drivers exceeding 45mph, just above the camera trigger speed of 42mph. Excess speed numbers were much higher around 6pm than at any other time of day at baseline, but this peak, too, had been flattened after three months of the presence of an (inoperative) camera housing, and had been further lowered by Time 3.
Table 4 sets out the data for all six Year 1 hypothecation project sites showing, for each time of measurement, total daily traffic flow, number and percentage of vehicles over the speed limit ('speeders') and number and percentage of vehicles over the site camera trigger speed ('offenders').

At all sites the changes in speeding behaviour have been far greater than any changes in traffic flow. The number of 'speeders' and the number of 'offenders' have both reduced substantially in the presence of a general deterrent - speed camera housings carrying the threat of detection and punishment - and the absence of a specific deterrent - a £60 sanction for exceeding the trigger speed at one of the six sites. Of course, some drivers using these routes may during the period April to October 2000 have received speeding tickets from the other 16 fixed speed camera sites in the Glasgow area or, indeed, from any of the now large number of sites in the UK, and this specific deterrence may have generalised to speed behaviour on Ballater Street or Edinburgh Road.

As the number of 'offenders' decreases, so does the revenue collected from them, as does the back-office workload generated by those offenders. And while the reduction in the number of speeders is admirable from the viewpoint of road safety, it is also depleting the income source. This could be remedied by increasing the number of cameras and camera sites covering an area or by lowering the trigger speed at current camera sites, in either way boosting fine revenue. The trigger speed controls two crucial factors in the administration and management of speed camera enforcement: the number of drivers paying the fixed penalty; and the amount of back-office work generated for the police ticket office and the court. If the trigger speed is set too high then income falls and project costs may not be recovered. If the trigger speed is set too low then workload rises until the additional income can be used to supplement the workforce, though additional lives may be saved by this option.

Figure 4: Number of vehicles travelling over 45mph (offenders) at all 30 mph site
Table 4: Number of vehicles travelling over posted speed limit and camera trigger speed

<table>
<thead>
<tr>
<th>Site</th>
<th>Survey</th>
<th>Total vehicles (No.)</th>
<th>Vehicles over speed limit (No.)</th>
<th>Vehicles over speed limit (%)</th>
<th>Vehicles over camera trigger speed (No.)</th>
<th>Vehicles over camera trigger speed (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ballater Street 30mph</td>
<td>April 2000</td>
<td>9,076</td>
<td>6,522</td>
<td>71.9</td>
<td>395</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>July 2000</td>
<td>8,759</td>
<td>4,533</td>
<td>51.8</td>
<td>262</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>October 2000</td>
<td>8,654</td>
<td>2,578</td>
<td>29.8</td>
<td>140</td>
<td>1.6</td>
</tr>
<tr>
<td>Berryknowes Road 30mph</td>
<td>April 2000</td>
<td>7,184</td>
<td>3,765</td>
<td>52.4</td>
<td>157</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>July 2000</td>
<td>6,496</td>
<td>2,111</td>
<td>32.5</td>
<td>105</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>October 2000</td>
<td>6,648</td>
<td>1,345</td>
<td>20.2</td>
<td>79</td>
<td>1.2</td>
</tr>
<tr>
<td>Edinburgh Road 30mph</td>
<td>April 2000</td>
<td>4,058</td>
<td>2,655</td>
<td>65.4</td>
<td>150</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>July 2000</td>
<td>4,435</td>
<td>1,517</td>
<td>34.2</td>
<td>63</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>October 2000</td>
<td>5,162</td>
<td>1,219</td>
<td>23.6</td>
<td>45</td>
<td>0.9</td>
</tr>
<tr>
<td>Sandwood Road 30mph</td>
<td>April 2000</td>
<td>6,706</td>
<td>4,738</td>
<td>70.7</td>
<td>231</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>July 2000</td>
<td>6,506</td>
<td>2,498</td>
<td>38.4</td>
<td>89</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>October 2000</td>
<td>Not available</td>
<td>Not available</td>
<td>Not available</td>
<td>Not available</td>
<td>Not available</td>
</tr>
<tr>
<td>Titwood Road 30mph</td>
<td>April 2000</td>
<td>6,031</td>
<td>3,533</td>
<td>58.6</td>
<td>218</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>July 2000</td>
<td>5,749</td>
<td>1,690</td>
<td>29.4</td>
<td>55</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>October 2000</td>
<td>6,029</td>
<td>1,060</td>
<td>17.6</td>
<td>33</td>
<td>0.6</td>
</tr>
</tbody>
</table>
### SITE-SPECIFIC OR AREA-WIDE EFFECTS?

Are these substantial reductions in mean speed, number of speeders and number of offenders specific to the six hypothecation sites, or were they just part of a general reduction in driving speed and speeding behaviour in the Glasgow area? There are another 16 speed camera sites in Glasgow with 30mph speed limits, some of which have been in action since 1993. When the available figures were examined, average speed for these sites fell from 30.8mph in July to 28.5mph in October, a reduction of 2.3 mph or 9 per cent. And the proportions speeding at these 'old' sites fell from 24 per cent in July to 17 per cent in October, a reduction of 29 per cent.

Thus some part of the July-October fall at the six new project sites may have been due to a Glasgow-wide reduction in speeding behaviour. Unfortunately retrospective Nu-metric data for the old sites was not available for April, so we are not able to characterise the old site improvement from 24 per cent to 17 per cent as part of a continuing downward trend or just a seasonal variation in Glaswegian speeding behaviour.

The new sites achieved reductions without live cameras; the 16 old sites all had a rotation of live and dummy cameras, so these 16 sites would have always produced a camera flash if a speeding vehicle passed. The five new hypothecation sites had no deterrents other than the empty camera housings.

#### Figure 5: Percentage of vehicles travelling over 30mph (speeders) for old and new sites

![Graph showing percentage of vehicles travelling over 30mph for old and new sites]

**Conclusions**

Six new speed camera sites in Glasgow were selected in accordance with developed criteria. Nu-metric survey data
established that, on average, 64 per cent of vehicles on the five 30mph roads were exceeding the posted speed limit. Three months later, with no change at the sites except the installation of the camera housings, a grey metal pole with a grey metal box on top, there had been a large decrease in the amount of traffic exceeding the local speed limit. Analysis of the Nu-metric data showed no substantial alteration to the traffic flow on these roads, with similar numbers of vehicles travelling on the roads at the same times as in the baseline Nu-metric survey. But now only 37 per cent of the vehicles were exceeding the local speed limit. At the time of the first survey the majority of motorists were speeding; by the time of the second survey, after the introduction of empty camera housings, the majority of motorists were keeping within the speed limit. A further Nu-metric survey was conducted three months later at the same sites. By the time of this survey all speed camera furniture had been installed and four of the cameras had just become operational. Some of the drivers at these sites would have triggered a flash from the camera, but few of them would have yet received speeding tickets from these sites. With, again, no change to the traffic flow and thus to the opportunities for speeding, the survey showed that now only 23 per cent of vehicles on the five 30mph roads were exceeding the posted speed limit. The number of speeders had fallen from two-thirds of passing motorists to one-quarter in six months.

The introduction of the speed cameras housings would seem to have persuaded more drivers to adhere more closely to the speed limit. These preliminary data from the six sites in the Strathclyde hypothecation scheme pilot area showed that drivers at all of the six speed camera sites reduced their speeds and continued to do so for six months. The reduction from Time 2 to Time 3 of the study at the six scheme sites was greater than the reduction found over the same three-month period at the 16 pre-existing, fully operational, Glasgow fixed speed camera sites.

Year 2 of the project begins in April 2001, during which Nu-metric surveys will enable continued monitoring of the situation. From this, it is hoped to discern whether the speed of vehicles begins to increase again, or whether the cameras ensure that speeds on these stretches of roads remain lowered.

References


Are those who get stopped by the police for speeding more deviant than the rest of us?

F. P. McKenna and A. E. Waylen, Department of Psychology, University of Reading, Reading RG6 6AL

Introduction

It is generally accepted in the research environment that speed is an important factor in accident involvement. This conclusion is based on a number of sources. For example it is found that casualties go up if the legal speed limit goes up (Rock, 1995). In addition, it is found that those who travel faster also report more accidents. This is true whether one uses questionnaire measures (French, et al, 1993), video simulation measures (Horswill and McKenna, 1999) or observation (Wasielewski, 1984) to assess speed. In attempting to sum up the relationship between speed and accident involvement the DETR cite evidence indicating that for every 1mph reduction in average speed a 5 per cent reduction in accident frequency is expected (DETR, 2000). Overall, the research community agrees that speed is an important factor in accident involvement.

It is less certain whether the public agrees. When drivers rank the severity of traffic offences speeding generally does not receive a high rank (Corbett and Simon, 1991). Usually exceeding the speed limit is rated as less severe than most other offences. In addition, the majority of drivers break the speed limit. DETR (2000) cites surveys that indicate that 69 per cent of cars exceed the 30mph speed limit on urban roads. This, of course, raises a problem if changing speed is to be considered a major factor in reducing accident involvement. However, attitudes to speeding appear to be ambivalent. In considering attitudes to the 30mph speed limit in town centres it has been found that 67 per cent believe that this speed limit is 'about right' and 21 per cent believe it should be lower (Silcock, et al, 1999). It would appear that drivers simultaneously believe that the speed limit is about right but that they will break it.

The present research was concerned with the attitudes and responses of a group of drivers who had been stopped by the police for breaking the speed limit. The question was to what extent are the attitudes and responses of those who have been stopped by the police different from those who have not been stopped by the police. A separate issue that was examined was the extent to which speeding might be viewed as an outlet for antisocial tendencies.

Method

PARTICIPANTS

Two groups of driver took part in the study. One group (which will be named the rehabilitation group) were recruited by the police. These drivers had been stopped for speeding and were offered the opportunity of attending the rehabilitation course instead of being fined and having points on their licence. A total of 117 drivers were recruited in this way. There were 69 men and 48 women with an average age of 40 years. They had held a driving licence (on average) for 21 years. The second group will be named the control group and were recruited from a range of different sources including local companies. They were recruited without any prior knowledge of any aspect of their driving. Where comparisons were made between the two groups, drivers from the control group were selected to match
those in the rehabilitation group on the following criteria: age, gender, and annual mileage. In addition, those in the control group must have indicated that in the last three years they had no prior driving convictions nor had they been stopped by the police. Using these criteria it was possible to produce a control group with 71 drivers and a rehabilitation group with 72 drivers.

PROCEDURE

The control group were tested either at their place of work or at the University of Reading between 1996 and 1998. The rehabilitation group were asked to attend a speed awareness and road safety evening in Reading (the sites where drivers were stopped for speeding were within the jurisdiction of Thames Valley Police and Reading Borough Council). All participants took part in video tasks which measured speed choice, close following distance, gap acceptance and hazard perception and all completed a series of questionnaires. Each of the video tasks consisted of footage of an actual driver's-eye view of various types of road: rural and urban single-carriageway roads, dual carriageways and motorways.

VIDEO TASKS

In the speed task, six different scenes were shown and for each drivers were asked to judge whether they would drive at the same speed as the driver in the video or whether they would choose a speed which was faster or slower. If they chose the same speed, they were asked to circle 0 on a response sheet where responses ranged from -35 to +35 in increments of 5mph (0 was the mid-point on the scale). If they chose a slower speed they were asked to estimate how much slower they would go and circle that number on the sheet with a minus sign in front of it, eg -10. If they felt they would drive more quickly than the driver in the video they were asked to estimate how much faster they would travel and circle that number with a plus sign in front, eg +15. Responses for each of the six scenes were averaged to give an overall mean score for speed choice.

The close following task consisted of one car approaching another from behind at a constant speed. Participants were asked to press a response button on two occasions: firstly, when the following car was at the distance from the car in front that each person thought he / she would follow at, and secondly when the following car was close enough to the car in front to make the individual feel uncomfortably close. Each response button was connected to a computer which recorded the time from the beginning of the scene to the time when each response was given. Buttons could be pressed discretely so that individuals could respond without influencing the other participants in the room. For this task, the same scene was shown four times and again scores were averaged across the four clips to give an average 'following distance' score and an average 'uncomfortable distance' score.

For the gap acceptance task, participants watched 24 clips of a car positioned at a junction waiting to turn left into the flow of traffic. Their view was as if they were sitting in the driver's seat at the junction, looking at the traffic approaching from the right. They were asked to record whether they would pull into specific gaps announced by the experimenter by circling either 'yes' or 'no' on a response sheet, depending on their decision. Their gap acceptance score was the total of all 'yes' responses.

Participants were asked to respond via the response button for the hazard perception task. Again they saw video footage of a driver's-eye view of the road through the windscreen and were simply asked to press the button once whenever they saw anything happening on the video which they considered to be hazardous. Within the video footage there were eight
specific hazards which discretely triggered a timer - the computer recorded the time taken from when the hazard appeared (and started the clock) to the time when each participant responded by pressing his / her response button. If the participant missed the hazard (ie didn't respond) then they were given a maximum score for that hazard. Response times were averaged over the eight scenes to give an overall mean hazard perception score.

QUESTIONNAIRES

As well as the video measures, both groups were also asked to complete a series of questionnaires. These included the questionnaire of speeding (West, et al,1993), the eight-item violations sub-scale from the driver behaviour questionnaire (Reason, et al, 1990), West's attitudes to driving questionnaire (1991) and his mild social deviance questionnaire (1993). In order to measure sensation seeking the shortened version of Zuckerman's Sensation Seeking Questionnaire (Kraft and Rise, 1994) was used. Participants were also asked to report whether or not they had driven after using different types of illegal drugs, how many units of alcohol they were prepared to drink / had actually drunk before driving and how many hours they would be prepared to drive / had driven without a break (McKenna, et al, 1998). Participants were also asked to provide demographic details concerning age, gender and details of driving history.

Responses from all participants were anonymous - individuals were given participant numbers which allowed matching of data collected from both questionnaire and video.

Those individuals who attended the speed awareness course (the rehabilitation group) also took part in a discussion about the impact that losing their driving licence would have on their day-to-day lives.

Results

While the sample of drivers stopped by the police is relatively small the age distribution is worth examining. In particular only 5 per cent of the drivers were aged 20 or under. Comparisons were made between the control group and the rehabilitation group on a number of factors:

SPEED

It was found that there was a significant difference between the control group and the rehabilitation group using both the West self-report measure (t(139) = 2.16, p = .032) and the video measure (t (141) =5.68, p <.001). In both cases the rehabilitation group were indicating slower speeds.

CLOSE FOLLOWING

In assessing normal following distance it was found that there was no significant difference between the rehabilitation group and the control group (t(140) = .27, p = .79). However, in assessing the distance at which drivers felt uncomfortable there was a significant difference (t(140) = 2.1, p = .039) indicating that the rehabilitation group felt uncomfortable at a closer distance.
GAP ACCEPTANCE

There was no significant difference between the rehabilitation group and the control group in the number of gaps accepted when emerging from a junction ($t(141) = 1.81, p = .073$).

HAZARD PERCEPTION

There was no significant difference between the rehabilitation group and the control group in the time taken to detect hazards ($t(139) = .586, p = .559$).

VIOLATIONS

There was no significant difference between the rehabilitation group and the control group in the number of violations reported on the Manchester scale ($t(139) = .726, p = .469$)

FATIGUE

There was no significant difference between the rehabilitation group and the control group in either the number of hours people are prepared to drive without a break ($t(135) = 1.31, p = .192$) or in the number of hours that they have actually driven without a break ($t(137) = .02, p = .982$).

ATTITUDES TO DRIVING

There was no significant difference between the rehabilitation group and the control group in their attitudes to driving using the West questionnaire ($t(140) = .152, p = .879$).

MILD SOCIAL DEVIANCE

There was a significant difference between the rehabilitation group and the control group in their antisocial tendencies as measured by West's questionnaire ($t(139) = 5.14, p < .001$). This difference was such that the rehabilitation group expressed fewer antisocial tendencies.

ALCOHOL

There was a marginal difference between the rehabilitation group and the control group in the number of units of alcohol that they were prepared to drink before driving ($t(141) = 1.916, p = .057$), with the rehabilitation group being prepared to drink less. There was a significant difference between the rehabilitation group and the control group in the number of units of alcohol that they had actually drunk prior to driving ($t(141) = 2.07, p = .04$). The rehabilitation group reported that they had drunk less than the control group.

ILLEGAL DRUGS

There was a significant difference between the rehabilitation group and the control group in the number of illegal drugs they had taken while driving ($t(141) = 2.5, p = .013$), indicating that the rehabilitation group had taken more illegal drugs.

MOTIVATION FOR ATTENDING THE SPEED AWARENESS COURSE

Drivers in the rehabilitation group were asked to rate their motivation for attending the course in order to avoid the standard fine and the standard three points penalty. A paired-samples $t$-test showed that there was a significant difference in their levels of motivation: drivers in this
group were more strongly motivated to avoid the points than the fine \( t(67) = 2.923, p = .005 \).

It should be noted that in making the above comparisons no account was taken for the number of comparisons made. If this is done then the \( p \) value that should be considered for significance would be .004, which in turn would suggest that there was relatively little difference between the groups.

**IS SPEED CHOICE AN OUTLET FOR ANTISOCIAL TENDENCIES?**

In order to address the above question the correlations between West's measure of antisocial tendencies and two measures of speed choice were computed. The relationship with more conventional measures of antisocial behaviour such as drink-driving and violations was included for comparison purposes. In addition, in order to compare the magnitude of the relationships it was possible to look at one measure that is generally cited as being related to speed choice: that is sensation seeking. The drink-drive measure is the maximum number of units that the driver has drunk before driving. The violation measure is from the Manchester violations scale but includes only those items unrelated to speed, ie the questions concerned with drink-driving, red-light running and disliking specific groups of drivers. The relationships are presented in Table 1. It can be seen that the measure of antisocial tendencies does correlate with speed choice and that it does so at about the same level as other antisocial activities. As noted Table 1 also includes relationships with sensation seeking. The point that is worth noting here is that sensation seeking does not show higher correlations with speed than antisocial tendencies.

Table 1: Relationships with antisocial tendencies and sensation seeking for the rehabilitation group

<table>
<thead>
<tr>
<th></th>
<th>Speed (video)</th>
<th>Speed (quest)</th>
<th>Drink-drive</th>
<th>Violations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.002</td>
<td>.020</td>
<td>.360</td>
<td>.000</td>
</tr>
<tr>
<td>(n = 117)</td>
<td>(n = 117)</td>
<td>(n = 118)</td>
<td>(n = 118)</td>
<td></td>
</tr>
<tr>
<td>Sensation seeking</td>
<td>.168</td>
<td>.173</td>
<td>.300</td>
<td>.156</td>
</tr>
<tr>
<td></td>
<td>.070</td>
<td>.065</td>
<td>.001</td>
<td>.097</td>
</tr>
<tr>
<td>(n = 115)</td>
<td>(n = 115)</td>
<td>(n = 116)</td>
<td>(n = 117)</td>
<td></td>
</tr>
</tbody>
</table>

In order to cross-validate the relationships outlined in Table 1 the same relationships were computed in the control group, which had the advantage of a larger sample. Table 2 presents these correlations.

Table 2: Relationships with antisocial tendencies and sensation seeking for the control group

<table>
<thead>
<tr>
<th></th>
<th>Speed (video)</th>
<th>Speed (quest)</th>
<th>Drink-drive</th>
<th>Violations</th>
</tr>
</thead>
</table>
Once again it can be seen that the measure of antisocial tendencies does correlate with speed choice and that it does so at about the same level as with other antisocial activities. As before it can also be seen that sensation seeking does not show higher correlations with speed than the antisocial tendencies.

**INTENTION TO CHANGE**

Drivers were asked whether they intended to change their speed in the future. They recorded this intention by indicating the extent to which they intended to drive faster or slower or indeed to make no change in their speed. In fact only about 2 per cent indicated that they would either not change their speed or that they would, in fact, go faster. A question then arises as to which individuals are more or less likely to change their speed. This poses an interesting question with reference to those who indicate that they choose faster speeds versus those who indicate that they choose slower speeds. It might be anticipated either that those who choose faster speeds have the greatest opportunity to reduce their speed and will express their intentions to do so or alternatively that those who most need to change their speed (the fastest group) may be the least motivated to do so. Table 3 indicates the correlation between speed choice and intention to change.

**Table 3: Relationships between speed choice and intentions to change speed in the future (rehabilitation group)**

<table>
<thead>
<tr>
<th>Intention to change</th>
<th>Speed (video)</th>
<th>Speed (quest)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.600</td>
<td>.210</td>
</tr>
<tr>
<td></td>
<td>.000</td>
<td>.077</td>
</tr>
<tr>
<td>(n = 74)</td>
<td>(n = 72)</td>
<td></td>
</tr>
</tbody>
</table>

The direction of the relationship is that those who choose faster speeds indicate less intention to reduce their speed. The particularly high relationship with video speed is partly produced by one person. The correlation reduces to .4 when this person is eliminated.
Discussion

In considering the overall differences between the rehabilitation group and the control group there is no obvious and clear cut interpretation to be made. There is, for example, relatively little evidence to support the view that the rehabilitation group is more dangerous or deviant than the control group. If anything the rehabilitation group looked, on balance, as if they may even have fewer dangerous tendencies; for example, they choose significantly slower speeds. Of course, this may be a social desirability effect. In other words the group stopped by the police may be most inclined to present a positive picture of themselves. There are a couple of factors that do not sit comfortably with this interpretation. The first is that it was made clear throughout the evening that there was no interest in, nor mechanism for, identifying individuals. In addition, if a general social desirability effect were in operation then the rehabilitation group should also present themselves in a positive light on other measures such as violations, attitudes to driving, drink-driving and antisocial tendencies. Support for this social desirability explanation can indeed be found in the results of analysis of antisocial tendencies and, to a lesser extent, in the drink-drive measures. However, there is no support for this explanation from attitudes to driving or violations. The evidence from taking illegal drugs and driving actually runs counter to the social desirability explanation - the rehabilitation group report taking more illegal drugs and driving.

An alternative interpretation of the speed effect emerged in discussions with the rehabilitation group. Several drivers in these discussions reported that they were - now - much more aware of their speed and were more careful in watching their speedometer. It may be that, at the time of testing, the drivers in the rehabilitation group were more speed aware than those in the control group. We have no independent evidence to support or refute this possibility.

In answer to the question posed in the title of this paper there is not much evidence to support the possibility that the individuals within the rehabilitation group are much more deviant than the rest of us. One uncomfortable implication of this might be that we have a massive problem on our hands in that what distinguishes those who have been convicted from those who have not is simply the act of being caught. Those who have not been convicted have not yet been caught. This may mean that trying to persuade people that speeding is antisocial may be extremely difficult. One individual on the course pointed out that he was simply among the majority of people who break the speed limit. Perhaps the drink-driving campaigns were successful because in the end they persuaded
people that drinking and driving is antisocial. The task involved in persuading people that speeding is antisocial may be rather more substantial.

Even though the majority of drivers do break the speed limit this does not mean that there is no case to be made in attempting to link antisocial tendencies and speeding. Indeed, the results presented here indicate that there is a significant relationship between antisocial tendencies and speeding such that those higher in antisocial tendencies were choosing faster speeds. It could, therefore, be argued that there is a case to be made for emphasising the antisocial nature of speeding. An empirical as opposed to a moral argument can be presented indicating that those who choose faster speeds tend to be more antisocial. In assessing the magnitude of this relationship it would appear that it is comparable with the relationship between speed and sensation seeking. This conclusion might be challenged on the basis that in this particular age group sensation seeking would not be high and that the associations between these factors might be greater for younger groups who are higher in sensation seeking. However, exactly the same argument could be presented for antisocial tendencies: these too decrease with age and likewise the relationship with speed choice might be stronger in younger groups. The age observed in the rehabilitation group is more likely to reflect the population of speeding drivers and it is relationships observed in this age group that are of most concern. Overall, if we think of speed as an outlet for sensation seeking then it seems clear that it also is an outlet for antisocial tendencies.

Of course one of the key issues is whether speed awareness courses would be effective in changing behaviour. This study was not designed to answer this question but some relevant information has come to light. We asked the rehabilitation group if, in the future, they would be likely to change their speed or not and, if so, whether they would be more likely to go faster or slower than previously. The logic of this question is that if we fail to influence their intentions then it is likely that the rehabilitation has failed. Even if we succeed in changing intentions this does not necessarily mean that changed intentions will be translated into changed behaviour. In other words this question may inform us more about failure than success. As noted, it was found that the majority of drivers in the rehabilitation group indicated that they intended to drive more slowly in future. In considering who was least likely to intend to reduce their speed it was found that it was those who chose faster speeds initially. This result invites the argument that, if those who are travelling at faster speeds are less likely to benefit from such a course, then perhaps they should not be offered it.
In responding to the question about what motivated them to attend the speed awareness course, drivers were asked to rate the importance of avoiding fines and penalty points. It was found that people rated the avoidance of penalty points as more important than the avoidance of fines and, indeed, the effect of accumulating points was one which often occurred during the discussion.

The issues discussed above show that there is no simple way to differentiate the 'speeding driver' from the rest of the driving population. The age distribution of the rehabilitation group also indicates that the sample is not unusual. However, there are anecdotal biases about people who speed. For example, one stereotype of the speeding driver is 'the boy racer'. There is relatively little empirical evidence to suggest that this cohort would represent a significant proportion of the group stopped by the police. Of course this is an exposure issue. There are fewer younger drivers than older drivers in the driving population: they do less mileage so their opportunity to be caught is less. This is not to say that young drivers are not a problem. They are a problem. However, the design of rehabilitation interventions to reduce speeding needs to be informed by the much wider demographic range of the speeding population as a whole. The stereotypical young male driver is not liable to be a major part of this group; instead, the age range will be wide with the majority middle-aged and both male and female drivers will be fairly evenly represented. Perhaps what does differentiate drivers regarding their intentions to speed is the extent to which they do exceed statutory speed limits. The results of this study suggest that there is a positive association between speed choice and antisocial tendencies - it may be that, in order to reduce speeding behaviour effectively, these two factors need to be looked at in combination.

Conclusion

In implementing many safety measures we often hope that we are in a position in which we can do some good but it is not likely that we will do much harm. It is not entirely clear whether this is the case for speed awareness courses. If penalty points and fines influence behaviour in a desirable direction then it could be that taking them away may have a negative impact on safety. In turn this could mean that it is critical that speed awareness courses have a positive impact because the alternative may not be 'no harm done'. Consider the case of antisocial individuals. By definition their concern is self-interest. A speed awareness course is of great advantage to them (as opposed to an accumulating points system) because it keeps them away from a position where their self-interest is threatened (losing their licence). A speed awareness course will
usually include a discussion of the benefits to vulnerable road users (eg pedestrians) of even small changes in speed, but benefits to others rather than oneself are not likely to be of much influence in behavioural change. For these individuals a points accumulation system that approaches loss of licence may capture their self-interest. In other words important questions remain about who should be invited on to speed awareness courses and under what conditions. The consequences of ineffective courses could be considerable.

References


10 From behavioural adaptation to safety modelling: Predicting the safety impacts of new technologies

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Introduction

Car manufacturers have recently introduced into the market a system that can automatically activate vehicle control independently of the driver. This system is adaptive cruise control (ACC), the speed and headway control system, which is being offered as an option by Jaguar and Mercedes-Benz. Equipped cars can activate the throttle and even the brakes without the driver touching the pedals, in response to the acceleration or deceleration of the preceding vehicle. ACC is just the first of many such systems, which are likely to take over increasing aspects of vehicle control, both longitudinal and lateral (Zwaneveld et al, 1999; Bastiaensen and De Hoog, 2001). This paper addresses how information on driver behaviour with such systems can be used to make predictions of the safety impact of those systems.

Behavioural adaptation

The new vehicle control systems have direct effects on driver behaviour through system parameters. Thus with adaptive cruise control the minimum time headway permitted by the vehicle manufacturer will prevent the driver from adopting a smaller headway without switching the system off or into standby. Similarly, with intelligent speed adaptation, maximum vehicle speed will, with a mandatory version, be set by the system. But there is overwhelming evidence that, beyond these direct engineering effects of the systems, drivers engage in further, indirect modifications of their behaviours when using these new devices. These indirect changes in behaviour are often termed 'behavioural adaptations'.

The standard definition of behavioural adaptation from an OECD report of 1990 is: 'Behavioural adaptations are those behaviours which may occur following the introduction of changes to the road-vehicle-user system and which are not intended by the initiators of the change.' The report continues: 'For behavioural adaptation to occur, it must be assumed that there is feedback to road users, that they can perceive the feedback (but not necessarily consciously), that road users have the ability to change their behaviour, and that they have the motivation to change their behaviour' (OECD, 1990). This further explanation makes the proposed mechanism for behavioural adaptation very close to the process outlined in Wilde (1982) and shown in Figure 1.

Figure 1: Risk homeostasis process (Wilde, 1982)
Mechanics or behavioural adaptation

Almost all the models of how behavioural adaptation works going back to Peltzman (1975) are, as might be expected, behavioural in nature. This may appear tautological, but it can be argued that this concentration on behavioural aspects leaves out some crucial dimensions of response, which may be highly relevant to new in-vehicle systems. One exception to the general rule of seeing adaptation as a purely behavioural process is the threat avoidance model of Fuller (1984), which sees the process as one of conditioned learning. Grayson (1996) has proposed a new definition for the phenomenon, seeking to bypass the debate about process. That definition is 'adverse behavioural consequences'. But that still begs the question about mechanisms.

More specifically, what has tended to be omitted (or dealt with completely separately) in the debate about whether there are behavioural adaptations to new in-vehicle systems is the human factors aspects. These include the well-known effects of workload, leading at one end of the spectrum to underload, low arousal and loss of situation awareness (Endsley, 1995) and at the other end of the spectrum to overload and stress leading to poor performance. Perhaps the most dangerous situation is low workload followed by a critical high-workload event, which could occur if a driver assistance system is not able to cope with a situation and therefore driver intervention is required. Bainbridge (1987) has pointed to such automation-induced complacency as one of the 'ironies of automation'.

Another type of error is that drivers may misunderstand the performance envelope of the system. Drivers will not necessarily understand the limitations of the technologies underlying an in-vehicle system or the constraints imposed by the designers on system operation. This could arise with an adaptive cruise control. After experiencing the fact that the system is capable of considerable deceleration (some ACCs have braking capability that encompasses 80 or 90 per cent of the distribution of driver braking severity), drivers may interpret an ACC as a collision avoidance system. As a result, drivers may tend to be slow in resuming manual control when a critical situation does develop, anticipating that the ACC will be able to cope. This is what Fancher and Ervin (1998) have termed the 'authority' issue - how much authority does the ACC have over the operation of the vehicle? Mode errors by the driver may arise: the driver may not be aware of whether the ACC is enabled or disabled, is in 'pure' cruise control mode or in headway mode. After leaving a motorway the driver may forget that the ACC is still on.

With driver assistance systems that intervene in or take over part of vehicle control, one part of the driving task is now monitoring the operation of the system rather than interacting
directly with the vehicle. This interaction will take place both directly through whatever interface is provided by the car manufacturer, and indirectly through sensing system operation. One crucial aspect of such monitoring is the detection of faults and failures in the system. Bainbridge (1987) has pointed out the poor performance of humans in monitoring tasks.

Equally, mode errors of the type that have been reported in aviation human factors with complex automated flight systems may arise: the driver may not be aware of whether the system is enabled or disabled, or in which mode it is currently operating. This could mean that the driver's intuitive prediction of how the system will function may be inaccurate.

System designers may use an in-vehicle display to help overcome such problems by imparting information on system status, operation and mode to the driver. But that in turn will bring its own set of problems in the form of visual distraction which may encourage drivers to take their eyes off the road and instead look at the in-vehicle display (Parkes, et al, 1991; Wierwille and Tijerina, 1998).

The new systems

We have just undergone a revolution in driving. Adaptive cruise control (ACC) is now on the market in Europe - it is available as an option on at least one Jaguar model and is predicted to be available shortly from a number of manufacturers. In Japan, ACC is already fairly commonplace. Traditional cruise control, which rather crudely maintains a driver-set speed, is not really viable on the crowded roads of Europe or East Asia, since it is only operable in relatively free-flow traffic conditions. ACC extends traditional cruise control by adding a headway function, so that the vehicle accelerates to and keeps its set speed unless time headway goes below a preset minimum, in which case the minimum headway is maintained by automatically reducing speed. Acceleration of the lead car is mimicked up to the maximum set speed. The function of ACC is to replace the driver in the task of car following, particularly on motorways and other high-speed roads.

ACC is revolutionary because this is the first time a major part of the driving task has been replaced by an automated system. With ACC in operation, the driver's task becomes lateral control of the vehicle, monitoring the functioning of the ACC system and resuming manual control in emergencies. And for the car manufacturers ACC is just the first step in a planned path towards fully automated driving, at least on some roads and in some situations (Zwaneveld et al, 1999). ACC will be supplemented by collision avoidance in longitudinal control and then by various warning and assistance systems for lateral control, including lane changes. Once a vehicle is capable of making autonomous decisions for both longitudinal and lateral control, then fully automated driving can become practicable.

How can we predict the safety impacts of these systems?

There are a number of alternative ways in which the safety changes brought about by the introduction of new in-vehicle systems have been modelled. Various alternatives are possible, but there are major drawbacks to all the current techniques.

ENGINEERING MODELS AT A MACRO LEVEL

'Engineering' models take the functional definition of a new system and deduce the predicted changes in behaviour from that functional definition. In the case of intelligent speed
adaptation, researchers have predicted the impact on accidents by using known empirical relationships between speed and accidents. Here the assumptions are that:

- flows remain the same;
- all other network conditions remain the same, eg signal timings;
- there is no behavioural adaptation to the introduction of ISA and no human factors impact of ISA.

It is then possible to apply a macro modelling approach which estimates changes in the distribution of speed and perhaps speed variance by road type. Using the empirical relationships between speed and accidents (or additionally between speed variance and accidents), researchers have predicted the impact of a reduction in speed on accident numbers and/or severity.

This was the approach applied for the safety predictions of the impact of ISA, made by external vehicle speed control (Carsten and Tate, 2000). The assumption here was that an advisory ISA system which provides a warning only would shift the normal distribution of speed downwards, but that the shape of the speed distribution would remain the same. A mandatory ISA would have a different effect - it would transform the speed distribution on a road in such a way that the speed distribution would be truncated, with no vehicles exceeding the speed limit. Three different ways in which speed limits could be applied in an ISA implementation were hypothesised. They could be fixed, ie identical to current posted speed limits; they could be variable, whereby there would be lower limits at certain locations in the network such as sharp curves; and they could additionally be dynamic, whereby speed limits would be lowered in the dark or in bad weather to make conditions as safe as in daylight or normal weather. Table 1 shows the resulting predictions.

**Table 1: Best estimates of accident savings by ISA type and by severity (from Carsten and Tate, 2000)**

<table>
<thead>
<tr>
<th>System type</th>
<th>Speed limit type</th>
<th>Best estimate of injury accident reduction</th>
<th>Best estimate of fatal and serious accident reduction</th>
<th>Best estimate of fatal accident reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Advisory</td>
<td>Fixed</td>
<td>10</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Variable</td>
<td>10</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Dynamic</td>
<td>13</td>
<td>18</td>
<td>24</td>
</tr>
<tr>
<td>Driver Select</td>
<td>Fixed</td>
<td>10</td>
<td>15</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Variable</td>
<td>11</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Dynamic</td>
<td>18</td>
<td>26</td>
<td>32</td>
</tr>
<tr>
<td>Mandatory</td>
<td>Fixed</td>
<td>20</td>
<td>29</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Variable</td>
<td>22</td>
<td>31</td>
<td>39</td>
</tr>
</tbody>
</table>
It is important to note that these predictions do not take into account any behavioural adaptation with ISA, nor has any sensitivity testing been conducted to investigate to what extent the results would be affected by changes in behaviour with ISA. In a sense, then, ISA is a special case among intelligent transport systems. Since the major effect of ISA is on speed, it is possible to apply the macro approach to safety prediction with some confidence, drawing on the empirically derived relationships between changes in speed and changes in accident frequency. But even for ISA, this leaves open the question of how the other observed effects of ISA (Carsten, et al, 1999; Comte, 2000; Carsten, 2000; Carsten and Comte, 2000) - on car following, on gap acceptance - and the observed pattern of differential system use might affect safety.

MICROSIMULATION TRAFFIC MODELS

There are a large number of microsimulation traffic models on the market. Examples include AIMSUN2, HUTSIM, INTEGRATION and DRACULA. Microsimulation models use a simplified representation of driver behaviour and vehicle capability to create a picture of vehicle operation. Typical driver parameters are desired speed, desired headway, reaction time, gap acceptance for a given situation such as a minor-into-major merging manoeuvre, propensity to change lane when obstructed, and propensity to overtake when obstructed. For the vehicle, parameters might be maximum speed, braking (deceleration capability), and maximum acceleration. Values for these parameters are drawn from a distribution, often a normal distribution with a certain minimum and a certain maximum value. Thus a model may have some 'aggressive' drivers with a high value for desired speed, a short value for desired headway, small values for gap acceptance and a high propensity to select the fast lane and to overtake. Other drivers will have the opposite characteristics. Behaviour can be constant, ie desired speed on 30mph roads is always the same for a given vehicle and driver, or can be made variable.

It is vitally important to bear in mind the purpose of microsimulation models as they currently exist. Their aim is mainly to represent typical or normal behaviour in a network, so that distributions are deliberately constrained so that collisions do not take place. This is not a problem from the point of view of predicting typical journey time, junction capacity, link capacity, fuel consumption, route choice, etc, since reasonably accurate prediction of these depends on 'normal' traffic behaviour. It is not even a problem for studying incidents from a traffic perspective, since an incident can be
artificially created and then traffic response to that incident examined.

Safety problems, however, are caused by abnormal behaviour - for example deliberate violations, errors such as perception errors or interpretation errors, or distraction resulting in delayed reaction. Such behaviours are both unusual and rare. In standard traffic modelling, they are deliberately excluded (behaviour is constrained so as not to allow them): no vehicles violate red lights, no drivers misjudge gaps, and no drivers fail to see the other vehicle(s) approaching at a junction. Similarly, no vehicles are driven too fast on curves and consequently lose control. Indeed the network may not even have curve radius coded, and vehicle dynamics in a curve are probably not modelled.

INCIDENT MODELS

These models have been applied to ACC, once again applying an engineering approach, but now using a microsimulation approach with individual vehicles being modelled. The assumptions concern both speed and headway. In terms of speed, the hypothesis is that speeds will become more homogeneous both for an equipped vehicle (the system will control speed with less variation than a driver is able to do) and in a given flow of traffic where the proportion of ACC-equipped vehicles is high. In terms of headway, the hypothesis is that headways will become more homogeneous (because they are controlled with greater precision by the system than by a manual driver) and that very short headways will perhaps be reduced (provide they are prevented by system design). Both the speed and headway effects imply smoother and therefore safer traffic flows. These relationships between engineering specification and predicted safety outcome can be modelled via microsimulation.

Thus Brackstone et al (1999) modelled the safety effects of ACC by simulating a platoon of 10 cars and examining the consequence of the lead vehicle braking sharply. ACC time headway was varied at two levels, ACC speed was set at either 60mph or 70mph, ACC deceleration had three levels, and the percentage of vehicle with ACC was set at 10 per cent or 20 per cent. For each combination, the model was run 200 times. The assumption was that initially the ACC on an equipped car would intervene, followed by a normal driver intervention. Perhaps not surprisingly in view of the model assumptions, the findings were that ACC reduced the probability of collision.

A similar approach was adopted by Sala and Mussone (1999) in an investigation of a collision avoidance system (CAS). Here the platoon composition was obtained for real motorway data
for a three-lane motorway. Again the lead vehicle braked sharply and the number of collisions was the major output. The percentage of vehicles equipped with the CAS was 0 per cent, 10 per cent, 25 per cent or 50 per cent. Large increases in the number of collisions were predicted with increasing system penetration.

There are two important points about this type of microsimulation:

- it does not predict changes in safety across a network but merely changes in safety for a given scenario;
- it does not take into account any behavioural or human factors effects of the system on driver performance, for example changes in lane position or headway choice with ACC or changes in situation awareness with both ACC and CAS.

THE APPLICATION OF NETWORK MICROSIMULATION TO SAFETY

Microsimulation of traffic networks has been applied to a limited extent for predicting safety changes with driver assistance systems. Thus the INTEGRATION model was used in the evaluation of the Travteck field trial of dynamic route guidance in Orlando, Florida (Van Aerde and Rakha, 1996). But in actual fact, the safety procedure here was not to have the model itself produce outputs of accidents or incidents, but rather to use the predictions of route choice made by the model and then apply post hoc safety factors for each road class. In addition an adjustment factor was applied, also post hoc, for 'gadget' effects, ie distraction.

Another network microsimulation did use actual collisions. Kosonen (1999) studied the effect of a combined ACC and ISA system on collisions with pedestrians for part of Gothenburg. Pedestrians were simulated as randomly crossing the streets without paying attention to the traffic. Penetration of the systems was 0 per cent, 20 per cent, 50 per cent, 80 per cent and 99 per cent. Severe accidents, defined as collisions at over 40kmh, were significantly reduced by the system. But once again, the finding, although interesting, cannot be translated into a predicted change in accidents for the network. It is not even possible to make a prediction of the overall effect on collisions with pedestrians because of the rather simple scenario used.

Network microsimulation of safety

Network microsimulation models offer a very attractive route to the prediction of safety with new driver assistance systems.
They have the necessary properties of behavioural rules which can be altered initially to represent baseline behaviour that includes abnormal or unsafe behaviour, and subsequently be made to represent behaviours with one or more new systems, using data from empirical observations. The safety output could be incidents (near misses or conflicts) or accidents. Conflicts have the advantage that they would be produced in far larger numbers and thus have greater statistical reliability and make fewer demands in terms of model run times. But there would be a significant cost to using conflicts as predictors, in that no validated conflict technique has yet been developed for high-speed roads or even for urban links.

Considerable thought would have to given as to how to represent driver errors and violations. In-depth accident data can provide a useful source of error patterns, but, as has often been noted, accidents are complex, multi-factor events, and a behavioural model would have to represent a larger variety of factors, some of which may be random, but others of which (eg fatigue and drink-driving) are by no means random. Violations are very definitely not random and violation-prone drivers would need to be represented.

A very extensive calibration effort would be required to get models to produce reliable patterns of behaviour and reliable safety outputs. Automatic data collection would help for collecting behavioural data. Accident distributions could be used to calibrate and validate the incident or conflict patterns.

Perhaps the greatest advantage of developing full network predictions of safety, with unsafe behaviour and safety outputs built directly into a microsimulation model, would be that such a model would be capable of taking into account varied responses to a system (eg the simultaneous choice of both higher speeds and shorter headways) and would even be able to represent different systems operating together in the same vehicle or various vehicles having different systems. It would also be possible to study the effects on safety of system penetration levels into the vehicle fleet.

Conclusions

Microsimulation models incorporating both behavioural and human factors responses to new in-vehicle systems have the potential to predict overall changes in safety across a network for a given system or set of systems. This would substantially improve decision-making about alternative implementations. But there are some formidable tasks to be achieved to realise such a capability. At present most microsimulation models are designed deliberately to outlaw the representation of unsafe behaviour or inadequate response. As a result, vehicle do not
crash nor do they tend to come into conflict. The first step is therefore to enhance the models so that they include unsafe behaviours and errors. It should be possible to calibrate the distribution of errors and violations against observed patterns in the real road network, acquired with instrumented vehicles and by automatic roadside observation. Motorways may be a good starting point for such work because of the relative simplicity of the traffic conditions on them. The safety outputs of such a model could in theory be either accidents or conflicts, but conflicts may be the more attractive option. Once again, extensive calibration and validation will be required. Finally, the models will need to be fed with the behaviours observed in laboratory and real-road trials with new systems. It will not be possible to skip this step, because the adaptations to and human factors problems with new systems are not reliably predictable. They can, however, be hypothesised, so that one use of the modelling capability could be sensitivity testing to hypothesised responses. This could be done even before empirical behavioural data were available. All of this would provide a proper set of tools for predicting the safety impacts of systems which have complex and often subtle effects on their users.

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11 Developing a psychological model of the driver

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Introduction to driving automation

Adaptive cruise control (ACC) heralds a new generation of vehicle automation (Nilsson, 1995). ACC controls both speed and headway of the vehicle, slowing the vehicle down when presented with an obstacle and speeding it up when the obstacle is removed. In this way ACC differs from traditional cruise control (CC) systems. In traditional cruise control, the system relieves the driver of foot control of the accelerator only (i.e., relieving the driver of some physical workload), whereas ACC relieves the driver of some of the decision-making elements of the task, such as deciding to brake or accelerate (i.e., relieving the driver of some mental workload), as well as the physical demands of accelerator control (Stanton, et al., 1997). Potentially, then, ACC is a welcome additional vehicle system that will add comfort and convenience to the driver. Certain psychological issues do arise, however, when considering any form of automation and these need to be properly addressed to improve overall system performance. It is envisaged that although the ACC system will behave in exactly the manner prescribed by the designers and programmers, this may lead to some scenarios in which the driver's perception of the situation is at odds with the system operation (Stanton and Marsden, 1996). From a review of the literature, Stanton and Young (1998) argue that the interdependency between psychological concepts is underrepresented. This study plans to investigate the seven main psychological issues in detail. First is the issue of locus of control, the extent to which removal of control from the driver affects performance of the vehicle. Second is the issue of trust that the driver has in the automated systems. Third is the situational awareness of the driver about the operational status of the technological system and the driving context. Fourth, and connected to the third issue, is the issue of mental representation that the driver builds up of the automated systems. Fifth is the issue of mental and physical workload associated with automation. Sixth is the issue of feedback, comparing human and automated intervention. Finally, driver stress and its implications for vehicle automation are considered.

There are some obvious (and some not-so-obvious) interrelations between the variables. From the literature, it would seem that mental workload plays a central role in the relationship. For instance, it is apparent that high workload in the form of traffic congestion can increase stress (Wilson and Rajan, 1995), but there is some evidence that this relationship is bidirectional. Matthews and Desmond (1995; 1997) provide evidence for the mechanism behind this relationship, and from this there are two novel yet logical conclusions relating workload to stress. The first is that stress can affect performance in low as well as high workload conditions. The second is that the effort involved in coping with stress actually adds to the task demands.

The question of whether feedback affects mental workload is contentious. Becker, et al., (1995) found that performance feedback generally lowered mental workload in a monitoring task. However, the results of Fairclough et al., (1997) suggest that time headway feedback has no effect on workload in a car-following scenario. Either way, any relationship here is obviously unidirectional, and the results of the present study will hopefully shed some light on it. Workload has also been known to affect situation awareness (SA) (Endsley, 1995; Jones and Endsley, 1996), but there is no evidence that this relationship is reversible. High
workload is detrimental to SA, as attentional resources are primarily engaged in maintaining performance rather than SA. Indeed, workload is evidently a causal factor in approximately 30 per cent of SA errors.

Situation awareness is also related to some of the other factors in this review. Stress weakens level 1 SA (perception) by causing attentional narrowing (Endsley, 1995). Trust can also affect SA, as Jones and Endsley (1996) found that 2.7 per cent of level 1 SA errors were due to overreliance on automation. Finally, as has been stated previously, SA is highly related to mental models theory. Endsley (1995) sees SA as a situation model, or a context-specific mental model. This is supported by evidence from Jones and Endsley (1996) that 6.9 per cent of level 2 SA errors, and 0.4 per cent of level 3 SA errors are due to poor mental models.

All of these factors are well established in the psychological literature but have yet to be fully explored with respect to vehicle automation (Stanton and Young, 1998).

Experimental method
The experimental method used in the main study is as follows.

PARTICIPANTS
The study employed 110 participants. Participants were selected to reflect the age and gender of the driving population at large in the UK. Forty-two of the participants were female. The average age was 33.6 years (minimum 18 years, maximum 73 years, standard deviation 12.7 years). The mean driving distance per annum of participants was 10,500 miles (standard deviation 6,600 miles). Participants were randomly assigned to experimental conditions to match for age and gender.

DESIGN
There were three independent variables (automation, workload and feedback), three dependent variables associated with driving behaviour (speed, lateral position on road and headway) and six dependent variables associated with the psychology of the driver (locus of control, trust, workload, stress, mental models and situational awareness). The three levels of workload were determined by manipulating the throughput of vehicles per hour (VPH) as follows: 800 VPH (low), 1,600 VPH (medium) and 2,400 VPH (high). The three levels of feedback were manipulated by the degree of information provided by the ACC system as follows: auditory feedback only (low), auditory feedback plus standard messages on ACC display embedded in the instrument panel (medium), and auditory feedback plus standard messages on ACC display embedded in the instrument panel together with a head-up display of the same information and a headway separation chevron (high).

PROCEDURE
The experimental procedure was as follows.

- Participants were recruited via local media. On agreeing to participate, a time for the study was agreed and participants met the experimenter at his office.
- On arrival, participants were escorted to the driving simulator laboratory.
- Participants were briefed immediately prior to the study as follows: "This study is investigating a new vehicle technology called adaptive cruise control. In a moment, I will ask
you to drive a practice run in the simulator, followed by two test runs. There are some
questionnaires to be completed before and after these runs. At the end of the study, you will
receive £10 for your participation. You are free to withdraw from the study at any time.
Unless you have any objections about the study, would you please sign this consent form."

- The participant then signed the consent form.
- Then the participant completed the three pre-trial questionnaires on a computer. These
  questionnaires were the DSSQ, Rotters I-E scales and the MDIE.
- The participant was then asked to read the ACC manual to familiarise themselves with its
  operation and behaviour.
- When the participant was satisfied that they understood the operation of the ACC system,
  they were allowed to have a practice driving the simulator for five minutes under both ACC
  and manual control.
- Participants who were undertaking the manual drive first had the following instructions: "You
  are on your way to work, which involves a 20-minute motorway drive. You are requested to
  keep your speed as close to 70mph as possible. Other than that you should drive in your
  normal manner."
- Participants who were undertaking the ACC drive first had the following instructions: "You
  are on your way to work, which involves a 20-minute motorway drive. You are requested to
  keep your speed as close to 70mph as possible. You should engage the ACC system as soon
  as possible with a set speed of 70mph and leave it engaged for the remainder of the journey.
  Other than that you should drive in your normal manner."
- After completing each drive, participants completed the NASA-TLX, SART, and DSSQ
  questionnaires on the computer. If they had completed the ACC drive, they also completed
  the mental models questionnaires and the trust questionnaire.
- After both drives, participants were debriefed on the nature of the study and received £10
  payment.

EQUIPMENT

The equipment comprised a driving simulator based on the Jaguar XK8 and a series of tools
to measure the dependent variables. The driving simulator environment is based around a
fixed-based Jaguar XK8. It is a semi-immersive environment, with the emphasis on
psychological and operational fidelity, placing it in the mid-range of driving simulators.
Transducers connected to the steering, brake and accelerator send digital signals to an Acorn
Archimedes RISC PC. Software inside the Acorn interprets the signals to position the driver's
trajectory along the motorway. The driver is presented with a three-lane motorway on a
projection screen viewed through the windscreen of the XK8 via an Epson colour LCD
projection monitor. The simulation is fully interactive: the driver has full vehicle control and
may interact with other vehicles on the road. The data logged include speed, position on the
road, distance from other vehicles, steering wheel and pedal positions, overtakes and
collisions (taken every 0.5 seconds automatically by the simulator software). The ACC
interface comprised a liquid crystal display in the instrument cluster and a set of buttons inset
into the steering wheel. A separate PC was used to drive this interface (an Elenex PC-466/1
and monitor). A Panasonic VCR NV-180 video recorder was used to record each participant's
drive, so that pertinent parts of the driver's interaction with the ACC could be assessed in a
playback session.
The dependent measures were collected using the following tools.

- A multidimensional trust scale based upon Muir (1994).
- The locus of control inventory (LOCI) from Rotter (1966).
- Driving internality-externality (MDIE) scales from Montag and Comrey (1987).
- A subjective, multidimensional, workload scale: the NASA-TLX (Hart and Staveland, 1988).
- Situational awareness rating technique (SART) (Taylor et al, 1995).
- Two questionnaires about ACC operation: a 10-item multiple-choice questionnaire and a series of 'what happens next' scenarios, to which a free-form response is required. These measures were developed by the researchers specifically for this project.
- A post-task verbal protocol was used to assess how well participants were able to explain their actions with ACC in the driving context. A video cassette player (Panasonic VCR NV-180) and monitor (LG 149 colour TV) were used.

Main results

Structural equation modelling techniques were applied to the psychological variables using EQS software on an IBM PC. To test the model the correlations between three indicator variables for each of these constructs were calculated. There are 110 cases with complete data under each of the two conditions. The EQS structural equation program was used to test the fit of the model to a variance/covariance matrix for each condition separately. In this model all the paths are significant at p <.05 and there are no additional paths between the latent variables that significantly improve the fit. The overall model fit is adequate (c2 = 197.34, df =132, p <.001, CFI = 0.901, RMSEA = 0.068 CI.90 0.068 - 0.0.84). Both well-being and mental workload had a significant association with situational awareness. The path coefficients have the same interpretation as standardised regression coefficients. A 1.0 standard deviation increase in well-being is associated with 0.53 standard deviation decrease in situational awareness. The effect of mental workload is slightly less (-0.45) and such that an increase in mental workload is associated with a decrease in situational awareness. Neither locus of control or mental model has a significant association with situational awareness. An external locus of control is associated with increased trust (0.28). An increase in trust is also associated with an increase in situational awareness (0.53). Finally it should be noted that neither well-being nor mental workload have direct influence on trust. Any effects are mediated via situational awareness.

Conclusions

It is fair to say that the structural equation modelling only partially supported the hypothesised psychological model developed on the basis of the literature review. The analysis shows that, in the ACC condition, none of the variance in situational awareness was explained by the driver's mental model. This led to the development of a new model on the basis of the data collected in the main experimental study. Mental workload contributed negatively, such that as workload increased situational awareness decreased. Well-being had a positive relationship: as well-being increased so did situational awareness. Increases in situational awareness and externality (from the locus of control scale) were associated with increases in trust. The use of automation to bring workload down to an optimal level can be
seen to have a positive effect on situational awareness. Similarly, promotion of the well-being of the driver (through improved mood, self-esteem and thinking state) also improves situational awareness. The key to these improvements can, in part, be found in the design of driver interfaces. If drivers find devices difficult or cumbersome to operate then this may well increase their workload and reduce their well-being. Dynamic allocation of headway control under conditions of high workload may also offer the opportunity to optimise the load on the driver.

To conclude, the model presented in the results section seems to suggest that situational awareness, mental workload, driver stress, locus of control and trust play central roles in the psychological model of AC operation. These concepts seem to overshadow mental models, at least as far as the data are concerned. This is at odds with the importance of the concepts as previously developed in the academic and applied research literature. Further research into understanding these findings is being contemplated.

Acknowledgements

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References


12 Driver distraction: A replication and extension of Brown, Tickner & Simmons (1969)

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Abstract

The study reported here replicates and extends a study by Brown et al (1969) in which concurrent performance of a verbal reasoning task was shown to disrupt drivers' ability to judge whether or not the car they were driving would fit through gaps of different widths. In the present study, the test-track-based gap judgement task was again combined with the original verbal reasoning task, but also with a task requiring largely executive (PASAT) or visuo-spatial (imagery-based clock face comparison) processing. Results showed that ability to perform the verbal reasoning and PASAT task was reliably reduced when combined with gap judgement, but effects were largely absent when the secondary task imposed a high degree of visuo-spatial load. Although no effect of concurrent tasks was observed on gap judgement, the results observed are consistent with the original findings, since substantial evidence of performance trade-off was observed.

Introduction

In 1969 Brown and colleagues reported a study which showed that drivers' ability to judge whether the vehicle they were driving could negotiate gaps of different widths was interfered with when they performed a verbal reasoning task. This study is important, not least in that it anticipated a number of important practical and theoretical developments. However, viewed in the light of more than 30 years of subsequent research on cognitive psychology, the study also leaves a number of issues unresolved. The purpose of the present experiment is to attempt to replicate what remains a very important study, and to address some of the outstanding theoretical issues it raises.

The Brown et al (1969) study was among the first to draw attention to the cognitive demands of what turned out to be the in-car telephone. Using a dual-task methodology to measure the 'spare mental capacity' of drivers (see Brown and Poulton, 1961, for an earlier use of similar methodology), Brown and colleagues were able to quantify the decrement in performance on both the driving (ie gap judgement) and telephoning (ie verbal reasoning or 'sentence checking') tasks. The results of the original study showed that drivers accepted more impossible gaps, and rejected more possible gaps, slowed their driving, and were both slower and less accurate on the verbal reasoning task. The obvious implication of these results was that telephoning and a driving task requiring decision-making were incompatible. Brown and colleagues reasoned the results emerged because 'concurrent telephoning produced both a relaxation of criteria' for accepting/ rejecting gaps 'and an impairment of perception' (1969, p. 423). Importantly, although drivers did drive more slowly when telephoning, Brown and colleagues conclude that the 'perceptual-motor skills employed in steering through possible gaps were not reliably affected by telephoning' (p. 423). However, they later add that studies which 'investigate the timing of control skills' are required 'before it could be concluded that these are entirely unaffected' (p. 423). The implications for the design and use of in-car telephones were here for all to see, and in a peer-reviewed academic journal.
These results are also important for theoretical reasons. Firstly, since some aspects of the driving task are interfered with by the concurrent reasoning task, while other aspects are not, the study represents an early demonstration of the fact that driving is not a single simple perceptual-motor task. Instead, any acceptable theory of the driving task requires an account which envisages control of multiple simultaneous task components ranging from simple motor control to complex decision-making (see Groeger, 2000). Secondly, by showing that the verbal reasoning task, which had previously been shown by Baddeley (1986) to be a reliable means of rapidly assessing verbal intelligence, interferes with an aspect of driving it suggests a clear link between cognitive capacity or resources and driving. This in turn raises the possibility that other tasks, which place differential demands on working memory, might disrupt different aspects of driving. Among the difficulties with capitalising on this possibility is uncertainty as to what the verbal reasoning task used by Brown and colleagues actually measures in cognitive terms, and why it should interfere with gap judgement.

When performing the verbal reasoning task participants listen to a sentence of the form 'C is before A', and then have to decide whether two letters heard immediately after the sentence (eg 'AC') are in the order specified in the preceding sentence. As already mentioned, Baddeley (1986) shows that the verbal reasoning task correlates with verbal intelligence, but it has also been reasonably widely used in the working memory literature - although not always as an index of the same aspect of Baddeley's (1986) three-component working memory framework. For example, Farmer et al (1986) show verbal reasoning task performance is disrupted by paced concurrent mouthing of the same syllable (eg 'dah', 'dah', 'dah', etc), but not by a similarly undemanding concurrent motor task (ie paced repeated tapping the corners of a square in a predictable order).

In contrast a 'spatial' reasoning task was found to be disrupted by the concurrent movement task, but not by the concurrent speaking task. This along with other evidence is taken to show that 'spatial' reasoning and motor control rely on similar working memory resources, while the verbal reasoning task requires some verbal memory resource. In Baddeley's working memory theory this verbal resource is referred to as the 'phonological loop', while the spatial memory resource, which is also involved in motor control, is termed the visuo-spatial sketch pad. However, it should also be noted that the verbal reasoning task has also been shown recently to be heavily reliant on the amodal attention system, known in the working memory model as the Central Executive (Baddeley et al., 1998).

In this study Baddeley and colleagues show that ability to perform random movements consistently (paced tapping corners of a square in a random order) is grossly interfered with by having concurrently to perform the verbal reasoning task, and vice versa. The fact that random tapping also requires motor control, raises the possibility that the verbal reasoning task is also being interfered with a more demanding 'spatial' task, contrary to the conclusion reached in the earlier study by Farmer and colleagues (1986). Thus, somewhat confusingly, performance of the verbal reasoning task appears to rely upon two, if not all three, of the key components of working memory identified by Baddeley, but even if it does why should it interfere with drivers' gap judgement, but not perceptual-motor control?

The study reported below addressed a number of possible answers to this question, in addition to seeking to replicate the original finding reported by Brown and colleagues. Firstly, it is possible that performing any difficult task at the same time as gap judgement will result in a performance decrement. In order to address this question the verbal reasoning task, and two other equally difficult tasks were paired with gap judgement. Secondly, since the verbal reasoning task correlates with intelligence, perhaps it is the case
that intelligence and gap judgement are related. In support of this, certain aspects of driving, particularly those requiring initiation of action, have been shown to be both intelligence-related and interfered with by certain secondary tasks (eg Duncan et al 1992) and intelligence and acquisition of driving skills are reliably correlated (see Groeger, 2000). This possibility was addressed by using secondary tasks which load differentially on intelligence. Thirdly, the main hypothesis, that both gap judgement and the verbal reasoning task both rely on the central executive, rather than on the visuo-spatial sketch pad, or phonological loop, was addressed by ensuring that the concurrent tasks used are known to rely on central executive or visuo-spatial memory. Since all concurrent tasks have the same requirement to listen to and output speech, if, rather implausibly, gap judgement relies on the phonological loop, all three should interfere with gap judgement.

In addition to the intelligence-related verbal reasoning task, participants performed a standard neuro-psychological test, and another developed in our own laboratories. In the latter visuo-spatial comparison task, or 'clocks' task, participants hear times such as 14.25, 16.40, etc, and must decide by imaging the clock face representing these times whether subsequent times would produce 'larger' or 'smaller' angular separations of the clock hands. The other task used was the paced auditory serial addition task (PASAT), which is widely used as an index of central executive efficiency. PASAT has previously been found to correlate with vigilance (Weber, 1988) and to relate reliably but minimally to IQ (Spreen and Strauss, 1991). It has also been shown to be highly sensitive to the transient changes in cognitive function which follow concussion (Gronwall and Sampson, 1974) and the more permanent cognitive damage following traumatic brain injury (Sohlberg and Mateer, 1989). In each case, following a period of single task practice, drivers drove towards the same sized gaps as those used by Brown and colleagues, while concurrently performing one of these secondary tasks.

Method

PARTICIPANTS

Eighteen male participants aged between 23 and 45 years of age took part. The median age was 35 years. All were experienced drivers who had held a driving licence for at least five years (median 13 years of driving experience).

PROCEDURE

Gaps of vehicle width (1.93m) -7.5cm, +0cm, +7.5cm, +15cm or +22.5cm were formed from 1.5m high cones, and placed, one gap per circuit, on the straight section of a test track (diameter 560m). The position of gaps was varied from trial to trial to prevent reliance on cues. Concurrent tasks began 160m before the gap was reached, tape recordings of all tasks allowed presentation to be carefully paced (one trial every three seconds), and the simple verbal response required to each was recorded for trial by trial by the accompanying experimenter.

There were three replications of each gap for each single and dual task gap condition. Single task gap judgements were made at the beginning and end of the test session. Between these two, the concurrent task and conditions were run in a counter-balanced fashion. In each case, a baseline measure of gap judgement, single task subsidiary task performance was made before the driving and memory tasks were combined.
Drivers were asked to strive to be as successful as possible on both tasks, but if necessary to prioritise driving. Gap acceptance and memory task performance were recorded, and speed and lateral position (SDLP) were measured over the final 39m of approach.

Results

A variety of different results emerged from the present study. The stability of performance over the course of the study, effects of concurrent task performance on gap judgement, effects of gap judgement on concurrent tasks and the relationship between decrements in performance on driving and memory tasks will be considered in turn.

The blocks of single-task gap judgement at the beginning and end of the experimental session allowed us to assess the extent to which drivers’ decision-making criteria or behaviour might change across the experiment. In fact, while drivers made 19 per cent of erroneous judgements at the outset, and 16 per cent erroneous judgements at the end, this difference does not approach statistical reliability. Similarly, drivers' speed and control of lateral position were similar at the beginning and end of the experiment. These data show that participants were performing reliably throughout, neither improving because of learning, nor deteriorating because of fatigue or boredom as the tasks progressed. Brown et al (1969) also note that learning effects were negligible in their study. It is also notable that in our study errors in gap judgement performance, whether because impossible gaps were accepted or possible gaps were properly accepted but a collision occurred as the gap was negotiated, were about half the rate reported by Brown and colleagues (circa 43 per cent). It is worth noting that the procedures used in the two studies differed in at least one important respect. In the Brown et al study, participants made 20 gaps judgements in the single- and dual-task conditions, on each 1.5 mile trial drive.

Thus, on average, gap judgements were made every 120 metres or so. Inevitably, since the angle of approach following a rejected gap would be different to that following a successfully negotiated gap, the judgement task would become markedly more difficult. In our study, in order to avoid such unwanted contamination, only one gap was negotiated for each circuit of the track, ie every 560m, and thus an erroneous decision on one gap was much less likely to have a collateral effect on later judgements. We believe that this important procedural change underlies the different rates of errors in the two studies, and that the procedural change deliberately made in the present study is desirable on methodological grounds. Perhaps more telling than the overall error rate is the relative effects of different gap sizes in the two studies. In both studies, error rates with 0cm and + 7.5cm clearance were more than double that observed where the clearance was 7.5cm less than the vehicle width, and very substantially higher than where the gaps approached afforded greater clearance.

Turning to the impact of concurrent task performance on gap judgement we find a pattern of results not easily anticipated from the study reported by Brown and colleagues (see Table 1).

Table 1: Errors in gap judgement as a function of gap size and differences between concurrent tasks

<table>
<thead>
<tr>
<th>Gap (cm)</th>
<th>-7.5</th>
<th>0</th>
<th>+7.5</th>
<th>+15</th>
<th>+22.5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
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</table>

Erroneously accepted/rejected
Only two comparisons yielded statistically reliable results, one of which appears to be an increased decrement in performance with the zero clearance gap when concurrently performing only the verbal reasoning task, the other of which is uninterpretable. We consider that the best interim summary of these results is that concurrent tasks did not affect gap judgement, contrary to the results reported by Brown and colleagues over 30 years ago. Also in contrast to their study, drivers in the present study maintained a similar speed on the final approach to gaps, in both single-task and dual-task driving conditions, rather than slowing in the dual-task condition. Our measure of control of lateral position also failed to show any impact of secondary tasks, which perhaps supports the conclusion reached by Brown and colleagues such that perceptual-motor aspects of steering were unaffected.

While these results might seem to bring the evidence presented by Brown and colleagues into question, our study demonstrates a dramatic impact of gap judgement on the working memory tasks (see Table 2). Specifically, statistically reliable increases in errors in the verbal reasoning task and paced auditory serial addition task occurred, as did the number of trials to which participants did not respond (ie 'misses'). Performance on the clocks task was unaffected by whether decisions were made when stationary or when also driving while performing the gap judgement task.

**Table 2: Performance on concurrent tasks as a function of driving and gap judgement**

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Cor.</th>
<th>Err.</th>
<th>Miss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>
Thus, performance suffered on the 'central executive' tasks, but not the spatial working memory task when drivers performed the gap judgement task. Within the working memory tradition this pattern of results would be assumed to occur because those tasks which show a decrement require similar cognitive resources. However, if it really is the case that gap judgement requires central executive resources, one might also expect performance to suffer not only on the working memory tasks, but on gap judgement as well. One possibility is that drivers were prioritising performance on the gap judgement task, and allowing performance on the working memory tasks to suffer. If this was the case we would expect to see less difference between single- and dual-task driving than between single- and dual-task working memory tasks. That is, performance trade-offs would result in negative correlations between deterioration in driving and deterioration in working memory, for those tasks that were cognitively incompatible with driving. This is precisely what was found. The correlation between the single versus dual task decrement in gap judgement performance and that between single and dual verbal reasoning was both negative and statistically reliable ($r = -0.48; p < 0.05$). The same was true for decrements in driving and PASAT performance ($r = -0.45; p < 0.05$), but importantly there was no reliable correlation between driving decrement and decrements in the spatial working memory task ($r = 0.15; \text{ns}$).

**Discussion/conclusions**

Although the present study did not reveal the impairment of gap judgement performance by concurrent verbal reasoning reported previously by Brown and colleagues, we consider that our study replicates the essence of the findings they report. Performing a demanding verbal reasoning task well and making decisions about whether one's vehicle will fit through a gap...
have again been shown to be incompatible, but perceptual-motor aspects of driving were unaffected by the additional cognitive demands imposed by the reasoning task.

There are at least three reasons why the expected decrement in gap judgement was not observed. Firstly, our statistical analysis is rather more exacting than the non-parametric sign-tests used to analyse the original data. It is possible that these less power-efficient analyses exaggerate the size of the effect observed. Secondly, it is possible that our subjects protected their driving performance more effectively than did those who participated in the Brown et al. study. This would also account for the fact that while our participants' speeds did not differ between single- and dual-task conditions, their participants slowed substantially in the concurrent task condition. A third, related, explanation which relates to procedural differences between the two studies is also plausible. The Brown and colleagues' procedure of having gaps repeatedly and rapidly encountered may have had the effect of accumulating what might be weak individual effects of the concurrent task. It is also possible that our procedure made trade-offs between task performance a more reasonable strategy to adopt in the face of incompatible conflicting demands for cognitive resources.

Importantly, what the present study goes on to show is that it is not the mere fact of performing a difficult secondary task while performing the gap judgement task that impairs performance. Only those tasks that the research literature has shown rely on the central executive are incompatible with gap judgement. A concurrent task that placed a substantial load on spatial aspects of working memory was unaffected. This suggests that the gap judgement task makes demands on attentional rather than spatial working memory resources, despite the reasonable intuitive assumption that judging gaps requires spatial processing. On the basis of the present study it would appear that speed control and steering or lateral position control draw minimally, if at all, on spatial or executive working memory resources. This might be taken by some to indicate that while decision-making aspects of driving cannot be considered 'automatic', more perceptual-motor aspects of driving are. Before such conclusions are hastily drawn, future analyses should examine whether this conclusion is warranted when performance is considered at a more molar level rather than the more gross analyses reported here. In the past such analyses of gear changing have yielded findings which question whether any aspect of driving can be properly considered automatic (see Groeger and Clegg, 1997; Groeger, 2000).
References


13 A review of the 'looked but failed to see' accident causation factor

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Introduction

In-depth surveys of road accidents have shown that a number of them are attributable to one or more of the involved road users having looked in the appropriate direction(s) but failed to see the person or vehicle with whom/which they collided. Such explanations almost invariably derive from subjective accounts of causation offered by individuals at the accident scene, or subsequently. This review was therefore commissioned by DTLR with the following objectives:

- to review the accident literature in order to estimate the magnitude of the problem, to investigate the types of road user most likely to report it and to evaluate the road and traffic conditions in which it is most likely to be recorded
- to evaluate the probability that the reported problem represents a 'genuine' phenomenon of attention, perception and cognition (that is, the road user at fault actually looked in the appropriate direction(s), the object collided with was visible within their visual field, yet it did not enter consciousness as a relevant hazard), relative to a number of alternative predictable possibilities
- to consider whether the phenomenon, if genuine, is researchable and, if so, to recommend methods by which its psychological basis may be most satisfactorily understood and appropriate countermeasures taken.

Evidence of a problem

The term 'looked but failed to see' (hereafter referred to as LBFTS) was first used in a variety of in-depth 'on-the-spot' (or 'at-the-scene') accident investigations carried out by multidisciplinary research teams in several countries during the 1970s and 1980s. All used a human factors/ergonomics approach, in that they attributed causation to the driver, the vehicle, the road and traffic environment and to interactions between these main factors. Their results were reasonably consistent in finding that the road user was the sole contributor in about 65 per cent of accidents, the environment contributed to between 20 and 30 per cent, whereas vehicle factors contributed only to between 3 and 13 per cent. Driver errors recorded as LBFTS were found to contribute to upwards of 10 per cent of accidents in these different surveys.

One of the better known of these surveys was conducted by a multidisciplinary team from the Transport and Road Research Laboratory almost 30 years ago and reported by Sabey and Staughton (1975). These authors listed a total of 3,704 drivers' errors which were subjectively assessed as having contributed to the 2,130 accidents surveyed by the team, and these are shown in Table 1.

Table 1: Drivers' errors contributing to accidents [Extracted from Sabey and Staughton (1975), Table 2A]

<table>
<thead>
<tr>
<th>Driver error</th>
<th>No. of errors</th>
<th>Driver error</th>
<th>No. of errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of care</td>
<td>905</td>
<td>Following too close</td>
<td>75</td>
</tr>
</tbody>
</table>
Too fast  450  Difficult manoeuvre  70  
LBFTS  367  Irresponsible/reckless  61  
Distraction  337  Wrong decision/action  50  
Inexperience  215  Lack of roadcraft  48  
Failed to look  183  Faulty signalling  47  
Wrong path  175  Lack of skill  33  
Lack of attention  152  Frustration  15  
Improper overtaking  146  Bad habit  2  
Incorrect interpretation  125  Wrong position  7  
Lack of judgement  116  Aggressive  6  
Misjudged speed/distance  109  
Total  3,704

On this evidence, LBFTS was certainly an important contributory factor in the accidents surveyed by these authors. It ranked third in order of importance among drivers' errors and represented 9.9 per cent of the total number of errors. It was not just a driver problem: this survey also showed that LBFTS contributed to 8.3 per cent of the 276 accidents in which pedestrians were considered to be at fault.

Table 2 presents a re-analysis of Sabey and Staughton's (1975) data, excluding accidents which occurred at night or involved drivers impaired by alcohol, drugs, fatigue or illness, in order to concentrate on perceptual rather than sensory or judgemental errors. LBFTS was found to be the most important of these perceptual factors, contributing to 22.8% of unimpaired drivers' errors during daylight.

Table 2: -Percentage contributions of perceptual and non-perceptual human factors to unimpaired drivers' errors during daylight [Extracted from Brown's (1984) re-analysis of drivers' errors reported by Sabey and Staughton, 1975]

<table>
<thead>
<tr>
<th>Perceptual factor</th>
<th>% contribution to drivers' errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBFTS</td>
<td>22.8</td>
</tr>
<tr>
<td>Distraction</td>
<td>15.4</td>
</tr>
<tr>
<td>Lack of attention/alertness</td>
<td>8.1</td>
</tr>
<tr>
<td>Faulty interpretation</td>
<td>6.6</td>
</tr>
<tr>
<td>Misjudged speed/distance</td>
<td>5.6</td>
</tr>
</tbody>
</table>
In 1996 the Department of Transport commissioned the Transport Research Laboratory to develop a prototype system in which the contributory factors in accidents could be linked to the data routinely collected as STATS19. Under this system police officers investigating an accident were allowed to use one from a list of 15 'precipitating factors' to record what went wrong and up to four from a list of 54 'contributory factors' to record why it went wrong. They were also asked to record whether the factors they recorded were 'definite', 'probable' or 'possible'. The new system was given a three month trial during the summer of 1996 and involved eight police forces. The overall incidence of recording LBFTS as a contributory factor was 7.5 per cent, the fourth most frequently recorded factor after 'failure to judge others' path or speed' (10.7 per cent), careless/thoughtless/reckless behaviour' (8.8 per cent) and 'inattention' (8.0 per cent). The incidence of recording LBFTS as a 'definite' contributory factor in multi-vehicle fatal or serious accidents on built-up roads was 15 per cent, greater than that of all other contributory factors.

Following this trial the linking system was adopted on a voluntary basis by a number of police forces in England and Scotland. Data collected during 1999 by 13 forces were analysed by DTLR Road Accidents Branch (TSR5) and those of particular relevance to LBFTS errors were provided for this review. The most important of these are shown in Table 3, where drivers' perceptual failures are listed in order of importance.

### Table 3: Frequency of recording perceptual failures, in order of importance

<table>
<thead>
<tr>
<th>Perceptual failure</th>
<th>Order of importance of perceptual failures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CF 1</td>
</tr>
<tr>
<td>Inattention</td>
<td>6,668</td>
</tr>
<tr>
<td>Misjudged others' path/speed</td>
<td>6,626</td>
</tr>
<tr>
<td>LBFTS</td>
<td>4,859</td>
</tr>
<tr>
<td>Failed to look</td>
<td>4,481</td>
</tr>
<tr>
<td>Misjudged own path/speed</td>
<td>1,925</td>
</tr>
</tbody>
</table>
Table 3 shows that LBFTS was recorded as contributing to 8,896 (17.4 per cent) of the total of 51,261 perceptual failures in these accidents. It contributed to 4,859 (18.9 per cent) of the 25,726 failures that were recorded as the primary factor (CF 1). It was the third most important contributory factor among these perceptual failures, both overall and where it was recorded as the primary factor in the accident. In order to examine this contribution of LBFTS errors in more detail, Table 4 shows the frequency with which it was associated with failures recorded as 'precipitating factors' in these accidents.

Table 4: -Frequency of recording LBFTS as contributing to drivers/riders' 'behavioural' failures which precipitated the accident

<table>
<thead>
<tr>
<th>'Behavioural' failure</th>
<th>Order of importance of LBFTS factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CF 1</td>
</tr>
<tr>
<td>Failed to give way</td>
<td>1,969</td>
</tr>
<tr>
<td>Failed to avoid object in carriageway</td>
<td>1,030</td>
</tr>
<tr>
<td>Failed to avoid pedestrian</td>
<td>282</td>
</tr>
<tr>
<td>Failed to stop</td>
<td>105</td>
</tr>
<tr>
<td>Loss of control</td>
<td>47</td>
</tr>
<tr>
<td>Failed to signal</td>
<td>32</td>
</tr>
<tr>
<td>All failures</td>
<td>3,465</td>
</tr>
</tbody>
</table>

Not unexpectedly, the principal consequences of LBFTS errors were failures to give way and failures to avoid an object in the carriageway. Some 81 per cent of accidents where LBFTS was recorded as a contributory factor occurred at road junctions. However, 61 per cent of all accidents in this database occurred at junctions and contributory factors were recorded in only about one in five of these accidents, therefore Table 5 shows the percentage of all accidents with a contributory factor where LBFTS was recorded.

On average, LBFTS errors contributed to 20.65 per cent of all accidents which occurred at junctions; this was 2.5 times as many as occurred away from a junction. LBFTS errors contributed most frequently to accidents at private drives/entrances, but almost as frequently at mini-roundabouts, which is surprising because these junctions would appear to
present few visual scanning problems and their priority rules are clear. In addition, they are relatively safe junctions, accounting for only 1.3 per cent of all the junction accidents in this study. This finding must therefore raise doubts as to whether LBFTS was the appropriate contributory factor to record in these cases.

It was found that 78 per cent of all LBFTS accidents occurred in daylight. However, accidents are more frequent during the day than at night. Taking this into account, LBFTS errors were found to contribute to 16.77 per cent of all accidents with a contributory factor during daylight and to 13.65 per cent during darkness.

Table 5: -Percentage of all accidents with a contributory factor where LBFTS was recorded, by type of junction

<table>
<thead>
<tr>
<th>Junction type</th>
<th>% of LBFTS accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private drive/entrance</td>
<td>25.21</td>
</tr>
<tr>
<td>Mini-roundabout</td>
<td>24.77</td>
</tr>
<tr>
<td>Multiple junction</td>
<td>22.69</td>
</tr>
<tr>
<td>Crossroads</td>
<td>20.86</td>
</tr>
<tr>
<td>T, Y, or staggered junction</td>
<td>20.73</td>
</tr>
<tr>
<td>Other junction</td>
<td>18.72</td>
</tr>
<tr>
<td>Roundabout</td>
<td>18.10</td>
</tr>
<tr>
<td>Slip-road</td>
<td>12.17</td>
</tr>
<tr>
<td>All junctions</td>
<td><strong>20.65</strong></td>
</tr>
<tr>
<td>Not at a junction</td>
<td><strong>8.14</strong></td>
</tr>
</tbody>
</table>

Table 6 shows the percentage of all accident involved cars and taxis with a contributory factor where LBFTS was recorded, by driver age and accident severity.

Table 6: -Percentage of all accident involved cars and taxis with a contributory factor which were recorded as LBFTS, by driver age and accident severity

<table>
<thead>
<tr>
<th>Age group</th>
<th>Accident severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fatal</td>
</tr>
<tr>
<td>0-16</td>
<td>0.00</td>
</tr>
<tr>
<td>17-21</td>
<td>8.70</td>
</tr>
</tbody>
</table>
Table 6 reveals that, for all categories of severity, the frequency of recording LBFTS as a contributory factor increased monotonically with driver age. Importantly, LBFTS was recorded 62 per cent more often for the over-65s than for drivers aged 17 to 21, but whether this relationship was mediated by age-related changes at the sensory, perceptual or cognitive levels remains to be determined.

Table 7 shows the percentage of all accident involved cars and taxis with a contributory factor where LBFTS was recorded, by driver sex and accident severity.

Table 7: -Percentage of all accident involved cars and taxis with a contributory factor which were recorded as LBFTS, by driver sex and accident severity

<table>
<thead>
<tr>
<th>Accident severity</th>
<th>Driver sex</th>
<th>Female</th>
<th>Male</th>
<th>Not traced</th>
<th>All drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>17.71</td>
<td>10.43</td>
<td>0.52</td>
<td>12.03</td>
</tr>
<tr>
<td>Fatal</td>
<td></td>
<td>20.52</td>
<td>15.74</td>
<td>10.60</td>
<td>16.91</td>
</tr>
<tr>
<td>Serious</td>
<td></td>
<td>19.59</td>
<td>17.04</td>
<td>9.76</td>
<td>17.58</td>
</tr>
<tr>
<td>Slight</td>
<td></td>
<td></td>
<td>16.79</td>
<td></td>
<td>17.44</td>
</tr>
<tr>
<td>All categories</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall, LBFTS was recorded 17 per cent more frequently in accidents incurred by female drivers than males. Whether this difference was mediated by attitudinal, motivational or experiential factors remains to be determined, although the latter seems unlikely to be involved since 'inexperience of driving' and LBFTS were seldom recorded as associated contributory factors in these accidents. The table also shows that LBFTS was recorded relatively infrequently in male drivers' fatal accidents. It is possible that male drivers less often survive their LBFTS accidents to provide evidence on contributory factors, but whether this finding reflects a difference in speed or location at which males and females incur LBFTS accidents cannot be determined from the data.

On the tabulated evidence, LBFTS does appear to be an important contributory factor in accidents. It was the third most
frequently recorded failure of perceptual skills, accounting for over 17 per cent of all such failures. Where it was the primary contributory factor, it contributed to over 56 per cent of accidents precipitated by driver or rider 'behavioural' failures. It contributed slightly more often to accidents during daylight than during darkness and to 2.5 times as many accidents at junctions than to those occurring away from a junction. Accidents with a contributory factor in which LBFTS was recorded increased monotonically with driver age and they were 17 per cent more frequent among female drivers than among males. The question remains as to whether these errors recorded by the police as LBFTS were 'genuine', as defined by the objectives of this review. Clearly there is scope for confusion in recording errors as LBFTS, given the 'plain language' description of the error. For example, 'looking' could have been recorded when the driver's eyes were turned in the appropriate direction but conscious attention was absent. Also, 'failing to see' could have been recorded both for an obscured hazard and for a failure to recognise the hazardous potential of a visible approaching vehicle. In an attempt to explore these confusions, Table 8 lists the frequency with which LBFTS was recorded as contributing to accidents in association with other perceptual failures.

**Table 8: Frequency of recording LBFTS and other perceptual failures as associated contributory factors in accidents**

<table>
<thead>
<tr>
<th>Perceptual failure</th>
<th>Total LBFTS associated with perceptual failure</th>
<th>Total as percentage of all recorded LBFTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inattention</td>
<td>1,089</td>
<td>12.24</td>
</tr>
<tr>
<td>Misjudged others' path/speed</td>
<td>1,562</td>
<td>17.56</td>
</tr>
<tr>
<td>Failed to look</td>
<td>829</td>
<td>9.32</td>
</tr>
<tr>
<td>Misjudged own path/speed</td>
<td>452</td>
<td>5.08</td>
</tr>
<tr>
<td>Personal, other</td>
<td>60</td>
<td>0.67</td>
</tr>
<tr>
<td>All perceptual failures except LBFTS</td>
<td>3,992</td>
<td>44.87</td>
</tr>
<tr>
<td>LBFTS errors</td>
<td>8,896</td>
<td></td>
</tr>
</tbody>
</table>

Table 8 shows that in almost 45 per cent of the accidents where LBFTS was recorded as a contributory factor it was associated with another perceptual failure of attention or judgement. 'Inattention' and 'misjudged own approach' were mainly recorded as subsidiary factors in accidents where LBFTS was the primary contributory factor. LBFTS was mainly recorded as a subsidiary factor in accidents where 'Misjudged others' approach' and 'failed to look' were the primary contributory
factors. Clearly it is possible for LBFTS to be recorded in the same accident as inattention, misjudgement or failing to look if these failures were attributed to different participants in the accident, or they related to a driver's different directions of gaze. However, the data are not clear on this point, therefore it is also possible that the term LBFTS is sometimes used as an 'explanation' for a range of other attentional, perceptual or cognitive errors, rather than to describe a genuine error in its own right. Possible candidates for inclusion in this range are discussed in the following section.

**Alternative explanations of errors recorded as LBFTS**

First, the possibility cannot be excluded that a proportion of the errors recorded as LBFTS are simply excuses offered by errant drivers, or the default option accepted by police officers in the absence of evidence to the contrary. Drivers may prefer to admit to LBFTS rather than confessing to not looking, or to an error of judgement which brings into question their driving competence. This possibility can never be quantified reliably from subjective reports of causality. Second, it seems possible from the evidence provided in Table 8 that a proportion of errors recorded as LBFTS are actually failures of hazard perception, in which the driver has seen a potential hazard but consciously rejected it as not presenting a danger. Third, a proportion of errors recorded as LBFTS may, quite reasonably, relate to a failure to see a hazard which is obscured from view by some feature of the vehicle or the environment. However, these are not genuine LBFTS errors as defined for the purpose of this review. Fourth, a proportion of errors recorded as LBFTS may have been incurred by drivers whose head and eye movements were habitual or autonomous, perhaps because of over-familiarity with the location, or tiredness, respectively, but who are not consciously processing visual information from the traffic scene. Fifth, a proportion of errors recorded as LBFTS may be genuine and result from the use by the driver of an inadequate search strategy, as described for example by Rumar (1990). That is, the driver looks only for hazards which experience has shown to be most common or most dangerous in the particular environment in question. Sixth, another proportion of errors recorded as LBFTS may be genuine and result from failures of selective attention, in which the critical features of hazardous and non-hazardous objects are confused because of over-hasty visual scanning of the traffic scene. The psychological bases of these latter two genuine types of LBFTS error are briefly discussed in the following section.

**Psychological bases of genuine LBFTS errors**

The particular aspect of the driving task in which LBFTS represents an error constitutes search for a safe gap in traffic.
This requires perception of the location, orientation (direction of travel) and speed of vehicles which demarcate gaps. Some of these vehicles will represent potential hazards whereas others will be non-hazardous. The driver's task is twofold; first, to direct attention to all relevant objects in the traffic scene and, second, to act on information which clearly distinguishes hazardous from non-hazardous objects.

Given this brief task analysis, explanations for genuine LBFTS errors can be found in the developing field of selective attention, where rapid advances are being made by combining methodology from behavioural psychology and cognitive neuroscience. Theorising here is still somewhat controversial (see Driver, 2001), but there appears to be sufficient agreement for an increased understanding of the nature and causation of the LBFTS error to be reached. For example, Duncan (1996) presents an 'integrated competition hypothesis' to explain the processing of selective attention. The essential aspect of his view is that top-down priming of neural activity biases competition for attention towards objects in the visual scene which are of particular relevance to the task in hand. Meanwhile, attention to other objects may be inhibited. This suggests that drivers will concentrate on features of the traffic scene which experience has shown to be of critical importance for safety and that other features may temporarily be ignored. Hence such drivers will be vulnerable to collision with vehicles or pedestrians behaving unexpectedly. In addition, Treisman (1996) has developed her 'feature integration' theory specifically for the visual modality. According to this theory, different features of visual stimuli are all extracted in parallel, 'pre-attentively', but attention has to be allocated serially to the location of each stimulus in order to integrate features appropriately into a meaningful percept. This suggests that drivers may rapidly scan the traffic scene for a single feature of a potential hazard, such as proximity, and decide to proceed without noticing the approach of a more distant but rapidly approaching vehicle. Alternatively, where drivers must take a decision in a busy traffic scene, they may fail to integrate the location, orientation and speed of an approaching vehicle into a coherent percept of danger because they have scanned the scene too rapidly. They may even integrate features from different vehicles, some representing danger and some not, resulting in an illusory percept of safety.

Taken together, these views suggest that there are three aspects to the genuine LBFTS phenomenon:

- limited capacity of an individual for processing information, which means there will be competition between visual stimuli for the viewer's attention;
• attentional selectivity, which means that certain features of an object may be given attention whereas others may not;

• illusory conjunctions of stimulus features from hazardous and non-hazardous objects, which means that some hazards may not be identified correctly.

It follows that LBFTS errors will be more probable when drivers view complex traffic scenes and that, having made the error, they will probably not recall 'seeing' the hazard in question.

Recommendations for research

Mainstream psychological research supports the existence of a genuine LBFTS error which meets the criteria established by this review. Evidence from the linking of contributory factors in road accidents to the data in STATS19 suggests that the LBFTS phenomenon is relatively important for road safety, although the precise magnitude of the problem may not be identifiable from existing data. The problem appears researchable and methods for addressing it are briefly outlined below.

Research is required to estimate the probability that LBFTS is being used as an 'excuse' by faulty drivers, or as a default option by investigating police officers. An appropriate method would be that adopted by Brown and Copeman (1975) to investigate drivers' attitudes to traffic offences. Research also seems required to refine the descriptor 'looked but failed to see' in order to restrict its use to errors in which drivers actively search for visible hazards but fail to become consciously aware of them, and to eliminate its possible use as a way of 'explaining' errors of inattention and misjudgements of speed and distance. Further analyses are required of the contributory factors data linked to STATS19 in order to reveal the precise types of manoeuvre and the traffic conditions which are most commonly associated with the LBFTS phenomenon. The aim would be to further understanding of drivers' visual search behaviour and the informational load on them when LBFTS errors tend to be made. Research is required to establish the statistical reliability of the age and sex differences in drivers' propensity to commit LBFTS errors, apparent from the contributory factors data for 1999. If these differences are verified, additional research is required to explore the extent to which LBFTS errors are a separate or joint function of individual differences at the sensory, perceptual and/or cognitive levels. More basic research is required to investigate the specific nature of the attentional failures which result in LBFTS errors. Of particular interest would be drivers' prioritisation of features representing a traffic hazard (location, orientation, speed, etc) and the order in which these features
fail to be integrated into a relevant hazardous percept of danger under conditions of increasing informational load and time stress.

Conclusions

Evidence from both the accident literature and an initial study of contributory factors in accidents supports the conclusion that the LBFTS phenomenon could be relatively important for road safety. The contributory factors data suggest that the term LBFTS may sometimes be used to describe behaviour which does not comprise a failure to become aware of a hazard in spite of attentive visual search. However, empirical research on selective attention in the fields of behavioural psychology and cognitive neuroscience supports the view that drivers can make genuine LBFTS errors, particularly in busy and complex traffic scenes where rapid visual search for hazards is required. It is concluded that the phenomenon is researchable and research findings seem likely to indicate the need for both training and engineering countermeasures.

References


Novice drivers' accident mechanisms: Sequences and countermeasures

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Abstract

Following two successful projects on right-turning accidents and overtaking accidents, based on police accident case files, we are nearly at the conclusion of a three-year project on the accident mechanisms of young drivers. A sample of 3,439 accident cases are to be considered, including 1,284 in detail, from Midlands police forces, involving drivers aged 17-25. Four types of accident are being analysed: right-turns; rear-end shunts; loss of control on bends; and accidents in darkness. Preliminary analyses will be presented of over 3,000 cases that have been gathered, together with a discussion of simple behavioural countermeasures that might apply within each category examined. Issues to emerge from the study already include age and gender differences in contributory factors; techniques for inducing exposure measures by examining 'crashee' age data; and an examination of driver attitudes as revealed in police interviews.

Introduction

The high accident rate for younger drivers has been of concern to such diverse official bodies as insurance companies, driving standards agencies and governments for many years. Road accidents are the most common cause of death among those aged under 25 in the USA, Canada and the European Union. Research conducted in these areas has shown that drivers aged 17-20, particularly males, have an accident rate per km/mile driven that is disproportionately high when compared with other groups. Forsyth (1992) quotes figures from the UK in 1987 that show male drivers between the ages of 17 and 20 having an average of 440 injury accidents per 100 million km driven. The average for all male drivers was 106 injury accidents. Comparable figures for female drivers in this age bracket were 240 versus 125 injury accidents per 100 million km driven.

Accident rates appear to drop rapidly above this age bracket. Figures for male drivers in the age range 20-24 years, for example, show a drop to 180 injury accidents per 100 million km driven. While this is a massive drop, it still represents an injury accident rate that is nearly 70 per cent higher than the baseline for all male drivers.

Recently, the Select Committee on Environment, Transport and Regional Affairs 19th Report (1999) contained evidence from the UK showing that, although the 17-24-year-old age group hold only 11 per cent of driving licences, they are involved in 25 per cent of fatal/serious injury accidents each year. Additionally, fatality rates for male drivers aged 17-20 are 10 times those of male drivers aged 35-54.

Some specific problems of younger drives

DARKNESS

Accidents for all drivers per unit of distance travelled are much higher during the hours of darkness than during the daylight. One of the possible reasons for the elevated accident rate seen in young drivers during the hours of darkness is tiredness. Always assumed to be more of a problem for older drivers, researchers such as Corfitsen (1994) have shown that tiredness
is a common affliction among young male night-time drivers, which leads to reaction times that can be three times slower than a driver who is 'rested'. Similarly, Pack et al (1995), in the USA, found that accidents that could be attributed to the driver having fallen asleep at the wheel had a peak of occurrence at age 20 years. Pack et al also point out that this is not only a problem at night. 'Sleepiness' accidents can also reach a peak during the early afternoon, described as 'siesta time' in certain cultures. Laapotti and Keskinen (1998) found that fatal loss-of-control accidents involving young male drivers typically took place during evenings and nights. The high numbers of accidents occurring in the early hours of the morning are also associated with the high numbers of single-vehicle accidents for this age range.

Internationally, the high accident rate of young drivers during the hours of darkness has led to the introduction of a driving curfew in certain areas as part of a graduated driver licensing scheme (GDLS), eg, in Canada (Doherty et al, 1995), and New Zealand (Langley et al, 1996). The introduction of such a scheme in New Zealand was closely followed by substantial reductions in car crash injuries, though Langley et al point out that caution should be exercised due to research suggesting that one of the principle effects of the GDLS on crashes may have been indirect through a reduction in overall exposure. Nevertheless, researchers in the United States, eg Miller et al (1998), have pointed out, using cost-benefit analysis, that the crash costs of younger drivers are high enough to limit driving after midnight.

**SPEED**

Young drivers have long been associated with offences and accidents involving speeding. An early comprehensive work in the USA by Harrington (1972), for example, showed that in a sample of over 13,000 driver records, speeding was the most common violation, and also the violation most frequently involved with fatal and injury accidents. STATS19 data for 1995 in the UK show that the importance of speeding as a contributory factor in injury accidents declines steadily with age.

Speeding was by far the most common offence for young male and female drivers in the UK cohort study by Forsyth et al (1995) and there also appeared to be an increase in the number of speeding violations as a whole over the first three years of driving. Forsyth et al suggest that this is a result of increasing driver confidence as initial driving experience is gained after passing the test. This is similar to a finding by Quenault and Parker (1973), where newly qualified drivers were assessed at 1, 13, 26, 39 and 52 weeks after passing the driving test. They found that average speeds in 30mph and derestricted zones tended to become higher with increasing driver experience.

Jonah (1986) reviews evidence that young drivers are less likely than older drivers to cite speeding as a major cause of accidents, and when asked to rank a number of driving situations in order of risk, young drivers ranked speeding significantly lower in risk than did older drivers. It has been suggested, eg by Brown (1982), that one of the reasons young drivers attach less importance to the risk of speeding is they are overconfident in their control and recovery skills. Brown concludes that 'relatively naive drivers tend to create accident opportunities for themselves because they often overestimate their ability to recover from error'. It has also been pointed out by Deery (1999) that psychological research separate from the road safety area suggests that people are generally overconfident about their skilled performance, and that in addition speeding can result from young males especially having a higher degree of risk acceptance while driving than that found in older drivers.
Parker (1991) found that speeding in younger drivers was often mediated by the effects of peer groups and significant others, resulting in the young driver having a perceived lack of control over violations such as speeding. Similarly, Tuohy and Stradling (1992) surveyed the knowledge and beliefs of both young drivers and 'pre-drivers' and concluded that both groups had a good knowledge of basic roadcraft: young drivers knew what was the correct behaviour, but attitudes, opinions and beliefs usually stopped them practising it.

**SINGLE-VEHICLE ACCIDENTS AND BENDS**

The proportion of single-vehicle accidents is much higher for younger drivers than for older drivers. STATS19 (UK) data for 1995 reveal that over one in five (22 per cent) of injury accidents for males aged 17-19 involved no other vehicle but the driver's own. These data are backed up by the self-report study of drivers by Maycock (1991); for the youngest group, single-vehicle accidents represent about 20 per cent of total accidents.

When the type of manoeuvre in aggregate records such as STATS19 (UK) is examined, it can be seen that younger drivers (17-19) are involved in twice the proportion of accidents while negotiating a bend that older drivers are (in this example, those aged 30-39). This is a feature associated with the over-representation of younger drivers in single-vehicle accidents. Clarke et al (1998), in their study of overtaking accidents, found that the second most common overtaking injury accident for drivers under the age of 21 occurred as a result of overtaking into a bend with little visibility ahead.

Laapotti and Keskinen (1998), in their study of young driver fatal loss-of-control accidents, found that there were differences in the causation of such accidents according to the driver's gender. Risky driving habits such as driving too fast and consuming alcohol played a bigger role in male drivers' loss-of-control accidents than in any kind of female drivers' accidents. Female drivers' loss-of-control accidents tended to be associated with slippery road conditions rather than risky driving habits.

**REAR-END SHUNTS**

Rear-end shunts have been found to be amongst the most common types of accidents for all drivers. West and French (1993) estimated that at least 30 per cent of all accidents on UK roads were shunts. While many of these accidents are seemingly trivial, whiplash injuries that can result from them are a significant problem. West and French, in their analysis of different types of shunt, found that 'active involvement in shunts was a function of being young and male'. ('young', in their terms, being under 23 years old, with a sample deliberately selected to contain 50 per cent 17 and 18 year olds).

**RIGHT TURNS**

In a previous study at Nottingham, Clarke et al (1998) discovered that young drivers (under the age of 25) were more than three times more likely to be involved in right-turning accidents (either on to or off a more major road) than typical mileage travelled each year by this age group would lead one to expect. West and French (1993) discovered that young drivers were at greater risk of 'passive' right-of-way violations. They reported that 'younger drivers [are] more at risk of an accident where another driver pulls out in front of them'. They say that this is most likely to occur due to a combination of such factors as speeding, slow perception of potential hazards, and a '[determination] to assert their own right of way'.
AGE VERSUS EXPERIENCE

Methodologically, it has always been difficult to separate the effect on accident frequencies of simple age compared with the experience of the driver concerned. Does a 24 year old with six months' driving experience have the same risk of an injury accident as a 17 year old with equivalent experience, for example? If this were true, the effect would not show up in accident statistics because there are many more 17 year olds with only six months' driving experience than there are 24 year olds with six months' experience. The most common measure of experience is, nevertheless, time in years since passing a driving test. Waller et al (2000), for example, looked at the decline in offences and crash incidents over seven years from the date of full licence attainment. The odds of any driving offence committed being seriously decreased by approximately 8 per cent per year of licensure, independent of gender. Similarly, the odds of an at-fault crash occurring decreased overall around 6 per cent per year of licensure, but the decline was more than twice as fast for women as for men. However, in any given sample of drivers, age and experience when measured in this way are very highly correlated, and this makes any separate effects very hard to determine. In the end, as Jonah (1986) observed, 'the attempt to separate the two concepts may well prove fruitless'.

Attempts have been made to define experience as the distance in miles/km driven since the test pass date, but not only is this difficult to determine, it also complicates the issue owing to the exposure effect. The driver in question may be more experienced as a result of driving a greater distance, but the greater the distance travelled, the more likely it is that he/she will have an accident. However, in Jonah's (1986) review of Canadian research on the subject, he concludes '. . . even when one controls for the quantity and quality of exposure to risk, young drivers are still at the greatest risk of casualty accident involvement, particularly those aged [under] 19'.

The In-Depth Accident Causation Study

This paper describes a DTLR funded project on the accidents of young drivers aged 17-25 that is nearing the end of its three-year time span. Four types of accidents will be examined during the course of this study, the main phase of which has been in progress for two years and which is due to be completed by the end of July 2001. The four types of accident will be described together with some results from our preliminary analysis.

Method

Our research uses police files as a primary data source, and the first step was to draw an appropriate sample of road accident files. We are using injury accident files involving at least one driver aged between 17-25 from two counties in the Midlands: Nottinghamshire and Derbyshire. Each file contains a report sheet - a statement of information about the accident, such as date, time, location, weather conditions etc. The files also contain an 'accident story' as interpreted by the attending police officer. This is written by the officer a short time after the accident by reference to his/her pocket book. It typically contains the actions, reported intentions and behaviours of the main drivers and witnesses. Other materials are also available in the more detailed files. These can include maps, photographs, statements of vehicle examiners, and most importantly, interview and witness statements containing detailed information about the course of events around the time of the accident. Such files are termed 'A' grade files, and take a good deal of time to read and interpret. Less extensively documented files are graded 'B'. The research uses a two-pronged approach, basing in-depth
type work on A grade files, and using B graded files to check on how well any conclusions reached represent the broader sample.

The essence of our approach is a detailed reading and re-reading of each file by experienced researchers with training in formal and statistical research methods, and considerable driving experience. Their task is to form a detailed causal interpretation of each accident sequence, which is then used with other 'facts and figures' from the case file as the basis for the next stage.

THE DATABASE

The data are input to a FileMaker Pro database customised to handle the information and search parameters required for this project. Figure 1 below shows the standard data entry set-up.

Figure 1: A standard data entry sheet on the database

It was early in the morning on a camp day in late Autumn. It was still dark and streetlamps were lit. The road was wet, but it wasn't raining. The driver (F, 21) of a Peugeot 105 (1) was travelling along an urban A road towards a 40mph limit. The Junction was controlled by traffic lights and she wished to make a right hand turn. She wasn't really paying much attention, and she said she saw a light change and thought it was her signal. She pulled off and turned right in front of an articulated HGV (2), driven by (M, 59), who had been
Figure 1: A standard data entry sheet on the database (cont.)

Data are entered describing the relatively objective facts of each case: time of day, speed limit, class of road etc. The database includes some fields configured as check boxes or 'radio buttons'; these provide quick access to selected cases during further analysis. Summary fields are also used to calculate things such as mean age of involved drivers. Any combination of fields in the database can be used to search for cases matching a variety of criteria. A variety of layouts are also used to present and analyse the data, in addition to the data entry layout above.

A 'prose account' is also entered for each case giving a step-by-step description of the accident. The causal story is always written from the viewpoint of the young driver, who is labelled as 'driver 1', though much consideration is also given to other drivers' actions and intentions. An interest is taken in all accidents involving the young driver, whether, to use West and French's (1993) terminology, they are 'actively' or 'passively' involved. The prose accounts give a detailed summary of the available facts, including information from witnesses that appears to be sufficiently reliable. Discrepancies can occur between the interviews of drivers and the statements of independent witnesses, but these can usually be resolved by considering all statements together with various other reported facts. These can include measurement of skid marks by police, vehicle damage reports etc. Figure 1, it should be noted, only shows part of a typical prose account because the text is held in an 'expandable field' in the database.

Next, a sketch plan of each accident is made from sources in the file. The orientations of the sketch plan and the icons contained in it are standardised for speed of entry and to allow direct comparisons between example or prototype cases.

A minimum set of possible explanations for each accident is recorded from a standard checklist adapted and developed from a previous study (Clarke, et al, 1998). The list has
subsections for the road environment, vehicle and driver characteristics, and specific driver actions. The emphasis throughout is on giving the finest grain description possible of each accident, not for use as a formal coding scheme, but rather to provide search and selection aids to identify homogeneous groups of cases for further qualitative analysis. In addition, we are piloting a version of a national 'contributory factors in accidents' form developed at TRL which involves the identification of one major precipitating factor (PF) from a possible list of 15, and a further coding of up to four contributory factors (CFs), together with a confidence rating in the CFs identified. Finally, entries are made in additional fields for comments and quotes from involved drivers.

Analysis and results

Following a pilot analysis of 240 cases, the following types of accident were selected for further study in the main body of the project:

- accidents occurring on rural roads involving loss of control on a bend
- right turns either on to or off a more major road
- rear-end shunts
- accidents occurring in darkness, with or without street lighting.

It was found that these (overlapping) types covered nearly 90 per cent of the pilot sample. A total of 3,439 cases have been coded during the main phase of the project. These comprise 1,284 A grade cases and 2,111 B grade cases (A grades account for 37.3 per cent of the total sample).

A basic statistical overview of the sample reveals that accidents occurring in the hours of darkness are notably high in 17-19-year-old drivers. In addition, this appears to be a problem for young males in particular, as Figure 2 (below) shows.

Figure 2: Percentage of the four accident types in each gender group, as a percentage of total accidents for each gender

By contrast, rural bend accidents involving young females are relatively rare.

The aim was to examine the four main divisions of accident for consistent features such as the type of driver involved, location, time, and ultimately the types of errors made by drivers in these different scenarios. In examining these questions it is necessary to account for exposure effects within the sample as a whole.
An induced exposure measure was provided by breaking the age range in the sample (17-25 years) up into three equally spaced bands and calculating standard normal residuals for each band. This measure, based on the chi-squared statistic, shows how much more (or less) common a given combination of accident type and age band is than would be expected, given the prevalence of the accident type and of the age group in the data overall and the sample size. A figure exceeding +/- 1.27 is approximately equivalent to a significance level of \( p < 0.05 \). Table 1, below, shows standard normal residuals for the three age bands and six different accident conditions (two of the accident types, right turns and darkness accidents, having been further subdivided so as to reveal any differences within the types).

### Table 1: Standard normal residuals for six types of accident and three age bands of young driver; for cases where young drivers have been judged fully or partially to blame for the accident

<table>
<thead>
<tr>
<th>Age band</th>
<th>Right turns 'on'</th>
<th>Right turns 'off'</th>
<th>Rear-end shunts</th>
<th>Rural bends</th>
<th>Darkness (street lights lit)</th>
<th>Darkness (no lighting)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17-19</td>
<td>-1.65</td>
<td>-2.34</td>
<td>-4.13</td>
<td>3.25</td>
<td>1.08</td>
<td>1.53</td>
</tr>
<tr>
<td>20-22</td>
<td>1.89</td>
<td>3.33</td>
<td>1.21</td>
<td>-0.77</td>
<td>1.42</td>
<td>-0.34</td>
</tr>
<tr>
<td>23-25</td>
<td>-0.24</td>
<td>0.78</td>
<td>2.92</td>
<td>-2.49</td>
<td>-2.49</td>
<td>-1.19</td>
</tr>
</tbody>
</table>

Figures exceeding +/- 1.27 shown in bold are approximately equivalent to a significance level of \( p < 0.05 \)

Over the following pages, plots of these standard normal residuals are shown for these categories of accident where significant differences are revealed (Figures 3-8). In all figures, the significance level of +/- 1.27 is represented as a threshold line. It can be seen that the younger age group in particular are over-represented in the sample with respect to accidents occurring on bends in rural areas (Figure 6) and accidents occurring at night with no streetlamps lit (Figure 8). They appear under-represented in both types of right turn accident, and in rear-end shunt accidents (Figures 3-5). This is not to say that 17-19 year olds do not have many right-turn or shunt accidents, but relative to every other type of accident in our sample that they are involved in, their propensity is low when compared with the rest of that sample. Similarly, this explains why the older age group (23-25 years) appear over-represented in rear-end shunt accidents.

**Figure 3: Prevalence of right turn 'on' accidents across three age groups shown as standard normal residuals**
Figure 4: Prevalence of right turn 'off' accidents across three age groups shown as standard normal residuals

Figure 5: Prevalence of rear-end shunt accidents across three age groups shown as standard normal residuals

Figure 6: Prevalence of rural bend accidents across three age groups shown as standard normal residuals
Figure 7: Prevalence of darkness (streetlights lit) accidents across three age groups shown as standard normal residuals

![Figure 7](image)

Figure 8: Prevalence of darkness (no streetlights) accidents across three age groups shown as standard normal residuals

![Figure 8](image)

**Experience**

Data on driver experience were collected by examining records for information regarding the length of time young drivers in the sample had held a full driving licence for cars (young motorcyclists being beyond the remit of this study); 906 records that contain such information have been entered in the database. This represents 26.3 per cent of the total number of cases. Figure 9 shows a simple distribution of the experience information in these records.

Figure 9: Distribution of driver experience in the sample, expressed as years full licence held (for all cases where records are available; n=906)
It can be seen in Figure 9 that the proportion of young drivers considered to be at fault or partially at fault ('active' in accident causation as opposed to 'passive', using West and French's (1993) definitions) does decrease with experience when it is defined as years a full car licence has been held. The proportional fall is illustrated for all cases in Figure 10. However, the proportional drop is not the same for all kinds of accident, as Figures 11-14 show. (Proportional data gathered from the sample in the following figures is represented by straight lines intersecting boxes, and a 'curve fit' second-order polynomial function has been overlaid.)

**Figure 10:** All cases: The proportion of cases where the young driver is judged to have been fully or partly at fault as a function of years full licence held (for cases where records are available; n=906)

**Figure 11:** Right-turn cases: The proportion of cases where the young driver is judged to have been fully or partly at fault as a function of years full licence held (for cases where records are available; n=254)
Figure 12: Rea-end shunts: The proportion of cases where the young driver is judged to have been fully or partly at fault as a function of years full licence held (for cases where records are available; n=248)

Figure 13: Rural bend accidents: The proportion of cases where the young driver is judged to have been fully or partly at fault as a function of years full licence held (for cases where records are available; n=183)

Figure 14: Darkness (with streetlights) accidents: The proportion of cases where the young driver is judged to have been fully or partly at fault as a function of years full licence held (for cases where records are available; n=310)
Figure 15: Darkness (no streetlights) accidents: The proportion of cases where the young driver is judged to have been fully or partly at fault as a function of years full licence held (for cases where records are available; n=114)

It should be noted that in the case of rural bend accidents (Figure 13), the proportion of young drivers of all levels of experience considered to be active in these cases appears not to fall at all due to the large number of single-vehicle accidents that occur in these circumstances. In fact, 393 of the 584 (67.3 per cent) accidents on rural bends in the sample involve no other car but the young driver's own. In all the other types of accident apart from rural bends, the falling curve functions could represent differing degrees of experience-based improvement in susceptibility to causing accidents in these separate ways. A simple frequency distribution of rural bend accidents and experience shows a marked improvement in the number of accidents after the 0-1 year level of experience has been passed, as in Figure 16.

Figure 16: Distribution of driver experience for rural bend accidents in the sample, expressed as years full licence held (for all cases where records are available; n=183)
Contributory factors; age and gender differences

It had been decided to examine contributory factors, firstly from the standard checklist adapted and developed from a previous study (Clarke, et al, 1998), and secondly from a version of a national 'contributory factors in accidents' form developed at TRL which involves the identification of one major precipitating factor (PF) from a possible list of 15, and a further coding of up to four contributory factors (CFs). Table 2 shows the percentage of total accidents involving specified factors for different driver groups from the first set of contributory factors. Figures show percentage of accidents involving the specified factor where the young driver was judged primarily at fault.

Table 2

<table>
<thead>
<tr>
<th>Factor</th>
<th>Male drivers (n=1756)</th>
<th>Female drivers (n=542)</th>
<th>All 17-19 year olds (n=829)</th>
<th>All 20-22 year olds (n=785)</th>
<th>All 23-25 year olds (n=685)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet road</td>
<td>26.0</td>
<td>23.4</td>
<td>28.0</td>
<td>24.2</td>
<td>23.6</td>
</tr>
<tr>
<td>Excess alcohol</td>
<td>9.5</td>
<td>2.2</td>
<td>6.3</td>
<td>7.1</td>
<td>10.4</td>
</tr>
<tr>
<td>Poor observation (all categories)</td>
<td>32.5</td>
<td>42.8</td>
<td>32.7</td>
<td>36.9</td>
<td>35.2</td>
</tr>
<tr>
<td>Misjudged speed/distance of other vehicle</td>
<td>4.2</td>
<td>7.4</td>
<td>5.4</td>
<td>3.9</td>
<td>5.5</td>
</tr>
<tr>
<td>Overbraking / Oversteering</td>
<td>4.5</td>
<td>4.8</td>
<td>6.2</td>
<td>4.1</td>
<td>3.2</td>
</tr>
<tr>
<td>Excess speed (limit+conditions)</td>
<td>43.2</td>
<td>20.3</td>
<td>41.3</td>
<td>37.7</td>
<td>33.7</td>
</tr>
<tr>
<td>Close following</td>
<td>10.1</td>
<td>13.1</td>
<td>8.7</td>
<td>10.7</td>
<td>13.4</td>
</tr>
<tr>
<td>Aggressive recklessness</td>
<td>7.7</td>
<td>0.7</td>
<td>7.2</td>
<td>5.6</td>
<td>5.3</td>
</tr>
</tbody>
</table>

Table 3, shows the percentage of total accidents in the sample involving specified causation factors (cfn) (from the accident causation coding pilot) for different driver groups. Figures show percentage of accidents involving the specified factor where the young driver was judged primarily at fault.
Table 3

<table>
<thead>
<tr>
<th>Factor (% in each column/group)</th>
<th>Male drivers (n=1079)</th>
<th>Female drivers (n=312)</th>
<th>All 17-19 year olds (n=496)</th>
<th>All 20-22 year olds (n=469)</th>
<th>All 23-25 year olds (n=426)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slippery road (cf41)</td>
<td>27.4</td>
<td>26.3</td>
<td>27.6</td>
<td>27.5</td>
<td>26.3</td>
</tr>
<tr>
<td>Impairment, alcohol (cf1)</td>
<td>9.2</td>
<td>1.6</td>
<td>5.4</td>
<td>7.7</td>
<td>9.6</td>
</tr>
<tr>
<td>Failure to judge other's path or speed (cf12)</td>
<td>7.7</td>
<td>8.7</td>
<td>7.5</td>
<td>7.9</td>
<td>8.5</td>
</tr>
<tr>
<td>Excess speed (cf21)</td>
<td>53.8</td>
<td>24.0</td>
<td>48.0</td>
<td>48.0</td>
<td>44.6</td>
</tr>
<tr>
<td>Close following (cf22)</td>
<td>13.3</td>
<td>21.2</td>
<td>10.7</td>
<td>14.1</td>
<td>21.4</td>
</tr>
<tr>
<td>Careless/thoughtless/reckless behaviour (cf9)</td>
<td>36.5</td>
<td>16.7</td>
<td>32.7</td>
<td>30.3</td>
<td>32.6</td>
</tr>
</tbody>
</table>

Though the two coding schemes are not analogous, certain similarities can be observed. The percentage of cases involving alcohol impairment in the male driver group is over four times the percentage of similar cases involving female drivers; this occurs across both coding schemes. The percentage of cases involving alcohol impairment also rises across the age groups in both schemes. Male drivers also show over twice the percentage of excess speed involvement.

The situation regarding reckless behaviour is somewhat more confused, as this is a separate category in the first coding scheme, and is included as a blanket category in the second, where it is grouped with 'careless/thoughtless' behaviour. Nevertheless, a distinct gender difference in the percentages is observed.

Gender differences are also apparent in the close following factor, with females showing more percentage involvement than males. This factor also seems (like alcohol impairment) to show a rise across age groups. This perhaps explains the results shown earlier (Figure 2 and Table 1), which suggest that females and the older age groups have a higher percentage of their accident involvement as rear-end shunts.

It should be noted that Tables 2 and 3 show results from coding schemes that operate quite differently in some ways, which explains why some percentages can seem markedly different across the two schemes. However, the pattern of percentages relating to similar factors across the schemes seems to tell the same story.
Qualitative analysis and discussion

This has been a statistical overview of the database as it stands currently. The project is ongoing, and such analyses set the scene for the more detailed qualitative work that will subsequently occur.

We are at the initial stages of building an analytical schema that might more fully investigate the sequential nature of accidents in our sample. There are, to start with, factors involving young drivers that can be of long standing. These include, firstly, putting oneself repeatedly in a situation of danger, eg by driving consistently over the speed limit, close following of other vehicles etc. These can interact with other background risks, such as number of passengers, inexperience of driving etc. All these risk factors can exist for an indefinite length of time, or 'lag', without an accident ever occurring. But certain trigger factors can then act as a catalyst to precipitate an accident. These triggers can be active, passive or, more importantly, 'invisible'. An example of a 'non' or 'invisible' trigger factor is the situation in rural bend accidents where, up until the point where the tyres lose adhesion on the road, there is virtually no feedback to the driver indicating that something is about to go wrong.

The nature of the indefinite lag between the initial factors has implications according to learning theory. Behaviour that is learned under indefinite lag conditions shows characteristics similar to those of a variable ratio reinforcement regime, in that typically the behaviour is very hard to extinguish. To again use the example of a rural bend accident, the driver may have driven round bends of the same severity a great many times under similar conditions, each time never knowing how close he/she actually is to sending the car out of control. On the one occasion that things go wrong, and an accident is precipitated as a result, the driver typically cannot understand how the accident has occurred. They have learned in the past that their behaviour is 'safe', and cannot now recognise that it was not. Comments from police interviews that reveal this attitude include:

Driver A: "I had reduced my speed to a speed slightly faster than the speed limit, but one which normally I would expect to be able to take the corner without difficulty at ... Even though I drifted a bit, I am sure that I never reached a point when I was totally out of control."

Driver B: "I wasn't doing anything wrong, it just went."

Driver C: "I wasn't going too fast, it just went."
Driver D: "Well, it was alright yesterday when my friend drove round it."

Driver E: "I feel it was because of the road surface."

Driver F: "I can't understand . . . I think something was on the road."

The various factors in the analytical schema are summarised in Figure 17.

**Figure 17: Analytical schema of causation factors**

In principle both the 'putting of self in a situation of danger', and the 'background' factors are avoidable and unavoidable risk factors; one or the other or both are the scene setters for a later trigger event that precipitates an accident. The investigation will focus on what particular risks go with which trigger event and/or responses.

**COUNTERMEASURES**

Taking the A case accidents, the next step was to consider, for each case in turn, any simple behavioural countermeasure which could have made a substantial difference to the outcome of the accident, either by preventing it or reducing its severity. A list of 28 possible behavioural strategies for avoiding typical young driver accidents was drawn up using established texts such as Roadcraft and The Highway Code, together with prior knowledge of the data. The countermeasures were concerned solely with simple driver behaviours and did not extend to
road/vehicle engineering factors which were outside the scope of this study. Tables 4–7 below show the top five countermeasures for each of the four accident categories, except with rural bend cases (Table 6), where only three main countermeasures were felt to apply to the majority of cases. The overriding message in rural bend accidents is, simply, drivers must slow down, preferably before entering a corner.

Table 4: Top five countermeasures for drivers most at fault in right turning accidents

<table>
<thead>
<tr>
<th>Measure</th>
<th>Frequency</th>
<th>% of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ensure foreground to distance is checked properly with a sweeping gaze</td>
<td>101</td>
<td>24.2</td>
</tr>
<tr>
<td>Come to a stop at junctions, especially if the view is in doubt</td>
<td>78</td>
<td>18.7</td>
</tr>
<tr>
<td>Re-check to the right (first point of danger) before pulling out</td>
<td>65</td>
<td>15.6</td>
</tr>
<tr>
<td>Give yourself enough time to be sure of the speed of approaching traffic</td>
<td>59</td>
<td>14.1</td>
</tr>
<tr>
<td>On approaching junctions, check your speed and look for emerging traffic</td>
<td>56</td>
<td>13.4</td>
</tr>
</tbody>
</table>

Table 5: Top five countermeasures for drivers most at fault in rear-end shunt accidents

<table>
<thead>
<tr>
<th>Measure</th>
<th>Frequency</th>
<th>% of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keep a safe stopping distance from the vehicle in front</td>
<td>81</td>
<td>27.0</td>
</tr>
<tr>
<td>Don't allow yourself to become distracted by anything (either inside or outside the vehicle) while driving</td>
<td>72</td>
<td>24.0</td>
</tr>
<tr>
<td>Look ahead of the vehicle in front for any hazards that might cause it to slow/stop</td>
<td>60</td>
<td>20.0</td>
</tr>
<tr>
<td>Ensure appropriate speed/distance in adverse weather conditions</td>
<td>27</td>
<td>9.0</td>
</tr>
<tr>
<td>Ensure foreground to distance is checked properly with a sweeping gaze</td>
<td>22</td>
<td>7.3</td>
</tr>
</tbody>
</table>

Table 6: Top three countermeasures for drivers most at fault in rural bend accidents

<table>
<thead>
<tr>
<th>Measure</th>
<th>Frequency</th>
<th>% of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ensure appropriate speed for bend severity: if in doubt slow down</td>
<td>160</td>
<td>73.1</td>
</tr>
<tr>
<td>Ensure appropriate speed/distance in adverse weather conditions</td>
<td>96</td>
<td>43.8</td>
</tr>
<tr>
<td>Avoid braking while travelling around a bend; finish braking before entry</td>
<td>47</td>
<td>21.4</td>
</tr>
</tbody>
</table>

Table 7: Top five countermeasures for drivers most at fault in darkness accidents
<table>
<thead>
<tr>
<th>Measure</th>
<th>Frequency</th>
<th>% of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ensure appropriate speed for bend severity: if in doubt slow down</td>
<td>153</td>
<td>23.5</td>
</tr>
<tr>
<td>Ensure appropriate speed/distance in adverse weather conditions</td>
<td>120</td>
<td>18.5</td>
</tr>
<tr>
<td>Ensure foreground to distance is checked properly with a sweeping gaze</td>
<td>55</td>
<td>8.5</td>
</tr>
<tr>
<td>Don’t allow yourself to become distracted by anything (either inside or outside the vehicle) while driving</td>
<td>52</td>
<td>8.0</td>
</tr>
<tr>
<td>Come to a stop at junctions, especially if the view is in doubt</td>
<td>47</td>
<td>7.2</td>
</tr>
</tbody>
</table>

DARKNESS - A HETEROGENEOUS GROUP

When the darkness accidents were examined, it was found that there were 118 A cases that could not be assigned any of our 28 countermeasures. These cases included:

- 39 cases involving excess alcohol; these were assigned no countermeasure at present because it was felt, in these initial stages at least, that the consequences of driving having consumed alcohol were already well understood by the majority of the driving population; 22 of these cases involved drivers carrying passengers

- 25 cases involving deliberate speeding, recklessness etc, usually as a result of ‘thrill-seeking’ behaviour which seems to be often linked to peer pressure, desire to impress, etc; 18 out of these 25 cases involved drivers with passengers of a similar age, or racing with friend(s) in other vehicles

- five cases involving stolen vehicles (TWOC)

- six cases of red-light running, nearly all ‘passive’ ie the young driver was hit by an older red-light runner

- 12 cases where pedestrians entered the road without due care, the young driver apparently being blameless

- 10 cases involving overtaking, the majority being caused by failure to appreciate restricted views of the road ahead caused by factors such as bends and hill crests; these cases were assigned a countermeasure reflecting this observation problem (no. 6).

The remaining 21 cases had miscellaneous causes that it was felt no countermeasure could address, for example, being dazzled by oncoming headlights, tyre blowouts (not caused by defects), collision with unlit and unmarked road works, etc.

In the final stages of the project, two of the things that remain to be done are to extract themes and patterns of medium
generality from the four accident types taken separately, and to attempt some overall generalisations which are typically true across all the case types, without being too banal. The medium-range synthesis will depend on more detailed examination of the database over the next few months, but some of the broadest conclusions can probably be sketched in tentatively even now.

Some of the accidents of young drivers are due to actions and mistakes that are typical of young drivers in particular. Others happen for reasons that apply to all drivers. Both sets of causes should be included. (We want young drivers to be on their guard against all the causes of accidents that might affect them, not just those which are peculiar to them.) But the two sets of causes should also be distinguished. (An understanding of the processes that give young drivers their exceptional accident liability requires us to pick out the accidents that are especially associated with youth and inexperience.)

Accidents in the dark might be expected to arise from problems of visibility. We find this not to be generally true. The hours of darkness are not only a time of reduced visibility and artificial lighting, they are also a time quite unlike mornings and afternoons, when different groups of road users are about, travelling for different reasons, and in different ways. To a striking degree, the problems of accidents in the dark are not a matter of visibility, but rather a matter of who uses the roads at night, and why, and how.

For many young drivers, especially males - to judge from those who end up in accident case files at least - driving is fun, challenging, exciting, a way of testing themselves, and a way of showing off. Of course there are limits. Speed, road conditions, weather, traffic, and vehicle performance all combine to produce a 'space' - a part of the multi-dimensional graph describing vehicle, driver and environment - in which one can move about safely. The safe region has edges. (Test pilots call them 'the envelope', and their job is to find and to 'push back' that envelope when flying new kinds of plane.) Some young drivers think they are test pilots too. Their interest is to find and explore the envelope, or else to assume they know where it is and to operate on its edges. They talk and behave as if this envelope - the dividing line between accident-free driving and collision - is visible, precise and stable. If that were true, they would get away with what they do, to the extent they were as skilful as they thought. But they are prancing on a crumbling cliff, not a hard edge. If it gives way, it will do so without warning, without apparent cause, and without the chance of recovery. No one knows exactly where the dangers lie. There is no clear line between safety and catastrophe. And what division there is, is constantly changing. Given that 'the envelope' works
like that, the only skill is to keep well away from the edge. This is the essential message that we must put across to young drivers.

They think that the driving styles that have been accident-free in the past will be accident-free in the future, unless they make a noticeable change - but they are wrong. They think that unsafe driving will soon reveal its dangers, and they can learn - but they are wrong. The normal conditions of successful learning do not apply.

The game of Russian roulette is not proved safe if you hear three clicks and no bang. The game of Russian roulette is only safe for those with the sense not to play it.

Conclusions

The work described here is ongoing - the main phase of the project will be completed by the end of July 2001. Important differences are emerging in the accident involvements that typify different groups of young drivers. Differences have been examined here with regard specifically to age, gender, experience, attitudes and countermeasures. Future analysis will further investigate the sequential nature and specific failure points within the four categories of young driver accident. The work described so far has proved a useful beginning to such future research.

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15 Research in traffic and medical accidents: A search for common themes

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Introduction

Research into the behavioural causes of traffic accidents has a long history and much has been learned. The research has been informed by developments in psychology and the study of non-traffic accidents. Research into the behavioural causes of medical accidents is very much in its infancy. There has been a great deal written about poorly performing doctors and recently there has been an upsurge in concern over the high error rates in clinical practice and the escalating costs of negligence claims, but very little has been done to research the psychological and behavioural factors involved. The purpose of this paper is to examine what has been learned in the field of traffic accidents and discuss how this might apply to our understanding of medical accidents. It will also examine whether there is anything that has been learned in the field of medical accidents that might provide new insights into traffic accident causation or prevention. The idea of comparing medical and traffic accidents appears to be novel, although there have been comparisons between industrial and medical accidents (Spencer, 2000) and more general accident models have been applied in both cases (Reason, 1993).

Defining medical and traffic accidents

Traffic accidents are typically defined as any collision between a motor vehicle and an object, person or vehicle resulting in damage or injury. Medical accidents are defined as adverse outcomes in patients seeking treatment arising from errors or a failure to follow accepted good practice. Thus both are defined as physical events, not behaviours. Drivers can make mistakes, even serious ones, without an accident ensuing, and so, fortunately, can healthcare professionals.

Deciding whether a traffic accident has occurred is not without its problems. Thus a minor scrape or injury to a small animal may not be counted. Also, there may be a question of whether deliberate or 'semi-deliberate' actions would count. However, in practice it appears to be something that drivers or observers can report with reasonable reliability (eg Liddell, 1982). With medical accidents it is more difficult. Table 1 summarises key issues arising in the definition of traffic and medical accidents.

One complicating factor with medical accidents is that the patients are generally sick and the job of the medical practitioner is to find out what is wrong and put it right or mitigate the harm. Therefore one avoidable adverse outcome is a failure to perform this task to an acceptable standard. For example, if a GP fails to diagnose cancer by not asking the right questions or not ordering the required investigations, or ignoring the notes, or not making the connection between the symptoms and the disease, then that is a medical accident just as much as if a surgeon cuts off the wrong leg. Thus, in a sense, in medicine there may have already been damage and the accident is that it is not properly dealt with. Another complication is that much modern medicine involves teamwork. In a traffic accident there is, generally, only one person at the wheel. In medicine there may be many people with hands on the wheel and a patient's welfare may be affected by any one of those or combination of them. A further complication is that medicine is as much art (or artifice) as science and many medical problems are insurmountable. Therefore, it is often much more difficult to determine...
whether a reasonable standard of care has been provided. When a vehicle crashes it is rarely because of the difficulty of the task; generally someone is to blame. In practice this means that to determine whether there has been a medical accident, it is necessary to have some form of inquiry involving experts. This often takes the form of analysis of case notes, which clearly raises further issues about the accuracy and completeness of source data. A final issue is that what constitutes good practice is constantly changing and individual clinicians often disagree with edicts emanating from institutional arbiters of good practice. For example, the Department of Health, NHS and all the relevant professional bodies agree that GPs should treat nicotine dependence with effective medications such as nicotine patches (West et al, 2000), but many GPs disagree with this and do not follow the guidance (McEwen and West, in press). Failing to follow the guidance will undoubtedly lead to avoidable health problems and death in some patients, but would it be right to treat these as medical accidents? In theory, yes; in practice, they would not be.

Table 1: Defining traffic and medical accidents

<table>
<thead>
<tr>
<th>Traffic accidents</th>
<th>Medical accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>Adverse outcomes in patients seeking treatment arising from errors or a failure to follow accepted good practice</td>
</tr>
<tr>
<td>Any collision between a motor vehicle and an object, person or vehicle resulting in damage or injury</td>
<td></td>
</tr>
</tbody>
</table>

**Issues**

- Severity of damage/injury
- Intentionality

- Severity of damage/injury
- Intentionality
- Pre-existing harm
- Involvement of teams
- Identifying whether an error has occurred
- Deciding what constitutes a reasonable standard

A framework for understanding medical and traffic accidents

Accidents can be studied as individual events or as rates (see Table 2). With regard to individual accident analysis, one can think of the proximal causation of individual accidents in terms of event sequences and consider for each event what would have happened if it had been different and what more distal causes might have led to it. For example, (Clarke et al, 1999) studied traffic accidents involving right-of-way violations in terms of the events immediately preceding these. Drife (1993) gives an analysis of an obstetric accident in which signs of fetal distress were not acted on promptly because of changes in shift and the midwife being inhibited about calling out a registrar.
Table 2: Types of research strategy

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysing individual accidents</td>
<td>• Identify <em>proximate</em> causation in terms of chain of events</td>
</tr>
<tr>
<td></td>
<td>• Include events where the presumption of a causal link with the accident can be made</td>
</tr>
<tr>
<td></td>
<td>• For each event, identify <em>distal</em> causation in terms of background factors</td>
</tr>
<tr>
<td>Studying co-variation between accident rates and other variables</td>
<td>• Identify <em>unit of analysis</em> (eg driver, medical team, nurse)</td>
</tr>
<tr>
<td></td>
<td>• Identify <em>unit of exposure</em> (eg month, 100 operations)</td>
</tr>
<tr>
<td></td>
<td>• Identify <em>putative causal factors</em> specified as variables (eg frequency of drink-driving, conscientiousness)</td>
</tr>
<tr>
<td></td>
<td>• Examine <em>co-variation</em> between accident rates and putative causal variables, controlling for possible confounding variables</td>
</tr>
</tbody>
</table>

Considering accident rates, one has to consider two additional factors: the unit of analysis (the driver, the patient, the doctor, the section of road, the country etc) and the unit of exposure (one year, 100 cases, 1,000 miles etc). Determining causes using accident rates is then often a matter of examining co-variation between these rates per unit of exposure and other factors. These factors may be features of the unit of analysis which may be stable factors (driver personality, driving speed, conscientiousness, level of training etc) or rates of occurrence of unstable factors (driving while tired, driving while intoxicated, etc); or features external to the unit of analysis which also may be stable factors (poor safety culture, inadequate protocols etc) or rates of unstable factors (bad weather, high traffic density, conflicts at work etc). There are many examples of this kind of analysis in traffic accident research (eg Elander et al, 1993).

Rates of death and injury from medical and traffic accidents

Traffic accidents are very common, although rates of death and injury are comparatively low. Thus in Great Britain in 1999, there were 3,421 deaths, 40,834 serious injuries and 280,957 minor injuries reported on the roads (DETR, 2000). It is not known how many non-injury accidents there are, but surveys of road users suggest an average accident rate per driver of one every 10 years (Maycock *et al*, 1991).
Medical accidents are also very common, and the numbers killed or injured are far greater than for traffic accidents. In an analysis of the case notes from 30,121 hospitalised patients in the USA it was found that errors occurred with about one in 50 hospital admissions leading to prolongation of stay, disability or death (Leape et al, 1991). The chances of a hospital admission resulting in death from error in management was found to be one in 300 (Schenkel, 2000). A similar Australian study of 14,179 case notes found one in 12 admissions to result in an avoidable serious adverse event (Weingart et al, 2000) and one in 50 admissions involving errors that led to the death of the patient. Less is known about the UK situation but one small study involving 1,014 patient records found similar rates. Errors occurred in one in 40 admissions leading to at least moderate disability; avoidable deaths occurred in about one in 200 (Vincent et al, 2001). Thus in the USA it is estimated that up to 100,000 deaths may be caused by medical accidents in hospital (Schenkel, 2000), while in the UK the figure is put at around 13,500 (Towse and Danzon, 1999).

There have been numerous analyses of errors in more specific medical situations. For example, an analysis of quality of care prior to admission into intensive care in 100 consecutive cases revealed that 54 cases received sub-optimal care (McQuillan et al, 1998). Another study examined causes of death in 149 patients who died in intensive care and found that in 42 per cent of cases there had been errors in diagnosis, most commonly involving undiagnosed infection (Mort and Yeston, 1999). A study of adverse drug reactions in India reported that avoidable adverse drug reactions occurred in 2 per cent of hospital admissions (Bhatt, 1999), and a comparable study in Europe found that approximately one in 100 of all hospital admissions were caused by avoidable adverse drug reactions (Raschetti et al, 1999).

These figures do not include mistakes occurring in general practice nor in routine screening (e.g. cervical screening and breast screening). In fact almost no research has been conducted in general practice, but an Australian study recruited 324 GPs to report 'critical incidents' over periods of up to 18 months. During that time 805 incidents were reported, of which 79 per cent were judged to be preventable and 27 per cent were judged to have the potential for long-term or permanent harm (Bhasale et al, 1998). Errors in screening are well documented in the press although systematic study of the rates of these is absent.

Most studies have focused on doctors and very little is known about other professional groups. With regard to nursing care it has been suggested that a critical incident approach could be helpful in that area (Meurier, 2000). Administration of drugs by
nurses has come under some scrutiny. In one hospital in Switzerland it was found that errors of one kind or another occurred in 27 per cent of drug administration cases (Schneider et al, 1998). These were mostly errors in timing of doses, administration technique and preparation. A study of pharmacists found that 72 per cent reported knowing of an undetected dispensing error in the past six months (Peterson et al, 1999).

The figures cited above represent the severe end of the spectrum. There can be little doubt that the rates of minor harm are much greater.

**Behavioural causes of traffic and medical accidents**

There has been considerable progress in modelling the causes of traffic accidents, taking into consideration environmental and behavioural factors (Abdel-Aty and Radwan, 2000). A relatively small proportion of the research undertaken has focused on analysis of individual accidents from a behavioural perspective, but there have been studies examining chains of events in particular traffic situations (Clarke et al, 1999). One possible reason for the paucity of this kind of research is the apparent simplicity of the sequence of events and the difficulty in drawing more general lessons from it. However, this approach has served to highlight the importance of factors such as driver fatigue (Connor et al, 2001).

Considering accident rates and focusing on the driver, certain themes emerge. First of all, individuals do appear to have a higher or lower risk of accident relative to each other measured over a given period of time, controlling for age, sex and mileage driven (eg French et al, 1993). Second, this relative risk is quite stable over time, although in novice drivers the overall risk declines with increasing experience (eg West and Hall, 1998). Third, this 'accident liability' is associated with more risky driving practices, particularly faster driving (West et al, 1993b). Fourth, accident liability is associated with more general personality traits, in particular social deviance. For example, several studies have found associations between questionnaire measures of social deviance and accident rates in drivers (Meadows et al, 1998; West et al, 1993a). Moreover, there is consistent and strong evidence linking criminal records with traffic accident rates with potential confounders controlled for (Junger et al, in press; West, 1998). Fifth, accident liability may be associated with ability to identify and respond appropriately to potentially risky situations (for a review see Elander et al, 1993).

If one focuses on pedestrians the situation is not so well researched, but it is apparent that children differ in accident
liability after controlling for age, sex and indices of risk exposure (Wazana, 1997; West et al, 1998). Moreover, accident liability is associated with risky behaviour and wider social deviance (Wazana, 1997; West et al, 1998).

It is worth making the point here that the study of individual differences in accident rates is aimed not only at identifying those at increased risk, but also establishing variables that are important and which may be acted upon at a population level. For example, the fact that more socially deviant individuals have more accidents suggests targeting social responsibility as a key variable in reducing accident rates generally. Thus, even though the 'variance accounted for' in accident rates may be low, the demonstration of a link with a predictor variable highlights the potential importance of that variable per se in accident causation.

Determining the role of alcohol consumption in accident rates has been a major theme of traffic accident research (Longo et al, 2000a; Longo et al, 2000b; Mounce and Pendleton, 1992; Skog, 2001; Zador et al, 2000). The most common methodology has been the case control study. One problem with this approach is the difficulty in controlling for confounding factors. Most notably, drink-driving rates are correlated with social deviance which is itself correlated with accident rates. However, several studies have found that higher rates of drink-driving were correlated with higher accident rates controlling for social deviance in novice driver samples (Horwood and Fergusson, 2000; West and Hall, 1998). In older drivers the relationship may be weaker (French et al, 1993).

Considering the risk environment, weather conditions and type of road are clearly related to accident risk (Abdel-Aty and Radwan, 2000; Bagley, 1992; Carson and Mannering, 2001; Cubbin et al, 2000). Measures to slow drivers down, protect pedestrians and control traffic intersections, while difficult to evaluate scientifically, have been argued to reduce accident rates. On the other hand, there is a question over whether the marked reductions in fatalities reflect fewer accidents or better protection of vehicle occupants. Thus, the rates of minor injuries from accidents have been static over recent years (DETR, 2000).

The behavioural causes of medical accidents have been subject to considerable analysis but relatively little systematic research. Examination of individual accident scenarios has tended to dominate and these tend to be descriptive rather than analytical (eg Bankier et al, 1997; Barendregt et al, 1992; Bates, 1999; Blosser et al, 1998; Bradbury and Cruickshank, 2000; Drife, 1993; Galloway et al, 1999; Jenny et al, 1999; McQuillan et al, 1998; Meurier, 2000; Troxel and Sabella, 1994).
It has been pointed out that analysing individual cases can be misleading. Thus a recent article reminds us of the pioneering work of Shewhart in seeking to locate the cause of variation in a system (Mohammed et al, 2001). Shewhart's approach categorises variation according to the actions needed to reduce it. It distinguishes between 'common-cause variation' which is intrinsic to a process and 'special-cause variation' which results from factors extrinsic to the process and requires action on these special causes. Shewhart argued that values that lie more than three $s$ from the mean of a series (where $s$ represents a variant on standard deviation allowing for correlated values over time) can be regarded as resulting from special causes - otherwise they are a product of common causes. In applying this to medical accidents Mohammed et al, 2001 show how high death rates in the Bristol heart surgery case and the Shipman case could have been picked up earlier. The general idea of looking for outliers in a series seems no more than common sense; it is the value chosen for the threshold that arguably lends power to this method. The threshold has been found to work well in physical sciences, but it remains to be seen what new insights it can generate in the field of medical or other accidents.

Moving on to consider rates of medical accidents, one study found that prescription errors were more likely in inexperienced doctors and in obstetrics and gynaecology and surgery and anaesthesia services (Lesar et al, 1990). Another study followed up 314 medical students and explored links between problems they experienced and their standard of care (Firth-Cozens and Greenhalgh, 1997). It was found that newly qualified doctors who reported higher stress levels also reported making more mistakes. The authors recognised that there may be some confounding because the doctors were also more self-critical and so there may be a reporting bias involved (Firth-Cozens, 2001). However, another study found that a stress reduction programme for clinicians in a hospital reduced malpractice claims compared with a control hospital (Jones et al, 1988). A study of interpretation of abdominal CT scans found significant differences between the error rates of five radiologists, supporting an accident liability concept (Bechtold et al, 1997). It is interesting that the authors interpreted their findings in terms of radiologists' expertise, but it is plausible that other attributes such as conscientiousness may have played a role.

Much has been written about 'sick doctors' (ie those with psychiatric problems or alcohol and drug dependence) (Brooke et al, 1991; Chiodo and Tolle, 1997; Fowlie, 1999; Rucinski and Cybulaska, 1985; Thapar, 1989) but there is little research on links between these and error rates or on factors that predict problem behaviour in clinicians. Perhaps surprisingly, there
have not been the studies on links between alcohol use and medical accidents that there have been with traffic accidents.

On a related theme, there has been research into doctors who are disciplined for professional misconduct or about whom disciplinary concerns have been raised. For example, one study in the Northern Health Region of England found that, in a five-year period, 6 per cent of medical staff had raised concerns among colleagues sufficient to warrant consideration of disciplinary action (Donaldson, 1994). The largest single cause was poor attitude or irresponsible behaviour, followed by lack of commitment to duties and inadequate knowledge. However, as with sick doctors, we do not know about the extent of associations with patient harm nor has there been systematic study of factors that lead to this behaviour. A study of 427 US surgeons found that those whose membership of a physician-owned malpractice trust was terminated because of a high rate of negligence claims against them were less likely to have completed fellowships, belong to clinical faculties or professional societies, have graduated in the USA or Canada, have speciality board certification or belong to group practices (Adamson et al, 1997). There is evidence of a relatively stable 'claim liability'. Thus one study of 8,247 US physicians found that having a malpractice claim between 1975 and 1980 increased the odds of a paid claim in the years 1981 to 1983 threefold (Bovbjerg and Petronis, 1994). However, a study of 3,686 Florida physicians found that malpractice claims were related to markers of greater rather than less medical knowledge (Ely et al, 1999). The problem with using litigation as a marker of error is that the correspondence between the two is very low. For example, examination of case notes suggests nine cases of negligence for every successful claim and many claims are unfounded (Lynch et al, 1996). Moreover, claims appear to have more to do with a poor doctor-patient relationship than error (Beckman et al, 1994). Moreover, claim rates appear to be affected by the area in which doctors practise (Kaplan, 1998).

Interestingly, while traffic accident research has attempted to tackle the difficult issue of accounting for risk exposure, this has been dealt with incompletely or not at all in the medical accident field. It has generally been presumed that calculating rates over time or per operations carried out etc is sufficient. However, this may not be so. As one becomes more senior and expert one tends to encounter more difficult cases and the opportunity for onward referral reduces.

Conclusions

The study of behavioural factors in medical and traffic accidents has followed very different paths. Medical accidents
have typically been studied through analysis and description. The presumed causes have tended to be a small number of bad doctors and unsafe systems. Corrective action has typically been to try to weed out bad doctors, retrain them or rehabilitate them and to establish guidelines for practice and to some extent instil a better safety culture (eg Bates, 1999; Berliner, 1999; Breen et al, 1998; Chao, 1987). Behavioural causes of traffic accidents have been studied largely through analysis, of factors associated with accident rates. Considerable advances have been made using this approach. In many studies the road user has been the unit of analysis although studies have also been carried out focusing on locations or other targets. The challenges facing the two areas of research have differed somewhat. Defining traffic accidents, while not without its problems, has been relatively successful and measurement has been relatively easy. For medical accidents, it generally requires considerable effort and more than one expert judge to determine whether an avoidable adverse event has occurred. This makes the task of collecting data from a large sample expensive and difficult. Proxies such as negligence claims have been used, but there are problems here in that there is only a weak correspondence between such claims and actual error.

In attempting to determine what, if anything, the two areas of study might learn from each other, one might conclude the following.

- Medical accident research may benefit from considering individual variability in accident liability as extending across the whole range of clinicians and not just in terms of identifying ‘bad’ doctors. The purpose is not just to identify high-risk clinicians but to establish the underlying causes of accidents which may be amenable to remedial action.

- In doing so, it could benefit from examining links between liability and variables that have been shown to predict traffic accidents, particularly social deviance and low conscientiousness.

- Traffic accident research may benefit from greater use of detailed analysis of specific accidents with a view to learning more general lessons from them. This might extend beyond mathematical descriptions to detailed qualitative analysis setting out chains of events and the role that distal causes might have in provoking those events.

In both areas of study, a common theme underlying remedial measures would appear to be the notion of ‘risk management (Spencer, 2000; Vincent et al, 2000). This recognises that it is unrealistic to hope that accidents can be eliminated. Therefore, an appropriate response is to establish systems for minimising both their occurrence and the harm that ensues.
References


16 On-the-spot research: Investigating human, highway and engineering factors in accidents

Julian Hill, VSRC, Loughborough University

Abstract

A new 'on-the-spot' (OTS) accident research project is now underway in the UK. This project enables expert investigators to attend the scene of an accident within 15 minutes of the incident occurring, which allows the collection of accident data that would otherwise be quickly lost. This paper considers previous studies and the justification for a new research approach before describing methodology used on the spot and during subsequent follow-up research. Investigations focus on all types of vehicles (including damage, failures, features fitted and their contribution); the highway (including design, features, maintenance and condition); the human factors (including drivers, riders, passengers and pedestrians); and the injuries sustained. Five hundred crashes will be studied in depth each year. The project objectives include establishing an in-depth database that will permit analyses to understand better the causes of crashes and injuries, and assist in the development of solutions.

Introduction

In order to develop effective strategies to reduce road crashes and injuries, national administrations and the motor industry have long recognised the need to determine what is happening in the real world. This is best achieved through carrying out in-depth crash investigations.

The UK was home to some of the earliest rigorous and scientific on-the-spot crash research carried out at the scene of road traffic crashes. Such in-depth investigations were begun in the UK by Starks and Miller at the Road Research Laboratory (DSIR, 1963). Mackay subsequently founded the Accident Research Unit at the University of Birmingham (Mackay, 1969) and put a multidisciplinary team in place to research the causes of crashes, the causes of injuries and vehicle crashworthiness. This work was expanded by Ashton and Staughton. (1977) to include on-the-spot pedestrian crash research yielding results relating vehicle design, velocity and injury patterns. A further team at the TRRL also conducted on-the-spot accident investigations (Sabey and Staughton, 1975) assessing factors that included the causes of crashes. Sabey and Staughton went on to quantify the role in road accidents of environment, vehicle and human factors.

CURRENT ON-THE-SPOT STUDIES

There are a number of on-the-spot accident investigation studies active across Europe today. These include the in-depth database maintained by the team at MUH (Otte, 1997), and the work of INRETS (Girard, 1993) currently examining crash causation in Salon de Provence and pedestrian injuries in Lyons. The European Accident Causation Study (EACS, 1998) is jointly funded by the European car constructors (ACEA) and the European Commission to study vehicle, road, traffic and human behaviour, together with some attention to the causes of injuries. EACS functions in addition to a number of independent studies conducted by several of the motor manufacturers.

Despite the considerable value of on-the-spot accident research, it has possibly not made the greatest contribution to in-car safety over the past 20 years. This is because a number of real-
world, retrospective studies have operated over this time and have played a much more important role in providing detailed in-depth crash injury data. One of the best-respected studies is the UK Co-operative Crash Injury Study (CCIS, 2001) which has been running since 1983. Similar studies are operated by NASS in the USA.

Mackay et al (1985) described the retrospective approach and the benefits found in comparison to on-the-spot methods. Retrospective studies, such as the CCIS, are inherently more cost effective because resources are focused on crashworthiness and injury investigations without additional costs associated with maintaining personnel on standby for long periods. Investigators examine cars at recovery yards, often several days post-impact. Thus the CCIS has been able to build a large, detailed crash-injury database that continues to provide valuable inputs to the regulatory and vehicle design processes. Carsten et al (1989) also demonstrated the value of such retrospective investigations in studying the causes of urban crashes.

However, the retrospective approach cannot be used to obtain perishable (volatile) accident data such as trace marks on the highway, pedestrian contact marks on vehicles, the final resting position of the vehicles involved, weather, visibility, traffic conditions and full witness details. Such information is lost during the clearing of the accident scene and it is only by prompt attendance at the scene of the crash that such information can be reliably obtained. Indeed, a review of retrospective studies will show that the breadth of good-quality data obtained is not generally as extensive as the results obtained by on-the-spot studies. It is possible, for example, to obtain accurate measurements of the positions of debris and of the vehicles themselves after the impact, instead of having to rely on sketches from drivers or police officers. Furthermore, interviews with those directly or indirectly involved in the crash may be attempted. Here there is the further advantage that the interviewee will have a recent memory of events and will not have had time for memory to be modified or for details to be forgotten.

Concern is now increasing for pedestrians and other vulnerable road users. Governments and vehicle manufacturers are recognising that all road users need to be protected, and as such are interested in not only the consequences of road crashes, but also in crash causation, road user behaviour and the effects of road engineering. Much of the information that is necessary to understand these complex issues is found at the scene of the crash and is lost once the accident scene is cleared. Current and accurate real-world data are needed and, as noted by Mackay et al (1985), retrospective methods are not adequate for investigating pedestrian impacts.

The New OTS Project

OTS is a new on-the-spot accident investigation method developed to overcome a number of limitations previously encountered. The new UK teams work closely alongside local police. This link is strengthened by the inclusion of a serving police officer on each team, which ensures a secure, direct and reliable link with the local police command and control system which provides immediate crash notifications. Response vehicles are used, driven by the OTS police officers, to give brisk journey times to the scene. In this way, it is possible to cover larger catchment areas than has previously been possible. It is a combination of the relatively large areas and increased traffic densities on modern roads that results in larger crash sample sizes than were attained in some earlier studies.
OTS is the result of over two years of preparation in the UK. The full project protocol was assembled by Morris et al (1999c) based on modules developed using a range of expertise from the VSRC (Morris et al, 1999a), TRL (Turner, 1999) and BARC (Hill et al, 1999a, 1999b). The method was tested and further developed using pilot studies in Nottinghamshire and the West Midlands over 1998 and 1999 (Morris et al, 1999b).

The data gathered by the project focuses on:

- all types of vehicles (including damage, failures, features fitted and their contribution)
- the highway (including design, features, maintenance and condition)
- the human factors (including drivers, riders, passengers and pedestrians and, where possible, data on the training, experience and other road user aspects that might have influenced the cause of the crash)
- the injuries sustained.

Protocols have been developed in line with recent international activities. These include the EC proposals for the development of a Pan-European Accident Database based on recommendations from the RS project (STAIRS, 1998, Ross et al, 1998). Similarly, the OECD RS9 Committee's common international methodology for in-depth (motorcycle) accident investigations (OECD, 1999) was considered when developing the protocols for motorcycle accident investigation. This has resulted in the UK OTS protocols being developed in line with the procedures set out in both STAIRS and the OECD RS9 methodology in order to make crash research data compatible across international projects.

**OBJECTIVES**

On-the-spot (OTS) accident data collection has been established with the following objectives:

- to establish an in-depth research database of a representative sample of road accidents in the United Kingdom
- to understand better the causes of crashes and injuries
- to assist in the development of solutions.

The remainder of this paper describes the organisation and methodology in place for OTS in the UK.

**PROJECT ORGANISATION**

The UK Department for Transport, Local Government and the Regions (DTLR) and the Highways Agency (HA), which is an Executive Agency of the DTLR, have both provided funding the two teams who are undertaking OTS investigations in England. The locations of the two studies are shown in Figure 1.

The Vehicle Safety Research Centre (VSRC) at Loughborough University covers the south Nottinghamshire area in the East Midlands.

The Transport Research Laboratory (TRL) is covering the Thames Valley region in the south-east.
A holistic approach is taken to each OTS investigation. This is made possible because funding originates from Vehicle Standards and Engineering, Road Safety Division at the DTLR and the Highways Agency. Consequently vehicle safety, human factors and highway engineering are all investigated together.

Data collection commenced towards the end of 2000 and will, in the first instance, continue until June 2003, resulting in a database consisting of at least 1,500 detailed crash reports.

**SELECTION OF STUDY AREAS**

Sample areas were examined and designed to ensure that the severities of road accidents occurring within the sample areas were representative of the severity of accidents occurring nationally. The results of this investigation are shown in Tables 1 and 2.

**Figure 2: The VSRC investigation team in action alongside Nottinghamshire Police**
Accident severities within the two sampling areas approximate well to the national distribution of accident numbers, with a slight overemphasis on serious accidents in the VSRC region which is balanced by a slight underemphasis on serious accidents in the TRL region. The sampling areas were also chosen to ensure a representative sample of accidents involving different road users was examined, as shown in Figure 3.

Table 1: Numbers and percentages of road accidents for 1998, classified by injury severity: VSRC study region and GB national statistics

<table>
<thead>
<tr>
<th>Accident injury severity</th>
<th>VSRC study region</th>
<th>GB national statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Killed</td>
<td>41</td>
<td>1.6</td>
</tr>
<tr>
<td>Serious</td>
<td>514</td>
<td>20.3</td>
</tr>
<tr>
<td>Slight</td>
<td>1979</td>
<td>78.1</td>
</tr>
<tr>
<td>Total</td>
<td>2,534</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 2: Numbers and percentages of road accidents for 1998, classified by injury severity: TRL study region and GB national statistics

<table>
<thead>
<tr>
<th>Accident injury severity</th>
<th>TRL study region</th>
<th>GB national statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Killed</td>
<td>32</td>
<td>0.8</td>
</tr>
<tr>
<td>Serious</td>
<td>373</td>
<td>9.8</td>
</tr>
</tbody>
</table>
Examining the accidents by road user type also shows that the sampling areas chosen are reasonably representative, with perhaps a slight over-sample of car occupant injury accidents in the TRL study region. The VSRC study region shows a slight over-sample of pedestrian accidents.

Areas chosen for the study were also made coincident with catchment areas for hospitals that were prepared to cooperate with the studies.

Ease of access to all areas of the study region was also important. Previous trials (Morris et al, 1999b) using blue light methods of reaching crash scenes have shown that all parts of each sample region must be reached within 15 minutes or else essential information will be lost. This has to be possible when maximum traffic congestion occurs as well as in quiet traffic conditions at night.

OTS crash investigations must relate to national data. The results of the STAIRS project, with which OTS is intended to be compatible, demonstrated the need to have a specified area that can be related to the national database for all reported injury crashes. All of the areas covered by OTS are completely...
identifiable from details within a unique police reference number, so a clear statistical link will be possible.

THE OTS TEAMS

Each OTS team is made up of some six investigators including a team manager, senior officer and a serving police officer. The project provides funding for both team police officers on a full-time basis. They are highly skilled advanced police drivers with crash investigation training and experience. VSRC and TRL also have personnel employed to provide follow-up support to the investigation team, including a medical specialist, police liaison officer and clerical officer. Both centres are further supported by local experts in human, vehicle and highway safety factors.

Typically, teams remain on standby for an eight-hour shift period and are ready to respond immediately to an accident notification from the local police control centre. The team travel to the crash scene in a specially marked high-conspicuity vehicle driven by the skilled police driver. The response team attending the accident consists of at least three investigators, including the police officer.

The two OTS teams use a rotating system of shifts which has been specially devised to ensure that each part of the day and night is equally covered by the shift periods. The plan also ensures that the days covered change so that, at the end of the year, the total cases will be statistically weighted to provide frequency estimates that are representative of the complete year.

The VSRC team office is located at the Nottinghamshire Police Traffic Wing in the centre of Nottingham. It lies at the centre of the radial network of trunk roads so that most points on the perimeter of the area can be reached very quickly.

The TRL team office is located at the TRL site in Crowthorne, Berkshire. The study region around TRL is traversed in the north by the M4 and in the south by the M3 and contains both junctions 11 and 12 of the M25. The location of any accident within the catchment area can be reached extremely rapidly, despite the often significant levels of traffic present on the roads in the region.

Both team regions contain a good mix of A and B roads and rural, urban and motorway environments.

ON-THE-SPOT PROCEDURE

Once the investigation team arrives at the scene of an accident, the safety of the investigation team, emergency services
personnel and the general public is the first priority. All team members are qualified in first aid, but to date this training has thankfully been unnecessary as ambulance personnel are usually present at the scene before the OTS team arrive.

The serving police officer on the OTS team has a very important role on arrival at the accident scene. It is his job to make contact with the police officer in charge of the accident scene and brief him as to the intended activities of the investigators. After safety and protocol issues are addressed, the team can then make contact with the various elements and people involved in the crash in the least invasive fashion possible.

A library of some 200 OTS forms has been prepared that cover all accident eventualities and possible vehicle, casualty and highway environments which may be encountered. A key objective is to capture within minutes of the crash the 'volatile' data which are present at the scene post-impact. The forms are therefore structured into priority levels such that the investigators begin with the most volatile information and progressively obtain as much additional information as possible, often obtaining some level 2 and level 3 information during follow-up activities on another day.

**ON-THE-SPOT PRIORITY LEVELS**

- **Level 1**: 'volatile' - the data are only available for a few minutes after the crash. Examples include vehicle rest positions, witness contact details and road surface and weather conditions.

- **Level 2**: available for two to three days - the data can be reliably collected several days after the crash. For example, tyre tread depth, and locations of roadside objects and traffic signs.

- **Level 3**: available semi-permanently - the data can be satisfactorily collected weeks or months after the crash. Examples include injury details and road dimensions.

**Investigative procedures**

As the investigation proceeds, the team collects the information required by the investigative protocols and makes video and photographic recordings of the accident scene. The vulnerable road users are considered first, followed by 'volatile' evidence on the highway such as contact marks, trace marks and damage to road features. Vehicles are investigated, with the smaller and more mobile vehicles being examined before the heavier vehicles. Detailed measurements are taken of the highway environment and all relevant information is recorded on a scene
plan. Finally all other information of interest is captured, time and scene conditions permitting.

CASUALTIES (INCLUDING PEDESTRIANS)

For all casualties, their post-impact positions, evidence of injuries and interaction with vehicles or other highway features are noted wherever possible. For pedestrians and cyclists, details of clothing (material properties, body regions covered and conspicuity) are also recorded.

VEHICLE INVESTIGATIONS

All vehicles encountered are examined regardless of type, age or the crash/occupant injury severity. Both primary and secondary safety features on the vehicle are considered, including:

- collision avoidance systems including ABS and speed limiters
- controls and lights: usage and condition on all vehicle types, including pedal cycles
- defects: tyres, brakes, steering, suspension
- crashworthiness: structures, bumpers, under-run guards (specification and fixings)
- damage assessment: full description, documentation and crash-energy calculations
- restraint systems: seatbelt usage, airbag effectiveness, pretensioner present, child restraint types, mounting and overall effectiveness
- occupants: injury causation (contacts), ejection/trapping
- loads: restraint and movement.

HIGHWAY INVESTIGATION

Details of highway layout are noted with special emphasis on safety features. Specific factors are assessed, as listed below.

- highway layout and design.
- traffic density.
- road surface: texture, temperature, friction, contamination.
- views and sight lines.
- signing, including visibility and positioning.
- meteorological conditions: precipitation, light levels, cloud cover, visibility, wind speed, temperature.
The local meteorological conditions are recorded in conjunction with road surface drainage and temperature measures. Based on the information collected, the investigator will seek evidence of crash causation and will assess any contributory factors on approach routes taken by each crash participant.

The trained investigation teams are always alert to possible visual illusion effects, environmental conditions, structural peculiarities, road structures and traffic control measures at the scene of an accident. Any existing safety scheme will also be appraised, where appropriate.

Finally, video recordings are made, at eye level, for the approach routes taken by each accident participant including pedestrians and cyclists.

WITNESS INTERVIEWS

Witnesses are identified, when possible, at the scene of the accident. If they give their consent, brief interviews are conducted immediately. Key witnesses details are then recorded, permitting more extensive interviews during follow-up investigations. Much consideration has been given to the style and labelling of the high-conspicuity clothing worn by both teams in an attempt to differentiate the research staff from the police attending the accident scene. The choice of clothing different from that of the police emphasises the neutral and independent stance of the investigators, as uniformed police officers do not interview crash participants for research purposes. In this way it is hoped that the researchers can gain the confidence of the interviewees and so obtain unbiased responses to research questions.

FOLLOW-UP INVESTIGATIONS

A number of follow-up investigations take place in the days after the first scene visit. The highway may be further examined during a follow-up visit, when specialist expertise may also be available. Skidding coefficient measurements may be taken by a SCRIM machine to determine whether road surface friction was a contributory factor. For motorcycle crashes, traffic flow exposure data are recorded under similar traffic conditions one week later, as required by the OECD methodology described earlier. Highway data held by local authority engineers may also be consulted in order to assess any previous history of crashes at the site.

Physical data recorded at the scene, including trace marks and debris locations, are used to calculate approach speeds and trajectories. Vehicle damage assessments also facilitate the determination of speed change at impact (delta V). Finally, the
analysis of velocity will attempt to calculate avoidance speeds to show the maximum travel speed at which the crash could have been avoided.

Injury data are obtained from hospitals and coroners by medical officers on each team. Strict data confidentiality procedures are rigorously observed, and permission has been granted by ethical committees at all participating hospitals.

Details coded for casualties include:

- characteristics: age, gender, mass, stature, predisposing medical conditions
- selected treatment details
- injury details: nature, extent, location and severity according to the Abbreviated Injury Scale (AAAM, 1990)
- anthropometric data suitable for reconstruction of pedestrian kinematics and possible mathematical modelling of interactions between pedestrians and vehicles
- general clothing, including motorcycle clothing
- motor and pedal cycle helmet specifications and damage.

HUMAN FACTORS

A postal questionnaire is sent to selected crash participants requesting further details concerning driving experience, familiarity with routes taken, vehicle details, injuries and other details. Previous experience with similar procedures at VSRC and TRL has consistently given a questionnaire return rate in excess of 60 per cent.

For those crashes where human factors are implicated as a cause, an investigation is made to identify the role of sensory, perceptual, cognitive and personal psychological factors. Investigators identify factors that appear to have a human factors component. The data are then reviewed by the human factors specialists on each team to determine key issues. In this way it is possible to attempt to state for each crash whether the key issues are:

- vehicle design, eg lighting, mirrors, A-pillar obscuration
- road design, eg sight lines, lighting
- driver experience/skill/judgement/impairment, eg training implications, alcohol.
CASE ANALYSES

A structured expert case review process is used to guide and advise the interpretation of all factors in each case. Reviews are held internally by each team, but also investigators are brought together at regular intervals with experts from VSRC, TRL, and other participating agencies, to assess and draw conclusions in the following areas:

- contributory crash factors
- crash prevention and remedial measures (in place or recommended, including new/future technologies)
- relevance to current research and/or regulatory issues
- feedback to investigators concerning methodology and improved practices
- quality control.

Contributory factors are classified using methodology developed by Broughton et al (1988). Causes of crashes are broken down into precipitating factors (eg 'Driver failed to avoid pedestrian') and contributory factors (eg 'view obscured by glare from sun'), each coded as 'definite', 'probable' or 'possible'.

CASE REPORT CONCLUDING REMARKS

Where possible, each case report concludes by listing contributory factors and possible counter measures under the following headings:

<table>
<thead>
<tr>
<th>Impacts to vehicles:</th>
<th>Precipitating factors, Causation factors, Possible countermeasures.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injuries to casualties:</td>
<td>Causation factors, Possible countermeasures.</td>
</tr>
</tbody>
</table>

Data management

A database has been designed using MS Access to hold all of the data collected during an investigation. This contains in excess of 3,000 fields that describe highways, cars, goods vehicles, buses, pedestrians, pedal cycles and motorcycles. Drivers, riders, passengers and their injuries may also be described in detail.

All information recorded will be completely anonymous and will not include personal details or other information that could identify individuals or their vehicles.
DATA ANALYSIS AND RESEARCH

Data analyses will be possible using a variety of software packages. The database will hold over 500 cases by the end of 2001, building to at least 1,500 by mid-2003. Statistical interrogations will be done using SPSS procedures. The case files will also be rich in video and photographic material that may be searched electronically and analysed on a case-by-case basis where required.

It is expected that the results from the OTS accident investigation project will make a significant contribution to road safety, vehicle crashworthiness and occupant protection. The safety improvements which will undoubtedly arise from this work will be seen not only in the UK but also in many other countries, which will be able to benefit from the high-quality research currently being carried out by VSRC and TRL.

Figure 4: The TRL investigation team in action

Acknowledgements

The OTS accident data collection project is funded by the Department for Transport, Local Government and the Regions (DTLR) and the Highways Agency.

This multidisciplinary crash research project would not be possible without help and support from a great number of individuals and organisations. The author would like to thank everyone who has helped to establish the OTS project, especially Nottinghamshire Police, Thames Valley Police, Hampshire Police, Surrey Police, the Queens Medical Centre in Nottingham, Frimley Park Hospital, Royal Berkshire Hospital, Heatherwood and Wexham Park Hospital, Her Majesty’s
coroners and the local authority engineers in both study regions.

The author would like to thank Pete Thomas and Martyn Smith at VSRC, Nigel Byard, team manager at TRL, and Iain Rillie at TRL for their help and contributions during the preparation of this paper. Additional thanks go to representatives of DTLR at Vehicle Standards and Engineering, the Road Safety Division and the Highways Agency for their continued help and guidance.

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A comparative approach to differential accident liability: Motorcyclists versus car drivers

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Different types of road users are at different risk of having a road accident. The aim of the present research is to explore the causal mechanisms behind the accident liability of a high-risk type of road user and a lower-risk type of road user.

The two types of road user to be compared were chosen according to the following criteria: there was to be a large and uncontroversial difference in accident risk between the two groups; at least one of the groups was easily accessible to make it possible to match demographic factors between the groups; and accidents involving the higher-risk group were viewed in the literature as a serious societal problem worthy of additional research. On the basis of these criteria, the high-risk group was chosen to be motorcyclists and the lower-risk group was non-motorcycling car drivers. After controlling for mileage, motorcyclists have been found to be eight times more likely than car drivers to be involved in an injury accident, over 20 times more likely to be injured themselves, and over 35 times more likely to be killed or seriously injured (Chesham et al., 1991).

Research into reducing the risk of 'unprotected' road-users (motorcyclists, cyclists and pedestrians) was judged to be of high importance by the Swedish National Traffic Safety Programme (Garder and Leden, 1998). Motorcycle safety was also judged to be an important area of research by a panel of international traffic experts, who ranked it more important than, for example, research into driving under the influence of alcohol (Garder and Leden, 1998).

What are the possible reasons behind why motorcyclists are more at risk than car drivers? There are arguably three key factors: the behaviour of motorcyclists differs from car drivers, the behaviour of other road users towards motorcycles differs from their behaviour towards cars, and the physical vulnerability of motorcycles differs from cars, both in terms of becoming involved in a crash in the first place and in the likelihood of injury given a crash. These are all likely to be important factors, but their relative impact on the overall difference in accident liability between car drivers and motorcyclists is unknown.

This paper presents preliminary findings from two studies that investigate the first of these three factors: how motorcyclists' behaviour differs from car drivers. Both studies involve a matched comparison between motorcyclists and car drivers on elements of behaviour that predict, or are thought to predict, accident involvement. As far as is known, systematic matched comparisons between road user groups with differing accident risk has not been attempted before. Previous accident research has tended to concentrate on the study of a single road user group, isolating predictors of accidents within the group. The lack of a comparative baseline limits interpretation of results for a particular group. For example, although it has been found that young male motorcyclists are at a higher risk of accident involvement than other motorcyclists (Chesham et al., 1991), this is also true of young male car drivers (Maycock, 1991). Once demographic characteristics and exposure have been controlled for, is it the case that motorcyclists still behave more dangerously than other groups?
Study 1

On average, those riding motorcycles are proportionally more likely to be male and are younger than those driving cars. This pattern emerges either when based on mileage per person per year (Department of Transport, 1994, Table 2.6), on number of journeys per person per year (Department of Transport, 1994, Table 2C), or on proportion of people who either rode a motorcycle or drove a car during a sample week (collapsed data from 1992 to 1999 of the National Travel Survey: Broadley, 2001). Young male car drivers as a group behave more riskily than females and older drivers and are also worse at hazard perception than older drivers (McKenna, 1998). Both these factors are likely to influence their accident liability and, indeed, young male drivers have a higher accident liability than either females or older drivers (McKenna, 1998).

The question we wanted to address in the present studies was whether motorcyclists' accident-related behaviour differs from that of car drivers, once demographic and exposure factors are controlled for. Are motorcyclists a law unto themselves or can demographic and exposure variables account for all differences in accident-related behaviour between motorcyclists and car drivers?

METHOD

Sample

Eighty-eight UK motorcyclists completed a battery of laboratory tests and questionnaire measures that related, or were thought to relate, to accident involvement. Forty three were asked to respond as if they were riding their usual motorcycle and 45 as if they were driving their usual car. A further 39 UK car drivers were asked to complete the tests as if they were driving their usual car. These car drivers had no (or, in the case of two participants, virtually no) motorcycle experience. The mean age of respondants was 40.2 years (s.d. 10.86), their mean annual total mileage (motorcycle and car) was 15,177 miles (s.d. 8084). There were 100 males and 27 females and 58 (45 per cent) had completed some form of advanced driver/rider training. Between the three groups, there was no significance difference in age (F (2,123) =1.27, p = .28), mileage (F (2,123) = 2.54, p = 0.08), gender (Pearson $\chi^2$ (2) = 2.94, $p = .23$), or in the proportion having undergone advanced training (Pearson $\chi^2$ (2) = 0.91, $p = .63$). There was no significant difference between the top speeds of the usual motorcycles of the two groups of motorcyclists (t(62)=1.41, $p = .16$) and no significant difference between the top speeds of the usual cars driven by the two groups who completed the tests as if driving their car (t(68)=.39, $p = .70$).

Participants were recruited by sending e-mails to companies, university staff, and some university students, placement of adverts in motorcycle shops and a local newspaper, and by word of mouth via motorcyclists' and drivers' clubs. They were paid £15 for participating.

Materials and procedure

Participants completed a battery of video-based tests of driving behaviour and performance in the Reading University driving simulator. The simulator consisted of a blacked-out cubicle, in which participants were positioned two metres from a back projection screen (1.42m x 1.07m). Participants who were asked to respond as if they were driving their usual car sat in a car mock-up (with seat, steering wheel, and pedals mounted on a platform). Participants who were asked to respond as if they were riding their usual motorcycle sat on a Suzuki B120
motorcycle mounted in a stabilising frame. The eye level of participants was the same both on the motorcycle and in the car mock-up. Digital video stimuli were projected on to the screen and, where appropriate, participants responded to events on the video with a hand-held button (a timing computer was triggered by specified events on the video, allowing participants' response latencies to those events to be measured). The video-based tests used were as follows.

- **Hazard perception test** (McKenna and Horswill, 1999; McKenna and Crick, 1991; McKenna and Crick, 1994). Participants were shown a driver's-eye view of various road situations and asked to press the response button as soon as they detected a potentially dangerous situation developing on the road ahead. Response latencies to eight selected hazards were measured and collapsed together to give an overall hazard perception score (standardised against a demographically stratified sample of the UK driving population). This test has been found to relate to accident involvement and can discriminate between novice, experienced, and expert drivers (McKenna and Horswill, 1999).

- **Video close-following test** (Horswill, 1994; Horswill and McKenna, 1999b; Horswill and McKenna, 1999c). Drivers were shown footage of a dual carriageway, in which the camera car was gradually closing on a car in front. Participants were asked to press the response button when they reached their normal following distance to the car in front and again when they reached the following distance at which they felt 'uncomfortably close'. New footage was filmed especially for the present study and 12 different scenes were used (the previous version of the test was only based on one scene which was repeated).

- **Video gap acceptance test** (Horswill, 1994, Horswill and McKenna, 1999b, Horswill and McKenna, 1999c). Participants were shown a view as if they were waiting to pull out of a T-junction, looking right at oncoming traffic. They were told to imagine they wanted to turn left to join the flow of oncoming traffic (this was a UK road where traffic drives on the left). They were asked to press the response button at any point that they would be willing to pull out into the stream of traffic. New footage was filmed especially for the present study. The oncoming stream of traffic was edited to include 60 gaps of differing lengths between successive vehicles. The total number of gaps (out of 60) participants chose to pull out into was recorded. A previous version of this test has been found to predict real-world age differences in gap acceptance behaviour (Horswill, 1994).

- **Video overtaking test.** This was a completely new test, devised for the present study. Participants were shown a number of video scenes filmed from the point of view of a driver/rider who was behind a slow-moving vehicle on a single-carriageway road. For each scene, they heard a voice say, 'Press the button if you would overtake . . . now'. The word 'now' was preceded by two tones a second apart to allow participants to anticipate the exact moment on the video the voice was referring to. Participants were asked to press the button if they would overtake at the point indicated by the word 'now', and not to press the button if they would not overtake. Scenes were chosen to give a range of overtaking opportunities that varied in risk level. Participants (including motorcyclists) were asked to assume that if there was an oncoming vehicle in the opposite lane, they would not be able to fit down the middle of the road between the oncoming vehicle and the car in front of them.

- **Video speed test** (Horswill and McKenna, 1999a). Participants were shown a range of traffic scenes and asked to judge the extent to which they would normally drive/ride faster or slower than the vehicle in the video. They recorded their choices on a response sheet (the simulator cubicle was not blacked out for this test so participants could see what they were writing). For example, if they wanted to drive 10 miles per hour faster than the video, they would write down '+10' on the response sheet. The speed test comprised seven scenes, though these were
interspersed with another 12 scenes that were part of another version of the speed test that is not analysed in the present paper. This speed test has been found to predict speed-related accident involvement (Horswill and McKenna, 1999a).

After completing the five tests in the simulator, participants were asked to complete a computer-based questionnaire. Those motorcyclists who were asked to respond as if they were driving a car in the simulator were asked to respond to the questionnaire items with reference to their car driving behaviour. Likewise those motorcyclists responding as motorcyclists while in the simulator were asked to respond to the questionnaire items as motorcyclists. The non-motorcycling car drivers responded to the questionnaire as car drivers. The different groups received questionnaires with minor wording changes to reflect whether they were responding as motorcyclists or car drivers.

The questionnaire included the following measures (other measures were recorded but are not analysed in the present paper), together with demographic and driving experience variables.

- **Three-item questionnaire on speed choice** (French et al, 1993; West et al, 1993b; West et al, 1991). This has been found to relate to drivers' observed speeds and accident history, as well as age and gender characteristics. The questionnaire has a good retest reliability ($r = 0.70$) over a two-year interim.

- **Eight-item driving violations questionnaire** (Parker et al, 1995a; Parker et al, 1995b). This is a measure of the frequency at which respondents committed a range of driving violations, such as running red lights and drink-driving. This has been shown to predict accident history and age and gender differences and be reliable over time.

- **Ten-item social motives questionnaire** (West et al, 1993a). This is a measure of mild social deviance, focusing on self-serving behaviour that might harm the interests of others. It has been shown to have good intrascale reliability and predicts accident involvement.

- **Seven-item attitudes to driving violations questionnaire** (West and Hall, 1997). This has been shown to predict accident involvement and self-reported speed choice.

- **Photographic animation measure of gap acceptance** (Horswill and Coster, in press a, b). Participants were shown a photograph of a driver's-eye view of a junction, at which they could see a single vehicle approaching. They were told to imagine that they were waiting at the junction and wanted to pull out in front of the approaching vehicle. As participants moved a cursor along a bar on the computer screen, the approaching vehicle drew nearer. Participants were asked to select the shortest gap in front of the oncoming vehicle that they would be willing to pull out into. There were 11 sequential static photographs making up the animation. Horswill and Coster (in press b) found that this photographic gap acceptance measure mapped on to age and gender differences reported in real-world studies and also correlated with the photographic speed measure and the speed choice and driving violation questionnaires previously described.

- **Photographic animation of overtaking propensity** (Horswill and Coster, in press b). Video footage was taken of a driver's-eye view of a single-carriageway road, in which the camera car was following a car in front and there was opportunity for overtaking. As the scene progressed, overtaking became more risky (another vehicle appeared, travelling from the opposite direction). Seventeen sequential static images from this footage were captured and digitised. The images were presented in a sequence that could be animated by respondents. As a cursor was dragged along an adjacent bar, different images were displayed such that the overtaking task became more or less risky. Respondents were asked to imagine that they had
been following the car in front for 15 minutes, driving at 20mph, and that they wanted to overtake. They were also told that the speed of the oncoming vehicle was 35mph. They were asked to indicate the most risky overtaking situation they would tolerate, by selecting the appropriate image and clicking the bar at that point. Their response was recorded as the number of the image they had selected (the higher the number, the more risky the overtaking situation).

- **Photographic animation of close following** (Horswill and Coster, in press a). Drivers were presented with a photographic driver's-eye view of the rear of a preceding car on a motorway. When participants moved a cursor along a bar on the computer screen, the car moved either closer or farther away. Participants were asked to select the distance at which they would normally follow the car and press the button on their computer mouse at that point. The following distance they selected, corresponding to a particular frame of the animation (there were 18 sequential static photographs making up the animation), was then automatically recorded. The photographic close-following measure has been found to correlate significantly with the photographic gap acceptance measure, the speed choice questionnaire, the driving violations questionnaire and the photographic speed measure, indicating that the test maps on to measures of drivers' risk-taking behaviours that have been shown to relate to real driving behaviour, and therefore is likely to have some degree of validity.

- **Photographic measure of speed choice** (Horswill and Coster, in press a, b). Drivers were shown photographs of four road scenes (motorway/freeway, rural road, and two urban residential roads) and asked to indicate what speed in miles per hour they would travel at in each situation in their usual car/motorcycle. Horswill and Coster (2000) compared intended speeds given in this photographic speed measure with a roadside survey of actual speeds at the locations depicted in the photographs. They found that, with certain minor exceptions, differences between intended and actual speeds were constant. They also found that responses to the photographic speed measure reflected known age differences in actual speeding behaviour (though not gender differences) and correlated significantly with the validated questionnaire measures of drivers' risk taking described above (the speed choice questionnaire and the driving violations questionnaire).

- **Sensation-seeking questionnaire - 10-item intensity subscale** (Arnett, 1994). This questionnaire has been found to relate more strongly to risk behaviour than Zuckerman's sensation-seeking scale (Zuckerman et al, 1978), while not containing any items relating to risk (unlike Zuckerman's scale). Also, the scale was judged to have more face validity than Zuckerman's and appeared to be more palatable to respondents in a previous study, yielding a substantially lower proportion of missing values (Horswill and Coster, in press b).

After completing the questionnaire, participants were debriefed and paid.

**RESULTS**

There were a small number of missing values for some of the responses that comprised each measure. In the present analysis these were replaced by group means.

All of the measures were tested for skew, and only the driving violations and video gap acceptance measures had skews greater than one indicating that they were likely to differ significantly different from a normal distribution (SPSS Inc., 1998). A logarithmic transformation was found to reduce the skew of the violations measure to 0.39 and the gap acceptance measure to -0.50. All analyses on these measures therefore use the transformed variables.
First, we carried out a principle components analysis with a Varimax rotation on the 15 measures taken in order reduce them to fewer and more orthogonal components. This was to avoid problems of multicollinearity in the multivariate analysis. The measures grouped together as follows.

**Factor 1 (speed/attitudes factor):** driving violations, attitudes to driving, social motives, speed questionnaire, photographic speed choice, video speed.

**Factor 2 (overtaking/gap acceptance factor):** video overtaking test, overtaking animation measure, video gap acceptance test, gap acceptance animation.

**Factor 3 (close-following factor):** video close-following test ('normal following distance'), video close-following test ('uncomfortably close following distance'), close-following animation measure.

There was a fourth factor but this was not obviously interpretable (only sensation seeking and hazard perception loaded on to it (> .4)). Hence, sensation seeking and hazard perception were entered into the final MANOVA as separate components.

Factor scores were constructed by obtaining z-scores of the measures that comprised the three factors and calculating a mean of these z-scores for each factor.

We carried out a MANOVA, with experimental group (motorcyclists on motorcycles, motorcyclists in cars, car drivers in cars) as the independent variable, and the three factors (speed/attitudes, overtaking/gap acceptance, close following) plus hazard perception and sensation seeking as the five dependent variables.

There was a multivariate effect of group, \(F(10,240) = 5.45, p < .001\). The univariate effects of group on the five dependent variables can be seen in Table 1.

### Table 1: Univariate effects of group on the laboratory measures

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Effect of group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed/attitudes factor</td>
<td>(F(2,123) = 10.21, p &lt; .001)</td>
</tr>
<tr>
<td>Overtaking/gap acceptance factor</td>
<td>(F(2,123) = 17.75, p &lt; .001)</td>
</tr>
<tr>
<td>Close-following factor</td>
<td>(F(2,123) = 0.28, p = .756)</td>
</tr>
<tr>
<td>Hazard perception</td>
<td>(F(2,123) = 3.60, p = .030)</td>
</tr>
<tr>
<td>Sensation seeking</td>
<td>(F(2,123) = 2.26, p = .108)</td>
</tr>
</tbody>
</table>

Student-Newman-Keuls post hoc tests were carried out on the significant effects. These are shown in Table 2.

### Table 2: Student-Newman-Keuls post hoc tests on the significant effects of group on the laboratory measures (see Table 1)

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>S-N-K post hoc tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed/attitudes factor</td>
<td>Motorcyclists on motorcycles were more risky than motorcyclists in cars</td>
</tr>
</tbody>
</table>
and drivers in cars ($p < .05$) who did not differ ($p > .05$)

<table>
<thead>
<tr>
<th>Overtaking/gap acceptance factor</th>
<th>Motorcyclists on motorcycles were more risky than motorcyclists in cars and drivers in cars ($p &lt; .05$) who did not differ ($p &gt; .05$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard perception</td>
<td>Motorcyclists in cars were faster at reacting to hazards than motorcyclists on motorcycles and drivers in cars ($p &lt; .05$) who did not differ ($p &gt; .05$)</td>
</tr>
</tbody>
</table>

An ANOVA was used to examine the three speeding measures combined (speed questionnaire, photographic speed choice, video speed) to allow a comparison with the observational speed results from Study 2. The effect of group on overall speed was significant, $F(2,124) = 11.24, p < .001$, and Student-Newman-Keuls post hoc tests revealed that motorcyclists on motorcycles were faster than motorcyclists in cars and drivers in cars (who did not differ). The effect of group on driving violations was also significant, $F(2,124) = 3.54, p = .032$, with the same pattern of post hoc effects.

The photographic speed measure was also examined separately as this was the only measure where participants gave an absolute speed rating in miles per hour (the metric used in Study 2), thus allowing an informal comparison of the findings of Study 1 with Study 2. The effect of group on photographic speed was significant, $F(2,124) = 15.31, p < .001$, and Student-Newman-Keuls post hoc tests revealed that motorcyclists on motorcycles were faster than motorcyclists in cars who were faster than car drivers in cars. The means are shown in Table 3.

Table 3: Means by group for the photographic speed measure

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Means (s.d.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorcyclists on motorcycles</td>
<td>43</td>
<td>53.40mph (4.73)</td>
</tr>
<tr>
<td>Motorcyclists in cars</td>
<td>45</td>
<td>50.19mph (4.90)</td>
</tr>
<tr>
<td>Car drivers in cars</td>
<td>39</td>
<td>48.06mph (3.35)</td>
</tr>
</tbody>
</table>

The social motives and attitudes to driving questionnaires were also tested separately. Neither could discriminate between any of the three groups (social motives, $F(2,124) = 1.37, p = .259$; attitudes to driving, $F(2,124) = 1.18, p = .311$).

The video overtaking test was the only measure that had not been previously assessed for ecological validity. The two groups who had completed the tests as if driving their usual car were combined (there was no significant difference in overtaking between these groups, $t(82)=1.31, p=.19$) and relationships with the other variables tested. There were significant correlations between the video overtaking measure
and age ($r = -.30, n = 83, p = .007$), video speed ($r = .34, n = 84, p = .002$), violations ($r = .36, n = 84, p = .001$), speed questionnaire ($r = .34, n = 84, p = .002$), sensation seeking ($r = .34, n = 84, p = .002$), and hazard perception ($r = -.31, n = 84, p = .004$). These correlations indicated that those who overtook more often were younger, choose faster speeds, committed more driving violations, scored higher on sensation seeking, and were worse at hazard perception. There was no significant sex difference for video overtaking and no significant correlation between video overtaking and either attitudes to driving or social motives. The video overtaking measure correlated significantly with the overtaking photographic animation measure ($r = .51, n = 84, p < .001$), video gap acceptance ($r = .46, n = 84, p < .001$), and gap acceptance photographic animation ($r = .35, n = 84, p = .001$).

**DISCUSSION**

The significant effect of the speed/attitudes factor on the group indicated that motorcyclists who imagined they were riding their usual motorcycles were more risky than both the demographically matched car drivers and motorcyclists who were asked to imagine they were driving their usual car. However, this effect was more likely to be created by the speed and violations measures than the attitudes to driving or social motives measures. One interpretation of these findings is that motorcyclists behave more riskily when on their motorbikes but are indistinguishable from non-motorcycling car drivers when driving their cars. Also, these differences in behaviour do not seem to be due to general personality or attitude differences between motorcyclists and car drivers.

The finding that motorcyclists overtook more often and pulled out into smaller gaps does not necessarily imply they are less safe than car drivers, given the superior acceleration of many motorcycles compared with cars. However, this implication could be tested empirically in future studies. Furthermore, the tendency for motorcyclists to overtake more often did not appear to transfer to their car driving.

The motorcyclists in our sample did appear to have better hazard perception than the car drivers, which mirrors findings by Underwood and Chapman (1998). However, while this benefit transferred to their car driving, it was absent when they were asked to imagine they were on a motorcycle. The most plausible explanation of these results is that the hazard perception test was originally designed for cars and some of the hazards measured involved fitting through restricted openings in traffic, which arguably represent less of a hazard for a motorcycle. This would imply that motorcyclists do have better hazard perception than car drivers overall, but to detect
differences in hazard perception for motorcyclists on motorcycles, a hazard perception test that specifically tested hazards for motorcyclists would be required.

It was difficult to assess the ecological validity of the video measure of overtaking propensity directly due to a lack of recent observational work on overtaking. However, the significant relationship with age may reflect the statistic that young drivers have proportionally more overtaking accidents than older drivers as a function of all accidents (Department of Transport, 1993, Table 3e). The overtaking measure also correlated with other measures of risk taking known to map on to real-world variables such as accident involvement. There was also a reasonable correlation between the video measure of overtaking and the photographic animation of overtaking, indicating that the two measures did reflect the same underlying construct to some degree. Though further work is needed to validate the overtaking test directly, the indications are that it at least provides a reasonable measure of drivers' risk-taking propensity.

Study 2

Any particular research method is associated with strengths and weaknesses. For example, while the laboratory-based methods used in Study 1 are highly controlled and yield a high quantity of detailed information, they are one step removed from the real world (though most of the measures used in Study 1 have been shown to map on to real-world variables to some degree).

One way of avoiding the weaknesses associated with any particular research method is to use more than one method to address the same research question. If we can show similar patterns of results using two completely different methods, it means that we can be more confident about our findings.

In Study 2, we attempted to address the same question as Study 1 (whether motorcyclists behave differently from a matched control group of car drivers) using a field study in which road users were observed unobtrusively from the roadside.

METHOD

Sample

Five hundred and eighteen observations were made in total. There were 98 motorcyclists (all male) and 420 car drivers (all male), who were matched to the motorcyclists as detailed below.

Sixteen of the motorcyclists were estimated to be between 17 and 29 years old, 82 were estimated to be between 30 and 55
years old, and none was judged to be over 55. Fifty-four of the
car drivers were estimated to be between 17 and 29 years old,
366 were judged to be between 30 and 55 years, with none over
55.

Procedure

Roadside monitoring took place at five different sites in the UK
(three in Reading, one in Exeter, one in Yeovil). Sites were
chosen on the following criteria: that the speed gun/video
camera could be used without road users being aware of it; that
the road had either a 30 or 40 mile per hour limit; and that the
site was clear of static hazards (eg pedestrian crossings).

All motorcycles that passed were speed-gunned if they met the
following criteria: their speed was unrestricted by other
vehicles in front; the motorcycle was judged to have an engine
capacity of at least 125cc (no mopeds); and estimation of rider
age and gender was possible.

Cars were selected to be matched to each motorcycle
observation on the following criteria: the drivers’ age was
judged to be in the same age range as the motorcyclists (17-29,
30-55, 55+ years); the drivers' gender was the same as the
motorcyclist; there were the same number of passengers in the
car as there were on the motorcycles (in most cases, none); the
direction of travel was the same; the site was the same; the time
of day was approximately the same (within two hours); the
matched observations were taken on the same day and the
weather conditions were the same.

If the speed gun could not be readied in time, speed was
measured using video footage of the vehicles taken with a
3CCD digital video camera positioned to film perpendicular to
the road. Work vehicles (taxis etc) and drivers or riders under
instruction or instructing were excluded from the sample.

Results and discussion

We found a significant difference between the mean speeds of
motorcycles and the matched group of cars, t(516) = 2.51, p =
.034. Motorcyclists travelled at 44.28mph (s.d. 9.27) and the
matched group of car drivers travelled at 42.12mph (s.d. 7.17).

Automatic speed data (Department of the Environment,
Transport, and the Regions, 1999) have found motorcycle
speeds to be exactly the same as car speeds, but with a much
larger variance. Though these data involved a much greater
sample size than the present study, motorcyclists were not
matched with car drivers, and the definition of motorcycles
included all powered two-wheeled vehicles (ie mopeds and
other lower-powered vehicles were included). This is likely to account for the discrepancy between the two studies.

The data mirror the results from the laboratory measures of speeding in Study 1, indicating that the finding was robust.

**General discussion**

The results from Study 1 and Study 2 indicate that motorcyclists do behave more dangerously than a matched group of car drivers. However, this appears to be a function of riding motorcycles rather than a property of the type of person who rides motorcycles, given that motorcyclists did not differ significantly from car drivers when both completed the battery of measures as if driving their usual car. Also, motorcyclists and car drivers did not differ on more general characteristics and attitudes, such as sensation seeking, social motives, and attitudes to driving/riding.

In order to aid interpretation of the magnitude of the effects found, the mean speeds recorded in Study 2 were mapped on to fatality risk given an accident, using the rule of thumb equation developed by Joksch (1993). Assuming the differences in mean speed choice reflect impact speed if a crash occurs, then the sample of matched drivers would have a 22 per cent chance of dying given a car crash at 42.12mph. If the motorcyclists crashed a car at their faster speed of 44.28mph (hence controlling for physical vulnerability as well as demographics), they would have a 27 per cent chance of dying. This could suggest that the large difference between the accident liability and severity of motorcyclists and car drivers is unlikely to be accounted for by differences in speeding behaviour once demographics and physical vulnerability are controlled for.

**Acknowledgements**

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**References**


18 New driver project

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Introduction

Almost half of the new drivers who obtain a full driving licence in the United Kingdom begin learning to drive at the age of 17. Drivers in the age group 17 to 21 years hold approximately 10 per cent of licences, have a lower than average mileage, but are involved in just over 20 per cent of all accidents, with most of these accidents occurring in the first year post-test. In addition, after controlling for mileage driven young male drivers are nearly twice as likely to be involved in a road accident during this period than females. It is known that new driver accident liability reduces by 30 per cent during the first year of driving but it is not clear which aspects of experience gained are instrumental in bringing about this reduction. Moreover, while there is some activity by road safety professionals in pre-driver training courses, very little is known about how effective these may be in bringing about the desired reduction in new driver accident involvement.

The main aim of the new driver project, funded by the Scottish Road Safety Campaign, was to establish whether or not classroom-based intervention strategies could be effective in addressing the problems described above.

Background information

In reviewing the literature on new drivers, young drivers or risk-taking novice drivers, three major methodological difficulties arise. First, there are wide variations in the definitions of the 'young driver'. For example, some studies have included all drivers between 16 and 25 years of age, other studies have restricted the definition to 16-20 or 18-25 years. Second, in studies that have highlighted differences in driving behaviour between young drivers versus older drivers, any significant results that arise may only reflect differences in driving experience rather than something intrinsic to youthfulness. However, given that age and experience are inextricably confounded for the most part, attempts to separate those two concepts may well prove fruitless. Third, there has been great variation in the methodological approaches that have been used to study driver risk taking. These approaches have ranged from self-reports to interviews, questionnaires, video displays, driving simulators and roadside observation. This diversity in methodological approaches and variations in the operational definitions of risk may also have contributed to some of the contradictory results in this area of research.

A review of the literature reveals that many authors have reported a consistent and robust connection between speeding behaviour and accident involvement. For example, a study by West, et al (1993) suggested that there is a consistent relationship between self-reported faster driving and increased accident risk. The West et al (1993) study also concluded that self-reports of speeding behaviour could be used as a successful surrogate for direct observations of speeding behaviour and that both self-reported and observed speeding behaviour are significantly associated with self-reported accident involvement. The West study also concluded that a faster driving style is associated with being male, being young and belonging to lower socio-economic groups. Furthermore, West and colleagues also argue that the association between demographic factors and accident risk are mediated by these variables. In addition to these findings, Manstead et al (1992) suggest that speeding may be
the most prevalent of all driving violations. Moreover, research by Brown and Copeman (1975) revealed that the respondents in their study suggested that speeding was seen to be the least serious in a series of traffic offences listed. This finding again emerged in a study by Reason et al (1990). Research by Parker et al (1992) also argues that, for some, speeding is regarded with a degree of tolerance. It is also known at this time that the most common cause of road traffic accidents is the inappropriate use of speed. It therefore seemed appropriate for the series of studies used for this research project to focus on attitudes toward speeding behaviours in particular and attitudes to driving violations in general, as the main behavioural items for the project to review.

Methodology

A sample of 451 new drivers was drawn from across Scotland. Each new driver in the study was between the ages of 17 and 21 years, held a provisional driving licence and had obtained less than two hours of professional driving instruction. The new drivers were randomly allocated one of three groups. The new drivers allocated to Group 1 were used for comparison purposes and were left to acquire their driving licence in the manner that was most suitable for them. The new drivers in Groups 2 and 3 also acquired their driving licences in a like manner but in addition they were required to attend classroom-based pre-driver training or a post-driving test training intervention respectively. The pre-driver training intervention for subjects in Group 2 was conducted as soon as possible after the start of their driver training and the post-driver training for subjects in Group 3 occurred within three months from the date the subject passed his or her driving test.

The research design allowed for four self-report cross-sectional studies to be undertaken. These studies were also connected to provide longitudinal aspects. The four individual studies were conducted using questionnaire sets that were completed by subjects as they started learning to drive, Time 1, immediately on passing the practical driving test, Time 2, three months post-test, Time 3 and nine months post-test, Time 4. (The design of the study is represented in Table 1.) The measures used in each of the four studies are shown in Table 2.

Table 1: Schematic representation of study design. Subjects entered the study at Time 1 and progressed left to right to Time 4

<table>
<thead>
<tr>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
<th>Time 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q'aire A</td>
<td>Q'aire B</td>
<td>Q'aire C</td>
<td>Q'aire D</td>
</tr>
<tr>
<td>Learning to drive period</td>
<td>Three-month driving period</td>
<td>Six-month driving period</td>
<td>Test pass plus nine months</td>
</tr>
<tr>
<td>Group 1</td>
<td>Pre-driver education intervention</td>
<td></td>
<td>Test pass plus three months</td>
</tr>
<tr>
<td>Group 2</td>
<td>On driving test pass</td>
<td>Post-driving test intervention</td>
<td></td>
</tr>
<tr>
<td>Group 3</td>
<td></td>
<td></td>
<td>Test pass plus three months</td>
</tr>
<tr>
<td>Time 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>April 1997</td>
<td>Time 2</td>
<td>Time 3</td>
<td>Time 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>March 2000</td>
</tr>
</tbody>
</table>
Table 2: Demographics items, measures and repeated measures used within the series of studies through Times 1 to 4

<table>
<thead>
<tr>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
<th>Time 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age and occupational status</td>
<td>Age and occupational status</td>
<td>Age and occupational status</td>
<td>Age and occupational status</td>
</tr>
<tr>
<td>A measure of additional motives</td>
<td>Additional motives (1st repeat)</td>
<td>Additional motives (2nd repeat)</td>
<td></td>
</tr>
<tr>
<td>Attitude to driving violations (West and Hall, 1994)</td>
<td>Attitude to driving violations (1st repeat)</td>
<td>Attitude to driving violations (2nd repeat)</td>
<td></td>
</tr>
<tr>
<td>Driving intentions (based on the theory of planned behaviour, Ajzen, 1985, 1988)</td>
<td>Driving intentions (modified)</td>
<td>Driving intentions (modified) (2nd repeat)</td>
<td></td>
</tr>
<tr>
<td>Driving time estimates</td>
<td>Driving time estimates</td>
<td>Driving time estimates</td>
<td></td>
</tr>
<tr>
<td>Driver knowledge questionnaire*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-report measure of driving style</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driver skills inventory (Lajunen and Summala, 1995)</td>
<td>Driver skills inventory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Police stops and offences</td>
<td></td>
<td>Social desirability scale</td>
<td>Self-reported driving speeds</td>
</tr>
</tbody>
</table>

* This was used to assess the impact of pre-driver training.

PRE-DRIVER EDUCATION INTERVENTION

As can be seen from Table 1 the subjects in Group 2 had the same questionnaire schedule as Group 1. In addition, as the subjects were recruited to the study they were formed into small sub-groups, ranging in size from approximately 12 to 25, to undertake one afternoon of classroom-based work involving
a standardised pre-driver training programme. This pre-driver training programme was constructed after a review of pre-driver training materials generally available at the time of the study and after a consultative process with road safety practitioners throughout Scotland. What emerged through this process was a consensus of opinion of what were the most salient issues confronting the novice driver and how these issues could best be tackled in an educational environment.

Examples of the topics covered in the pre-driver education programme were:

- motor insurance
- vehicle maintenance
- social issues
- Highway Code
- roadcraft
- post-accident procedures
- drink/drugs/fatigue
- attitudes, pressures and social standards.

POST-DRIVING TEST INTERVENTION

The subjects in Group 3 had the same questionnaire schedule as Groups 1 and 2. The subjects in this group were formed into small sub-groups of approximately 12 to 25, after they had passed their driving test. In these small sub-groups they attended for one afternoon of classroom-based work for an intervention that was informed by constructs of the theory of planned behaviour, (Ajzen, 1985, 1988), the health belief model and protection motivation theory (Rogers, 1975). While social cognition models are capable of providing a framework in which specific behaviours can be understood, they also can be used to assist in the development remedial strategies aimed at bringing about desired behavioural change.

Issues raised in the post-test intervention included:

- issues of personal vulnerability - raising personal vulnerability in the driving task by exploring how vulnerable new drivers are to accident involvement
- risk perception - how new drivers may underestimate driving risks
- an exploration of the new personal driving beliefs that may result from becoming a new driver
Results

MAIN FINDINGS

- As new drivers start learning to drive their attitudes, beliefs and intentions towards the driving task already appear to be formed.

- New male learner drivers are less likely to abide by the legal and social conventions of driving with regard to speeding behaviour.

- New male learner drivers also reported that they were less likely to take cognisance of what their parents, close friends or friends of the opposite sex thought about their driving.

- The results of a classroom-based pre-driver training intervention revealed that subjects who attended for this type of training did not score significantly higher on a related driving knowledge test in comparison with those who did not.

- Differences in the self-reports were found between those who attended a classroom-based post-test driver training intervention at Time 3 on Lajunen and Summala's (1995) driving skills inventory, indicating some effect of the post-test intervention. The driving skills inventory (DSI) consists of two sub-scales, a measure of driving safety motives and a measure of perceived driving skill. Figure 1 shows the combined mean scores from the subjects in each of the three groups in the study, recorded from the studies at both Time 2 and Time 3. The figure also shows that while all three groups have similar scores at Time 2, those subjects who attended for the post-test intervention, Group 3, had significantly lower scores at Time 3, indicating that these new drivers perceive their driving skills and safety motives to be less well developed.

- At nine months post-driving test, no overall differences were found between the pre-driving test intervention subjects, the post-driving test intervention subjects and those who were left to acquire their driving licence in the standard way. However, the subjects in Group 3 did report better behavioural intentions towards speeding at Time 4 but other self-reported measures found no differences.
Discussion

It is important to note that the information and results drawn in the present series of studies were by self-reports. While there is evidence to suggest that self-report measures of driving behaviour and actual driving behaviour are closely correlated, it is important to note that self-reported driving behaviour and actual driving behaviour may not be one and the same thing.

The results from the first study at Time 1 revealed that the subjects, at the time when they started learning to drive, appeared to have their attitudes, beliefs and intentions towards the driving task already formed. The results of the study at Time 1 also suggest that new male learner drivers are less likely to abide by the legal and social conventions with regard to speeding and, in addition, that they are less likely to take cognisance of what their parents, close friends or friends of the opposite sex would think about their driving than females. If it is the case that these driving predispositions are formed some time before the actual process of learning to drive takes place, this may be of importance to road safety practitioners and may have bearing on how future interventions are constructed.

The second study at Time 2 revealed no support for pre-driver education courses. This may be in line with the findings of McKnight (1985) that suggested that strategically based education or information with the emphasis on driving style or technique is wasted upon novice drivers, as they do not yet have the skills to deploy tactical styles of driving.

In contrast to this, the results from the third study at Time 3 do provide positive evidence of an effect of the post-driver intervention, with differences between the groups being found on the DSI's measures of driver safety motive and perceived driving skill. This is an encouraging finding. Fitts and Posner (1967) suggest that learning to drive has three phases that range...
from the basic acquisition of skills required to control the vehicle, through to driving becoming a cognitively automatic process. They also argue that the driving test is often successfully passed before many of the required skills reach the automatic stage. The findings from the study at Time 3 also suggest that at least the self-reports of drivers can be changed by a post-driving test intervention, and that these changes are measurable at three months post-test.

The results from the study at Time 4, nine months post-test, suggest the subjects in Group 3 had better self-reported behavioural intentions towards speeding than subjects from the other two groups. In contrast to this, changes in self-reported behaviour, measured over time using West and Hall's (1994) attitude to driving violation scale, and the measure of additional motives fail to detect this behavioural intention. Both these measures were used at Times 1, 2 and 4. The mean scores for all groups in the study rose gradually and significantly over this time without either intervention apparently having any effect. This is a disappointing finding from a road safety perspective.

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19 The role of experience in searching road scenes

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Introduction

We have previously found a variety of changes in drivers' visual search as a function of traffic experience. Experienced drivers show wider scanning strategies than novices in a variety of situations and shorter fixation durations in dangerous situations. Practically, such changes are of interest because they appear at a time when drivers' involvement in accidents is decreasing rapidly, suggesting that there may be road safety benefits to interventions which attempt to speed up such changes. Theoretically most researchers assume that such changes are brought about by increases in driving-related knowledge, which is often thought to be stored in the form of visual schemas. However, few driving researchers have explored the nature and function of such schemas in any detail. This paper reviews some of the psychological literature exploring the ways in which visual schemas are thought to operate, and relates this to the driving literature on visual search. We then extend a standard psychological test of visual schemas for use in the driving domain, to see whether there is evidence for such schemas developing as a function of traffic experience. In the basic task participants have to search for objects in static driving scenes which are presented either as standard views from the driver's perspective or as randomly jumbled scenes. The difference between search times in jumbled and normal scenes is taken as a measure of relevant driving-related knowledge. Drivers are more disrupted than non-drivers by the jumbling of the visual scene, although they are not always faster than young non-drivers doing the task. Such differences are indicative of the progressive development of situation-specific schemata. We propose that such schemata, rather than particular learned strategies, generally explain the observed changes in visual search as a function of driving experience. Such results have important implications for what can and cannot be taught or tested in novice drivers.

Visual Search in Driving

Understanding drivers' typical patterns of eye movements while driving is of theoretical interest and offers practical benefits in terms of possible changes to both road and vehicle design, and in the hope of introducing training interventions. However, despite a large number of studies of visual search in driving, there has only recently been any consensus emerging about what the standard patterns of visual search are, and how they change as drivers become more experienced and, typically, safer. This paper will begin by briefly reviewing drivers' typical patterns of eye movements, with particular emphasis in the ways that these are based on stored knowledge about the road environment and modified as a function of traffic experience. This will serve as a basis for relating such applied studies with more theoretical work from psychologists interested in processes that operate in more general scene viewing.

Almost all researchers agree that visual search concentrates on a point near to the focus of expansion (the point in the visual field in front of the driver where objects appear stationary) with occasional excursions to items of road furniture and road edge markers (eg Helander and Söderberg, 1972; Mourant and Rockwell, 1970, 1972). This reliance on the focus of expansion in the scene has been assumed to be because it provides precise directional information to the driver and is the location near to which future traffic hazards are likely to
be first visible. In the context of general scene viewing it can also be regarded as being the
generally most informative part of the visual scene in terms of the concentration of objects.
Increasing the complexity of the visual scene (by adding vehicles, road furniture, or irrelevant
signing) increases the number of eye movements made and decreases the mean fixation
durations on individual objects (Erikson and Hörberg, 1980; Luoma, 1986; Miura, 1990;
Robinson et al, 1972; Rutley and Mace, 1968). This seems to be a natural response to having
more objects available in the visual field to look at. However, it is not clear whether
decreases in fixation durations mean that objects are processed incompletely or that
redundant fixation time is simply reduced. Cohen (1981) found that subjects viewing slides in
the laboratory adopt longer fixation durations than those actually driving a vehicle in the
same situations. He concludes that this is because of the lack of time pressure in his
laboratory task and argues that on the road subjects adopt more task-relevant strategies and
pick up more information per unit of time. Whether or not this is the case it suggests that
fixation durations while driving may be determined both by the visual stimulus and by the
task as perceived by the subject.

The eye movement patterns become slightly more complex when the driver is required to
negotiate a curve. Drivers generally adjust their fixation locations to maximise their sight
distance and provide information about the future curvature of the road (Helander and
Söderberg, 1972; Shinar et al, 1977). In many cases this means focusing on the tangent point
made by the driver's line of sight ahead to the inside of the curve (Land and Lee, 1994),
though information about lane position from closer to the vehicle's current position also
seems to be necessary for accurate curve following (Land and Horwood, 1995; McLean and
Hoffmann, 1971, 1973). In such situations it appears that the most informative region of the
visual scene has changed, possibly because of the need for visual input to allow steering
control, but possibly just because of the occlusion of objects by the road edge. Although
extended fixations near the tangent point are frequently observed, these may be largely a
function of the lack of alternative sources of visual information, a possibility which is
supported by large individual differences in the number of off-road features which drivers
choose to fixate (Land and Lee, 1994).

The evidence presented so far suggests that eye movements may be primarily determined by
the nature of the visual scene rather than being modified by experience with particular road
situations or representing complex learned strategies of information acquisition. However,
theories of eye movement control allow for a role of experience in both the rapidity of
information uptake from a particular region, and in the ability to process low-level
information parafoveally. It is thus of theoretical interest to see whether these patterns change
as a function of traffic experience. This is also an area of great applied interest. In Britain a
driver in their first year of driving since passing the test has been estimated to be 69 per cent
more likely to be involved in an accident than one in their second year of driving (Forsyth et
al, 1995). Clearly such calculations are dangerous because of the confounding of experience
with changes in age and exposure (Brown, 1982), but careful modelling of the effect suggests
that it can be largely attributed to changes in traffic experience (Maycock et al, 1991), with a
38 per cent reduction in accident risk over the first year for a 17 year old being solely
attributable to the increased experience (Forsyth et al, 1995). There is also evidence that
young drivers may be particularly likely to be involved in accidents where inattention is
specified as a contributory factor in the crash (Lestina and Miller, 1994). Clearly changes in
visual search as a function of traffic experience may be directly related to accident
involvement and are of great practical importance to study.
Work in Nottingham has consistently found changes in visual search as a function of traffic experience (e.g., Underwood et al., 1997). In on-road driving we observe that novice drivers have particular limitations in visual search compared to experienced drivers when driving on high-demand dual carriageways (Crundall and Underwood, 1998). It is possible that such differences are partly attributable to problems that novice drivers have with simple control skills on high-speed roads. Until a driver has learned to control steering with information from peripheral vision, frequent fixations are necessary on the edge of the road to determine road position. Although such effects are of concern, it seems likely that drivers will rapidly develop the control skills necessary to get around such problems in visual search. Novice drivers seem to be well aware of such limitations and may attempt to adjust their exposure appropriately in order to avoid such situations until their competence has developed. What is of greater concern is the possibility that visual search may be inadequate in hazardous situations which are harder to avoid. Chapman and Underwood (1998a, 1998b) have found that most drivers increase their fixation durations and reduce their spread of search in hazardous situations, but that such focusing of attention in hazardous situations is particularly pronounced in novice drivers. An inability to recognize and process driving hazards rapidly in novice drivers is clearly of considerable practical importance and we have explored possibilities for training interventions to counter such effects (Chapman et al., 1998). The problem with interventions aimed at improving scanning strategies is that they may ignore the deeper problem. Poor scanning strategies may be the inevitable outcome of slow processing of information at any particular location. There is no point in training drivers to scan more rapidly if this prevents them from fully processing information from the locations they have already fixated. It would clearly be desirable to understand more about the ways in which drivers do process information in the driving scene, the ways in which they decide which regions to fixate next, and the degree to which this relies on other forms of driving-related knowledge.

**TOP-DOWN INFLUENCES ON DRIVERS' VISUAL SEARCH**

When a driver selects information to attend to in a road scene we can assume that both bottom-up and top-down processes are operating simultaneously. Bottom-up visual information in terms of the luminance, motion, colour, texture, contour density and the like will be available to varying degrees depending on distance from the current fixation point. Presumably an experienced driver will also have the ability to weight such low-level visual information based on their expectancies about the road environment. In the broader literature on scene perception De Graef (1998) suggests that such visual schemas may produce three separate effects on visual processing - increased top-down processing of expected objects (hence producing fast reaction times to questions about such objects and generally short fixation durations), suppressed bottom-up processing of expected items (since this information is likely to be redundant), and enhanced bottom-up processing of objects that do not match expectations.

In a driving context Theeuwes (1996; Theeuwes and Hagenzeiker, 1993) has demonstrated the importance of top-down processes in the perception of traffic scenes. In the initial study, Theeuwes and Hagenzeiker (1993) had drivers search for a target object embedded in a traffic scene. Drivers would first be told the name of the object that they would be searching for, then see a driving scene without the object present for about half a second. After a brief (1600ms) mask they would then see the scene again with the object (a traffic sign, cyclist, or car) present in either an expected or unexpected location, and have to respond target present or target absent as rapidly as possible. Error rates in this task were significantly lower when the target appeared in an expected location, and there was a (non-significant) tendency for
reaction times to be faster in the expected condition. In a follow-up study, Theeuwes (1996) recorded drivers' eye movements while watching a video-recorded approach to intersections. Drivers searched for a blue sign which was again either in an expected or unexpected location. Reaction times were significantly faster when the sign was in an expected location (by between 100 and 200ms depending on condition), as was the time taken to fixate the critical sign. One obvious question which is raised by this research is whether these expectancies arise only as a function of traffic experience, or whether they are obvious to anyone who has performed the experimental task for a few trials. Clearly it would be interesting to look for differences in reaction times and search strategies as a function of driving experience.

Miltenburg and Kuiken (1990) had drivers watch video recordings of six common traffic situations while recording their eye movements, although they did not systematically manipulate schema expectancy. They tested 47 subjects split into four groups on the basis of their driving experience, ranging from novice drivers with less than one year of driving experience, to very experienced drivers with more than five years of experience and more than 100,000km driven in the previous year. They found that for one of their scenes, crossing an intersection, experienced and very experienced drivers fixated more briefly than inexperienced drivers, who in turn fixated more briefly than novice drivers. They found no evidence supporting their other two experimental hypotheses, that novice drivers might fixate closer to the front of the car, or that experienced drivers might fixate relevant objects sooner. They did find a number of differences between their groups in a post hoc analysis, particularly noting that novice and inexperienced drivers spent longer fixating near to the vehicle when the film showed the car negotiating a bend. Other differences were present but did not change across the four groups in a way that suggested a relationship with traffic experience. The problem here seems to be the difficulty of using eye movement recording in complex traffic scenarios. It would be desirable to adapt simple visual search tasks from the general visual perception literature to explore the development of driving schemas. One series of studies which is particularly relevant was started in the 1970s by Irving Biederman.

Perceiving real-world scenes

In Biederman's (1972) study participants viewed briefly presented slides of real-world scenes. An object from the scene was cued by an arrow displayed briefly either immediately before or after the scene and the participants' task was to choose from a display of four objects which one had been cued. Scenes could be presented either as full coherent pictures, or divided into six sections (as shown in Figure 1) and jumbled before viewing. As might be expected performance in terms of percentage correct recognition was improved by having prior knowledge of the response alternatives (the four objects to choose between) and by receiving the spatial cue before rather than after the picture. Of greater theoretical interest is the finding that in all conditions performance was better (by approximately 5 per cent) when the scenes were coherent rather than jumbled. Biederman found no interaction with the other factors, suggesting that these effects were not brought about by participants knowing where to look in jumbled scenes in advance, and were not dependent on memory load effects. Instead it seem necessary to propose a role for global scene-processing units or schemas.

Biederman et al (1973) extended the previous methodology to look at reaction times. In this study the same stimuli were used as in the Biederman (1972) study, but were now presented at a noticeably larger size (19 rather than 5 degrees of horizontal visual angle). This time participants saw an initial object which was present in one-third of the scenes and absent in the other two-thirds. Their task was to respond as rapidly as possible either 'yes' or 'no' to the
question of whether the pictured object was present in the scene. Note that this version of the task actively encourages visual scanning of the scene to attempt to find the target object. Biederman et al (1973) distinguished between possible and impossible no conditions. A possible no condition might require participants to search a street scene for an automobile that was not in fact present in that street scene. In contrast an impossible no condition might require participants to search for the same automobile within a photograph showing the interior of a kitchen. Once again, half of the scenes were jumbled into six sections, and the other half were presented in their normal coherent form. In jumbled yes trials the target object was always presented in its normal position within the scene and the jumbling only applied to the remaining five sections.

Biederman and colleagues found that jumbling the scenes still impaired performance, here as measured by an increase in correct reaction times in all conditions. Generally the fastest responses were to the impossible no condition, and the slowest responses were to the possible no conditions. They also found an interaction between coherence and response category such that the impairment brought about by jumbling was least for yes responses (approximately 60ms) and greatest for possible no responses (504ms), with the fast impossible no responses showing an intermediate impairment from jumbling of 227ms. Participants made virtually no errors in the impossible no condition (less that 2 per cent errors), but made frequent errors in the other conditions (17 per cent in all conditions except the jumbled yes condition, where errors were significantly higher at 24 per cent). Biederman et al (1973) conclude that their results are consistent with viewers possessing a schema (cf Bartlett, 1932) for visual scenes which can be rapidly activated. When the activated schema is clearly incompatible with the target object (the impossible no condition) viewers are able to make fast accurate responses. They further conclude, more speculatively, that the activation of such a schema enhances rapid identification of individual objects within a scene, hence the coherence advantage for yes and possible no conditions. It should, however, be noted that alternative explanations of these data in terms of schemas used in eye guidance are possible. Nonetheless the idea that rapid processing of ’gist’ or scene schemas is an important part of visual perception is widely accepted, and it seems clear that jumbling scenes interferes considerably with this process. This immediately suggests the possibility that such a jumbling methodology might prove useful for measuring the development of schemas in an applied domain such as driving.

**Figure 1: Passing a typical driving scene divided into Biederman's six sections**
The development of driving schemas

In using Biederman's methodology to test for the development of driving-related schemata it is necessary to consider the likely contents of such structures. Clearly the form of knowledge that is most likely to be developed as a function of driving experience is a visual representation of driving situations as typically viewed while driving. We have thus selected an extensive set of high-quality colour digital stills taken from the drivers' point of view while driving on a wide range of different road types. The first problem with adapting Biederman's methodology for use with driving situations is evident from Figure 1. We quickly found that it is difficult to divide driving scenes into six neat sections in the way that Biederman had with everyday scenes. As discussed above, visual search in driving scenes tends to be focused around the focus of expansion, or tangent points in the visual scene. Unfortunately, such points tend to be inconveniently near to the midline in any picture taken from the drivers' point of view.

After extensive experimentation with a variety of driving scenes from a wide variety of different road types, we found that the division of the scene which was most likely to include complete identifiable objects within single sections was the division shown in Figure 2. Here the scene is divided into nine equally sized and shaped sections, roughly centred such that the focus of expansion typically appeared in the middle of the central section. Although it was sometimes necessary to move the image border small distances in order to ensure that objects appeared completely within individual sections, such movements never changed the basic view of the scene from one where the driver was looking straight ahead with the focus of expansion (where clear in the scene) present within the central section. In contrast, the
division shown in Figure 1 almost inevitably meant that the midline horizontal division crossed interesting driving-related objects. Small adjustments to prevent this generally required the whole scene to be adjusted vertically such as to include unreasonably large amounts of either sky in the upper segments, or road in the lower segments.

In order to balance for position effects we felt that it was important that the scenes used in our test would involve objects appearing equally often in each of the nine positions. In fact, when parsing our the selection of scenes that we already had it became clear that certain sectors were far more likely to contain objects than others. As labelled in Figure 2, section 5 almost always contained a complete object which would be of interest to the driver. Sections 1, 4 and 6, generally contained such objects as well. In contrast, sections 2, 3 and 9 were created particular difficulties. We eventually had to undertake additional filming to ensure that we had a good selection of objects in the lower and higher numbered sectors. This meant that the final corpus of scenes we chose to use over-represented interesting objects appearing overhead (particularly motorway signs as shown in Figure 1) and immediately in front of or to the sides of the vehicle (often traffic information written on the surface of the road).

Although this means that the corpus of scenes we use is not precisely representative of the distribution of visual information in everyday driving scenes, by controlling for frequency of occurrence within the corpus, it is possible to look for experience-related biases in drivers responses to objects in certain sections rather than others. Thus, drivers may be more aware of the typical distribution of information in actual scenes that non-drivers. By matching the frequency of objects and locations within the corpus we should be able to prevent any learning during the experiment from creating artificial expectations.

**Figure 2: Passing a typical driving scene into a revised nine sections**
Method

Individual participants performed a short practice task, then watched a series of 126 driving scenes. In each case they saw an individual object (for example a road sign) and then had to decide whether that object was present in the driving scene they saw. Objects were taken equally often from each of the nine regions of the scene shown in Figure 2. There were seven different conditions, thus in each condition two objects were used from each of the nine locations presented in a random order across the experiment. Participants made a simple yes or no response as quickly as possible each time they saw a scene. A new target object was shown before each scene. The seven conditions relate to the type of response that the participant was making and the way in which the nine segments were presented. In the simplest case a participant would see a green traffic light (as in region 1 of Figure 2) and then have to search for it in a simple coherent scene (eg Figure 2 presented without the numbers or dotted lines). The correct response in this case would be 'Yes' - the object is present in the scene. Alternatively the scene to be searched could be one where the object was not present. In this case, a distinction was made between 'possible' and 'impossible' no responses based on that used by Biederman (1972).

Figure 3: An example of a coherent scene from the 'possible no' condition
In a 'possible no' condition (as shown in Figure 3) the location of scene was broadly consistent with type of road environment from which the target was taken, but clearly did not contain the object of interest. In contrast, an 'impossible no condition' would use a scene from a very different road class from that in which the target was actually located (eg the scene shown in Figure 1, when search was for an object taken from Figure 2).

In addition to the response manipulation, the nine sections of the scene could either be presented in their original 'coherent' form (as in Figure 3), or could be rearranged 'jumbled' (as shown in Figure 4). The yes, possible no, and impossible no conditions of both jumbled and coherent scenes create six conditions. The final, seventh condition relates to the way in which the jumbling took place and represents an additional extension to the procedure used by Biederman (1972). In Biederman's experiments, the jumbling procedure always meant moving the surrounding five sections of the picture, but leaving the target in its original position. This was intended to ensure that the location of objects was the same whether the picture was jumbled or coherent. However, it seems likely that driving experience might aid visual search, both in terms of allowing people to have coherent complete visual schemata and also in enabling drivers to predict rapidly in which section of the picture a target object was likely to appear. In order to test for this, we included two versions of the 'jumbled yes' condition. In one case the target object appeared in its original position, but the remaining eight sections were jumbled in the way that Biederman used. We refer to this condition as 'partly jumbled'. In the other condition all locations were jumbled, ensuring that the target object did not appear in its original position - 'fully jumbled'.

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In order to provide a broad range of driving experience for the initial study we chose to contrast people with very minimal experience of driving with those of various levels of experience. All participants were recruited in the same way by responses to posters and e-mail notices within the University of Nottingham, or from responses to an advertisement in a local newspaper. We selected 20 non-drivers on the basis that they were people who did not possess and had never possessed a full driving licence, and matched these on age with a sample of 20 drivers. Because of this procedure, both the non-drivers and the matched drivers tended to be relatively young (a mean of 23 years), and the drivers were relatively inexperienced (a mean of five years licensed, with an annual mileage of approximately 7,000 miles). We refer to this group of matched drivers as 'novice' drivers, though it should be noted that they will generally have considerably more driving experience than the 'novice' groups we have used elsewhere (eg Crundall and Underwood, 1998; Chapman and Underwood, 1998a, 1998b). We also tested a group of 20 older, more experienced drivers with a mean age of 40 years and an annual mileage of over 12,000 miles.

Figure 4: An example of a jumbled scene from the 'yes' condition

Participants were asked to respond as quickly as possible, but no particular emphasis was made on whether they should focus on answering correctly all the time or whether they should concentrate on responding quickly at the risk of making errors.
Results and Discussion

Participants generally found the task relatively easy and enjoyable. This study is currently ongoing, but an indication of the pattern of results will be given here for the purposes of discussion. The design of the study allows for an analysis of variance using one of the jumbled yes conditions, but not both. Preliminary findings will be divided into those analyses exploring the basic effects - eg repeating Biederman's basic design with driving stimuli, - and those which extend this design to investigate experiential differences. Initial indications of differences in reaction times and percentage correct data will be briefly described. Only correct reaction times will be considered here. No analysis of differences between the nine target locations has yet been conducted. The full design has one between-subjects factor - driving experience (non-driver versus novice versus experienced) and two within factors - coherence (jumbled versus coherent), and trial type (yes versus possible no versus impossible no).

There is a large effect of coherence on overall percent correct responses, with the general tendency being for participants to perform better when responding to jumbled scenes than coherent ones. Although this result may appear surprising it is not actually inconsistent with Biederman's (1972) results, and may reflect a degree of overconfidence where participants are scanning coherent scenes. It is worth noting that errors are relatively infrequent - no more than 10 per cent in any condition. There is also a clear effect of trial type, reflecting a very low level of errors (approximately 3 per cent in the impossible no condition. Although we were concerned that the impossible no condition for driving stimuli might not be as clear-cut as that used by Biederman, these results confirm that the difference between the possible and impossible no conditions was important for these stimuli. Preliminary data also suggest that coherence affects the different response conditions differently. Coherence has no noticeable influence on the impossible no condition, but impairs performance for the possible no condition, and particularly for the yes condition. It is of interest to note that for percentage correct, the partly jumbled condition is behaving extremely similarly to the fully jumbled condition. This may reflect the fact that errors are coming from failures to spot an object after relatively complete search rather the search itself terminating before all locations have been considered.

With respect to reaction times, there is a general tendency for participants to react faster when responding to coherent scenes than to jumbled ones. Note that this is the opposite result to that emerging with percent correct, though it accords with our expectations - as Biederman found, visual search is faster in coherent scenes. There is also large difference emerging in reaction times between the different response types. The possible no condition induces much longer reaction times (over 1,200ms) than the other conditions, for which mean reaction times are all below 1,000ms. In reaction times there is no clear difference between yes and impossible no conditions. This is in contrast to Biederman's findings where reactions to impossible no stimuli were notably faster than any other condition. This is likely to reflect the fact that because all our scenes were driving situations, no object was ever truly impossible in the context. Perhaps our condition could be more accurately described as unlikely rather than strictly impossible. Although a mini-roundabout might be inconsistent with a motorway schema, it would nonetheless be consistent with a more general driving one.

Coherence appears to provide a smaller reduction in reaction times for yes responses than in either of the no conditions. Interestingly, the part jumbled condition induces fast reaction times, closer to those of coherent scenes than the fully jumbled ones. This suggests that there is a tendency for participants to perform a fast visual search of the most likely location in
which the target might appear. Where the target is indeed present, this results in a fast yes response, comparable to reaction times in the coherent condition. However, it is important to note that participants would not know that they were in a part jumbled condition, so will be likely to continue searching the scene for the object even if it has not been found in the anticipated location. This may account for the low error rates previously noted in the part jumbled condition. These results are thus consistent with the idea that driving schemas are effective because they guide initial fixations, rather than being necessary just for processing the scene as a whole.

Driving experience also seems to affect accuracy, with the experienced drivers performing better than the non-drivers, and the novices falling in between. The coherence of the scene seems to have a large influence on novices, a smaller influence on non-drivers, and little influence on the experienced drivers. It is worth noting here that error rates for the older, more experienced drivers were very low indeed, and the lack of difference between conditions might reflect a ceiling effect for this group. The difference between experienced and less experienced drivers overall seems to reflect greater caution in performing the task with increasing age or driving experience and is something that we have noted previously in a series of laboratory-based tests of driving-related abilities (e.g. Ismail, 1999).

For reaction times, however, the data are much clearer. There is an overall tendency for the experienced drivers to have longer reaction times than both novices and non-drivers. This could be partly attributed to age differences, but may also be associated with the lower error rates, implying a greater degree of caution in the responses of more experienced drivers. What is very noticeable is that coherence has a larger effect on reaction times for both novice and experienced drivers than it does for non-drivers. Theoretically this is exactly what would be expected if both groups of drivers have relatively well-developed schemas for road situations, and such schemas are useful in guiding visual search in coherent but not jumbled scenes.

**General discussion**

So far we have only conducted some preliminary analyses, and have only explored the basic task. One key aim of this research is to relate it to visual guidance when viewing driving situations, and for this we are currently recording the eye movements of participants while they perform the task. This should clarify our initial interpretations of differences between jumbled and partly jumbled situations and help us to understand the nature of visual knowledge and its development as a function of traffic experience. The preliminary results seem to show clearly that driving scenes, suitably modified, behave in the same manner that the everyday scenes used by Biederman did. They also provide clear evidence for the existence of driving-related schemata which appear to be guiding visual search. This can be evidenced in two ways. Firstly the difference in performance between possible and impossible no conditions clearly indicates that viewers are sensitive to gross differences in driving situations. A fast parsing of the gist of driving scenes seems to be enabling viewers to identify rapidly the types of scene where certain objects are particularly unlikely to appear. Of more interest is the second difference - that jumbling scenes slows down visual search, and the drivers are more affected by this jumbling than non-drivers are. Because of the evidence from the partly jumbled condition, we currently suspect that this effect is caused by drivers visual schemata allowing them to predict rapidly the relevant areas of the scene in which particular objects are likely to appear and making fast initial eye movements to these locations. However, this does not rule out the existence of additional effects that are operating
after the initial eye movement and further analysis, including eye tracking data, will help to clarify this possibility.

One of the clearest but most difficult findings is that older, more experienced drivers are slower on all aspects of this task. Initially this seems to create serious problems for the interpretation and practical development of this task; however, this is a problem we have encountered previously in a range of laboratory tasks (eg Chapman and Underwood, 1996; Ismail, 1999). In a variety of computerised tests, older, more experienced drivers adopt more cautious strategies resulting in longer reaction times, but lower error rates. Theoretically this does not create any particular problem with the task. Since it is differences in reaction time that are of interest rather than absolute times, we can afford to ignore overall differences in reaction time between groups. However, focusing just on differences does open up the possibility that participants who understood the nature of the test might 'cheat' by making deliberately slow responses to jumbled scenes. If the experimental methodology were to be developed for use as a direct test of driving experience there are a number of possible approaches that could be taken. One approach would be to attempt to balance errors and reaction times, either using a scoring procedure to weight the trade-off, or by encouraging all participants to adopt the same criterion. An alternative approach might be to measure simple reaction time to non-driving objects and remove this from a final score to account for non-driving related differences in simple or complex reaction times.

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**References**


20 Do driving test errors predict accidents? Yes and no

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Introduction

In the British practical driving test, candidates are continuously monitored for 48 categories of predefined errors, each of which is assessed as a dangerous, serious or more minor fault. Serious or dangerous faults are those judged to involve potential or actual danger, and candidates making one or more of them fail the test. Before May 1999 there was no specified limit on the number of minor faults a candidate was allowed to make without failing, although examiners could decide that a pattern of repeated minor faults indicated a serious fault. Only the first two minor faults in any category were recorded. Since May 1999 examiners have recorded all minor faults, renamed 'driving faults', and candidates making 16 or more of them have failed the test.

Setting the maximum permitted number of driving faults at 16 has meant that just under 0.5 per cent of candidates failed the new test through making too many driving faults. The intention was to tighten the failure criterion if it could be shown that to do so would fail candidates with raised accident risk.

To provide evidence on whether tightening the failure criterion would be justified, Road Safety Division, DETR (now DTLR) commissioned TRL to investigate the relation between the number of driving faults recorded during the test, and accidents in the first six months of post-test driving. This paper describes some of the results of that investigation. Further information on the wider project to review the practical driving test is provided by Baughan (2000).

The survey

OVERVIEW

Names and addresses of a sample of drivers who had passed the practical driving test were obtained from the Driving Standards Agency (DSA) together with their driving test records. The drivers were asked to complete a postal questionnaire, covering accidents during the first six months of post-test driving and a number of other questions relating to exposure, driving style, driving competence, attitudes towards driving violations, and driving behaviours.

It was recognised from the outset that the ability of driving test errors to identify drivers who go on to have a raised accident liability would be limited (Baughan, 1998). Nevertheless, if an adjustment to the test were able to identify and fail a new group of drivers with an only slightly raised accident liability, the potential accident savings might be worthwhile. Initially the failers would be returned for more training or practice before being allowed to drive unsupervised; in the longer term the new testing requirements might be expected to induce learners to reach a higher standard before coming for a test in the first place. The indications from the TRL Cohort Study (Maycock and Forsyth, 1997) were that minor driving test faults did have useful predictive power.

The question of whether it is possible to identify a group of relatively unsafe drivers by means of driving test faults is conceptually not a simple one, the main problem being the meaning of the term unsafe. A group of drivers who have more accidents in a given time than
another group might well be regarded as relatively unsafe, and as a worthy target for a safety intervention. But, as is well known (eg Maycock et al, 1991), accident liability depends on many factors and, crucially, on exposure to risk. It is therefore possible that the raised accident liability of the group might be explained by such variables. This would imply that although the group members had more accidents than other drivers, their standard of driving was not intrinsically worse or less safe. Corrective measures (such as inducing further training and practice by causing them to fail the driving test) might produce a safety benefit for the group, but the fairness of applying the measures solely to group members when they are intrinsically just as good as other drivers might be questioned.

Consider now a group whose members' driving is intrinsically worse/less safe than that of the rest of the driver population: they have a raised accident liability when exposure to risk is controlled for. This group, too, might be regarded as a good target for safety interventions such as using the driving test to encourage them to have more training and experience. However, in practice the group members might actually have no more accidents than the rest of the population, because their exposure to risk is lower. It might then be argued that targeting a safety intervention on the group was unfair to the group members, or inefficient in terms of resource allocation, because their relatively unsafe driving was already compensated for by the reduced exposure to risk.

The implications of the above situations for safety interventions are not clear-cut. In each situation, interventions might be effective in reducing the numbers of accidents amongst the unsafe or the high-accident group, but might be seen as unfair - in the one case because they penalised a group whose standard of driving was not inferior, and in the other because they penalised a group whose inferior standard of driving was compensated for by a reduced exposure. Only where a group of people drive less safely than the rest of the population and actually have more accidents does the situation become more straightforward to interpret. Clearly, therefore, it was necessary for the survey to examine the differences in actual numbers of accidents between high and low faults groups, and to investigate whether there is a relation between faults and accidents once any differences in exposure between high and low faults groups have been allowed for.

SAMPLE DESIGN

Analysing a sample of driving test records showed that only 1.5 per cent of test passers made 15 driving faults, so it was decided to pool those making 14 and 15 faults into one group. Similarly, people making 0, 1 and 2 faults were put into one group, leaving 13 'number of driving faults' groups in total. The smallest of these was the 13 faults group, accounting for about 4.4 per cent of test passers.

The survey sample was issued in monthly waves to people who had passed the test about seven months earlier. The size of each wave was limited by the number of candidates passing the test each month who made 13 faults (all these candidates were included in the sample). The first wave had equal numbers of people in all 13 groups, as had waves two and three. Two further waves included only people making eight or more driving faults.

THE QUESTIONNAIRE

The questionnaire asked about accidents in the first six months of post-test driving, pre-test driving experience, driving exposure since passing the test, near accidents, and police warnings and prosecutions. It included a number of questions about driving ability, driving
style, attitudes to driving violations, hazard involvement, and aberrant driving behaviours that previous research has found to be related to accident liability.

FIELDWORK

The survey was administered by the National Foundation for Educational Research (NFER) under contract to TRL. A single reminder, including a copy of the questionnaire, was issued to people who had not responded two weeks after the initial posting. The questionnaire title was 'Transport Research Laboratory Driving Questionnaire' and the survey was described as a survey of the driving experiences of recently qualified drivers being conducted to help improve driver testing.

Results

ACHIEVED SAMPLE

The response rate to the survey was 42.2 per cent. Some respondents were excluded - eg because they provided incomplete data for variables that were to be used in statistical modelling. This left 29,559 records for the main analyses - and reduced the effective response rate to 37 per cent.

PROPORTIONS OF DRIVERS INVOLVED IN ACCIDENTS

Figures 1a and 1b show the percentages of men and women in each number-of-faults group who reported having been involved in an accident in the first six months of driving after passing the test.

Figure 1a: Accident involvement and driving faults - males

Figure 1b: Accident involvement and driving faults - females
There was no obvious pattern of accident involvement being associated with high numbers of driving faults. There was, however, a suggestion of such a relation for women. This was confirmed by a weighted regression analysis of the proportion of each driver fault group who were involved in accidents, which showed, for women, a weak linear component that was statistically significance at the p=0.10 level only.

The above analyses were in terms of the proportion of people in each number-of-faults group who were accident involved. Parallel analyses were carried out on the mean number of accidents reported by the members of each group. They lead to similar conclusions.

**CAN A DRIVING FAULTS THRESHOLD IDENTIFY A GROUP WHO ACTUALLY GO ON TO HAVE MORE ACCIDENTS THAN THE OTHERS?**

The following analysis first sets the simulated 'failure' threshold at 14 driving faults and compares the accident involvement of two groups of people: those with 14 or 15 faults and those with less than 14. Next, the threshold is set at 13 faults, and the accident involvement of those making 13 or more faults is compared with those making fewer than 13. This is repeated for failure thresholds down to seven faults. Tables 1a and 1b show the results.

**Table 1a: Accident involvement of high and low faults groups - males**

<table>
<thead>
<tr>
<th>comparison</th>
<th>Higher faults group</th>
<th>Lower faults group</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>acc inv</td>
<td>not acc</td>
<td>proportn</td>
</tr>
<tr>
<td>14,15 v rest</td>
<td>179</td>
<td>939</td>
<td>0.160</td>
</tr>
<tr>
<td>13-15 v rest</td>
<td>378</td>
<td>1,898</td>
<td>0.166</td>
</tr>
<tr>
<td>12-15 v rest</td>
<td>578</td>
<td>2,852</td>
<td>0.169</td>
</tr>
<tr>
<td>11-15 v rest</td>
<td>801</td>
<td>3,877</td>
<td>0.171</td>
</tr>
<tr>
<td>10-15 v rest</td>
<td>1,014</td>
<td>4,884</td>
<td>0.172</td>
</tr>
<tr>
<td>9-15 v rest</td>
<td>1,241</td>
<td>5,915</td>
<td>0.173</td>
</tr>
<tr>
<td>8-15 v rest</td>
<td>1,492</td>
<td>6,986</td>
<td>0.176</td>
</tr>
<tr>
<td>7-15 v rest</td>
<td>1,609</td>
<td>7,631</td>
<td>0.174</td>
</tr>
</tbody>
</table>
Table 1b: Accident involvement of high and low faults groups - females

<table>
<thead>
<tr>
<th>comparison</th>
<th>Higher faults group</th>
<th>Lower faults group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>acc inv</td>
<td>not acc</td>
</tr>
<tr>
<td>14-15 v rest</td>
<td>188</td>
<td>1,205</td>
</tr>
<tr>
<td>13-15 v rest</td>
<td>388</td>
<td>2,485</td>
</tr>
<tr>
<td>12-15 v rest</td>
<td>586</td>
<td>3,789</td>
</tr>
<tr>
<td>11-15 v rest</td>
<td>793</td>
<td>5,124</td>
</tr>
<tr>
<td>10-15 v rest</td>
<td>998</td>
<td>6,431</td>
</tr>
<tr>
<td>9-15 v rest</td>
<td>1,185</td>
<td>7,811</td>
</tr>
<tr>
<td>8-15 v rest</td>
<td>1,360</td>
<td>9,134</td>
</tr>
<tr>
<td>7-15 v rest</td>
<td>1,488</td>
<td>9,949</td>
</tr>
</tbody>
</table>

The tables show that women who make 11 or more driving faults were statistically significantly more likely to report an accident than the rest. The same applies for 10 or more, nine or more and seven or more faults - in other words, setting the failure threshold at 11, 10, nine, or seven would fail women with a higher likelihood than the rest of reporting an accident. Setting the failure threshold at 14, 13, 12 or eight driving faults would tend to have the same effect though the effects for these groups are not statistically significant - note, though, that the statistical power of the comparisons decreases in the upper rows of the table because the sample size for the higher-faults group diminishes.

These differences in accident involvement are rather small: for example, 13.4 per cent of women who made 11 or more driving faults reported an accident and 12.2 per cent of the rest did - a difference of 1.2 percentage points. The 95 per cent confidence interval for this difference is 1.2 +/- 1.07 percentage points. This is equivalent to the statement that women making 11 or more driving faults were 9.4 +/- 8.1 per cent more likely than the others to be involved in an accident.

For men, it is not possible to find a pass-fail threshold that fails a group of 'higher accident' men. There is even a (non-significant) tendency for men who make 14 or more faults to be less likely than the rest to have an accident. The same applies to men who make 13 or more, and 12 or more, faults.

Tables 1a and 1b also demonstrate that women are less likely than men to be involved in accidents. This applies in all the 'numbers of faults' categories. Women who make (say) 11 or
more faults are more likely to report accidents than other women, but they are less likely to report accidents than the men in any 'number of faults' category.

AGE AND EXPOSURE OF HIGH-FAULTS DRIVERS

Table 2 shows that people who made more driving faults tended to be a little older than the rest, and to drive in the dark rarely or never. This was true for both men and women.

Table 2: Age, exposure and number of driving faults

<table>
<thead>
<tr>
<th>No. of driving faults</th>
<th>Average age (yrs)</th>
<th>Proportion who drive often or sometimes in the dark</th>
<th>Average miles (six mths)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>males</td>
<td>females</td>
<td>males</td>
</tr>
<tr>
<td>0,1,2</td>
<td>20.5</td>
<td>20.7</td>
<td>0.98</td>
</tr>
<tr>
<td>3</td>
<td>20.0</td>
<td>20.9</td>
<td>0.98</td>
</tr>
<tr>
<td>4</td>
<td>19.8</td>
<td>21.1</td>
<td>0.97</td>
</tr>
<tr>
<td>5</td>
<td>20.3</td>
<td>21.3</td>
<td>0.96</td>
</tr>
<tr>
<td>6</td>
<td>20.6</td>
<td>21.2</td>
<td>0.96</td>
</tr>
<tr>
<td>7</td>
<td>20.5</td>
<td>21.2</td>
<td>0.97</td>
</tr>
<tr>
<td>8</td>
<td>20.5</td>
<td>22.3</td>
<td>0.95</td>
</tr>
<tr>
<td>9</td>
<td>20.8</td>
<td>22.1</td>
<td>0.96</td>
</tr>
<tr>
<td>10</td>
<td>20.9</td>
<td>22.7</td>
<td>0.96</td>
</tr>
<tr>
<td>11</td>
<td>21.1</td>
<td>22.8</td>
<td>0.96</td>
</tr>
<tr>
<td>12</td>
<td>21.2</td>
<td>23.0</td>
<td>0.96</td>
</tr>
<tr>
<td>13</td>
<td>21.6</td>
<td>23.5</td>
<td>0.96</td>
</tr>
<tr>
<td>14,15</td>
<td>21.2</td>
<td>22.9</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Mileage and driving in the dark are indices of exposure to risk, so their associations with numbers of driving faults might be expected to reduce the accident liability of the high-faults groups and explain the lack of a strong relationship between numbers of faults and accidents. In other words, high-faults people might be intrinsically less safe as drivers, but might have no more accidents than low-faults people because they have less exposure to risk. There is a complication here: in this sample, where everyone has completed six months of post-test driving, mileage and proportion of night driving become important indices of experience as well as of exposure. Given that accident liability is known to fall sharply as drivers gain
experience, the experience effect is likely to offset at least some
of the exposure effect of mileage. In other words, the high-
faults people tend to have lower exposure to risk (reducing their
accident liability) and less driving experience (which may
increase their accident liability).

FITTING ACCIDENT MODELS

To find out whether a relation between driving faults and
accidents appears once the effects of the above variables are
removed, models of the type developed by Maycock et al
(1991) were fitted to the data. First, the number of accidents
was modelled as a function of mileage covered in the first six
months, age when passing the test, and whether the driver
drove often or sometimes at night rather than rarely or never. A
term for driving faults was then added to the model. The model
has the following functional form:

\[
\text{Accidents} = \text{miles} b_1 \times \exp\left\{ \frac{b_2}{\text{age}} + b_3 \times (\text{drive in dark}) + b_4 \times (\text{driving faults}) \right\}
\]

Males and females were treated separately. Table 3 shows the
values of the parameters that were statistically significant at the
5 per cent level or better.

Table 3: Accident model parameters (all-accident model)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Model without driving faults</th>
<th>Model with driving faults</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>males</td>
<td>females</td>
</tr>
<tr>
<td>b1, miles</td>
<td>0.279</td>
<td>0.237</td>
</tr>
<tr>
<td>b2, 1/age</td>
<td>40.48</td>
<td>19.36</td>
</tr>
<tr>
<td>b3, drive in dark = no (^1)</td>
<td>-6.502</td>
<td>-4.651</td>
</tr>
<tr>
<td>b3, drive in dark = yes (^1)</td>
<td>-5.955</td>
<td>-5.287</td>
</tr>
<tr>
<td>b4, all driving faults</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Deviance (^2)</td>
<td>9,447.7</td>
<td>9,514.5</td>
</tr>
<tr>
<td>Diff. in deviance</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>% of non-Poisson variation explained (^3)</td>
<td>9.6%</td>
<td>13.4%</td>
</tr>
</tbody>
</table>

1. Eg the model term \{b3*(drive in dark)} takes the value -6.195 for males who
drove often or sometimes in the dark, and -6.752 for those who did not (with-
driving-faults model).

2. The deviance statistic indicates how well the model fits the data. Difference in
deviance between the models with and without driving faults indicates the
improvement in fit produced by including driving faults. It is distributed as chi-square on the number of degrees of freedom change between the models (in this case, one extra parameter, so one d.f. change).

3. For an explanation of this see Appendix B of Forsyth et al (1995).

* statistically significant ($p < 0.001$)

Mileage and proportion of night driving are each positively associated with accidents in the model, indicating that in this cross-sectional study, the exposure effects of these variables outweighed their experience effects.

The fact that the driving faults term is statistically significant indicates that there is a relation between driving faults and accidents not apparent from the data presented in Figures 1a and 1b, where it is masked by differences between high- and low-faults drivers in terms of mileage, driving in the dark, and age. Figures 2a and 2b illustrate the relationship between driving faults and accidents as predicted by the model once mileage, age and driving in the dark are held constant.

**Figure 2a:** Predicted number of accidents in the first six months for males aged 21 who drive 4,000 miles, and drive 'often or sometimes' in the dark

![Graph showing predicted number of accidents vs driving faults for males aged 21 with 4,000 miles and driving 'often or sometimes' in the dark]

**Figure 2b:** Predicted number of accidents in the first six months for females aged 22 who drive 3,000 miles, and drive 'often or sometimes' in the dark

![Graph showing predicted number of accidents vs driving faults for females aged 22 with 3,000 miles and driving 'often or sometimes' in the dark]
PRACTICAL SIGNIFICANCE OF THE MODELLING RESULTS

The models can be used to compare the predicted average accident liabilities of two groups of people - those making $n$ or more driving faults, and those making fewer than $n$ faults - while removing the effects of between-group differences in age, mileage and driving in the dark. The results show, for example, that men making 12 or more driving faults would have a mean accident liability between 7.4 per cent and 25.6 per cent higher than the others. The equivalent figures for women are 9.8 per cent and 31.6 per cent. (These ranges are 95 per cent confidence intervals.)

RESPONSIBILITY FOR ACCIDENTS

The foregoing analyses are concerned with all the accidents that drivers reported in the survey. In principle, it is possible that different, perhaps stronger, relations between driving faults and accidents might exist for subsets of accidents. One obvious subset consists of accidents for which the survey respondents themselves were responsible. Respondents were asked how much they were to blame for the accident. There was no relation of any practical importance between number of faults and blameworthiness.

LOW-SPEED MANOEUVRING ACCIDENTS

In a study of this type, by far the majority of accidents involve only minor damage and no injuries. The argument for basing policy on this type of information is that the consequences of
an accident are largely a matter of chance, so that minor accidents have a similar underlying causal structure to those with serious consequences and therefore have the potential for serious consequences themselves. To the extent that this is true, interventions that reduce the number of minor accidents would also be effective in reducing serious accidents.

While this argument is undoubtedly a strong one, it is obvious that there are some differences in causal structure between minor and severe accidents. For example, accidents at very low speeds are unlikely to result in serious injury to the vehicle occupants. This is not to say that such accidents are unimportant. They gain importance from being numerous, and the behavioural aspects of their causal structure may in fact have much in common with higher-speed accidents. The same poor vehicle control or poor observational skills that lead to a low-speed accident might also increase the risk of higher-speed accidents with severe consequences. Moreover, a low-speed accident that involved reversing into an unseen bollard might equally well have involved reversing into a child.

It is therefore not possible to pre-define a set of accidents that are truly trivial, and that tell us nothing about the propensity of an individual to have more severe accidents. Nevertheless, concerns have been expressed that this survey would be dominated by trivial accidents having little to do with road safety, and that it might lead to failure criteria being set for the driving test that would unfairly penalise candidates with a raised liability for trivial accidents alone. Low-speed manoeuvring accidents were suggested to us as an example of such accidents. It was therefore decided to ask respondents whether they would describe each accident as a 'low-speed manoeuvring accident', so that the data could be analysed both including and excluding such accidents.

Restricting the analysis to non-low-speed manoeuvring accidents produced results similar to those for all accidents.

**DRIVING FAULT TYPES AND ACCIDENTS**

All the foregoing analyses concern the total number of driving faults recorded for a test candidate, and are relevant to the question of whether the test failure criterion for total driving faults should be adjusted. In principle, some types of fault may be more important than others as indicators of driving safety. Their association with accidents may have been masked by the presence in the analyses of other, less useful, faults. It was therefore necessary to investigate whether subsets of driving faults are predictive of accidents, with a view to setting separate test failure criteria for subgroups of driving faults.
**COHORT STUDY CATEGORIES OF DRIVING FAULTS**

In the original TRL cohort study of novice drivers, Maycock and Forsyth (1997) grouped the driving test faults into two main categories, each with four subcategories, as shown in Table 4.

**Table 4: Driving fault categories (after Maycock and Forsyth, 1997)**

<table>
<thead>
<tr>
<th>Car control faults</th>
<th>Perceptual/judgement faults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of controls</td>
<td>Awareness and anticipation</td>
</tr>
<tr>
<td>Normal driving</td>
<td>Violations</td>
</tr>
<tr>
<td>Manoeuvres</td>
<td>Driving too fast</td>
</tr>
<tr>
<td>Use of mirrors and signals</td>
<td>Driving too slowly</td>
</tr>
</tbody>
</table>

**MODELLING CATEGORIES OF DRIVING FAULT AND ALL ACCIDENTS**

Once again, statistical modelling was used to find whether each category of faults was predictive of accidents once the effects of age, mileage and driving in the dark have been taken into account. The two faults associated with the emergency stop were excluded from the statistical modelling because, since May 1999, only about a third of candidates are tested for the emergency stop.

Models were produced for all accidents, and for non-low-speed manoeuvring accidents. To allow the relative importance of each category of fault to be compared, Table 5 summarises the 'deviance explained' by each category of faults. The values of deviance explained provide a way of ranking the importance of the fault categories as predictors of accidents both within and between models, once differences in mileage, age, and driving in the dark have been allowed for. Table 5 indicates the following.

- Total faults predicted all accidents somewhat better than it did non-low-speed manoeuvring accidents. This was especially so for male drivers.
- Total faults was better than any other faults category at predicting all accidents.
- For non-low-speed manoeuvring accidents, the best predictors were normal driving faults for male drivers, and total control faults for female drivers.
- For male drivers' non-low-speed manoeuvring accidents, normal driving faults were a better predictor than total control faults, suggesting that the other components of total...
control faults - ie controls, manoeuvres, and mirrors/signals - somehow reduce the usefulness of total control faults as a predictor of these accidents.

- Male drivers' non-low-speed manoeuvring accidents were less predictable from driving test faults than are the three other categories of accidents. This is consistent with the hypothesis that for men, once low-speed manoeuvring accidents are discounted, factors associated with behavioural choice rather than performance error are even more dominant as accident predictors than they are for women.

- Mirrors/signals faults, and driving too slowly on test, contributed little or nothing to explaining accident liability.

- Violation faults on test contributed little or nothing.

The implications of these findings for the driving test would appear to be that there is little justification for basing failure criteria on the subgroups of driving faults examined in Table 5. Total faults was the best or equal-best predictor for three out of the four accident types examined in Table 5 and in the fourth type (male drivers' non-low-speed manoeuvring accidents) it was nearly as good as the best predictor (normal driving faults).

**Table 5: Fault category parameters - deviance explained by driver fault categories**

<table>
<thead>
<tr>
<th>Category</th>
<th>All accidents</th>
<th>Non-low-speed accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>males</td>
<td>females</td>
</tr>
<tr>
<td>Control faults</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c - controls</td>
<td>06.06</td>
<td>06.10</td>
</tr>
<tr>
<td>d - normal driving</td>
<td>09.83</td>
<td>07.58</td>
</tr>
<tr>
<td>m - manoeuvres</td>
<td>05.83</td>
<td>02.88</td>
</tr>
<tr>
<td>s - mirrors/signals</td>
<td>00.01</td>
<td>00.80</td>
</tr>
<tr>
<td>Total control faults</td>
<td>10.28</td>
<td>12.87</td>
</tr>
<tr>
<td>Perceptual/judgemental faults</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a - awareness</td>
<td>03.90</td>
<td>05.15</td>
</tr>
<tr>
<td>v - violations</td>
<td>00.09</td>
<td>00.75</td>
</tr>
<tr>
<td>f - too fast</td>
<td>06.79</td>
<td>01.37</td>
</tr>
<tr>
<td>h - too slow</td>
<td>00.97</td>
<td>00.94</td>
</tr>
<tr>
<td>Total perceptual/judgemental faults</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
FACTOR AND DISCRIMINANT ANALYSES OF DRIVING FAULTS

The subcategories of faults used in the modelling above were established by Maycock and Forsyth (1997) on the basis of judgement, rather than empirical analysis. It may, therefore, be possible to find better groupings to predict accidents and/or to represent underlying driver competencies or dimensions of the driving task. This was explored in two ways: factor analysis to attempt to categorise faults according to some underlying structure, and discriminant analysis to discover the best subset of faults for identifying accident-involved people. Neither approach produced meaningful or useful groupings of faults.

CHARACTERISTICS OF HIGH-FAULTS DRIVERS

If a tightening of the failure criterion for driving faults is to be considered, it will be desirable to form a reasonably complete picture of the type of driver likely to fail the revised test.

DSA records show that women who pass the test tend to make more driving faults than men. It has been shown above that for men and for women, high-faults drivers tend to be slightly older than the others, to drive lower mileages, and to drive less often in the dark. It is not clear why this should be, though a speculative explanation involving real or perceived driving ability, driving confidence and possibly access to a non-school vehicle pre- and post-test suggests itself. This receives some support from self-ratings of relative speed and relative driving ability collected during the survey. High-faults people tended to rate their driving as relatively slow and relatively poor. Replies to other questions in the survey revealed that high-faults people tended to have taken more driving tests than had low-faults people, and had more hours of professional instruction, and fewer hours of pre-test driving supervised by a friend or relative (Table 6). As Groeger (2000) has suggested, people who find it difficult to learn to drive may gravitate towards professional instruction, and one mechanism here may be that their driving does not inspire 'informal' supervisors with confidence.

Table 6: Driving faults and learning to drive

<table>
<thead>
<tr>
<th>No. of driving faults</th>
<th>Hours of professional instruction</th>
<th>Hours with a friend or relative</th>
<th>Total number of driving tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-6</td>
<td>28.9</td>
<td>25.2</td>
<td>1.73</td>
</tr>
</tbody>
</table>
**Discussion**

**DOES THE SURVEY SUPPORT CHANGING THE FAILURE CRITERION IN THE DRIVING TEST?**

The main purpose of this study was to discover whether driving faults during the driving test are predictive of accident risk in a way that would justify changing the current failure criterion of 16 or more driving faults. To do this, it was necessary both to examine the relation between driving faults and actual numbers of accidents, and to use statistical modelling to allow the influence of exposure to risk to be explored.

Statistical modelling showed that once the effects of mileage, age, and driving in the dark have been removed, reasonably strong predictive relationships between driving faults and accidents are revealed. This is true for 'all accidents' and for accidents not classified by the respondent as low-speed manoeuvring accidents. The modelling results are consistent with the argument that high-faults people are intrinsically less safe as drivers, implying that they would have more accidents than low-faults people if they were to decide to drive the same mileages, and as often at night, as low-faults people. The results imply that there is a case for failing high-faults drivers on the grounds that their driving is relatively unsafe and might be improved by further training and practice. Allowing them to pass the test is to rely (it could be argued) on a control mechanism (ie the self-controlling of exposure) that is not understood, and that could presumably be overridden at any time by a driver who so chooses.

Whether this argument is sufficient on its own to justify failing high-faults people might be challenged for two reasons. First, it
is clear from the study that high-faults people tend to limit their driving (or to have it limited by factors outside their control) such that they do not actually have more accidents than low-faults people. Secondly, exposure and driving experience are highly correlated in this sample of novice drivers, with mileage being the main indicator of both. (Driving experience defined in the usual way - ie how long a person had been driving since the test - was held constant at six months.) In this cross-sectional sample the net effects of mileage and night driving were found to act as exposure variables rather than experience variables, but we cannot be sure that this would be so for individual drivers who decide to drive more. If high-faults people were to decide to drive more during their first six months of driving, we cannot be absolutely certain whether they would have more accidents (because of their increased exposure) or fewer accidents (because they become more experienced).

**TARGETED VERSUS GENERAL SAFETY INTERVENTIONS**

The assumption underlying efforts to improve the ability of the driving test to identify drivers with a raised accident liability is that to do so will improve road safety. As observed above, in the period immediately following a change to the test failure criterion the test would identify these drivers and cause them to have more training and/or practice before driving unaccompanied. In the longer term, the new testing requirements would be expected to influence the training system such that more drivers would reach the new test standard before coming forward for test at all. While such changes are likely to be beneficial, there is no guarantee that bringing a group of relatively unsafe drivers up to a new test standard will also bring their accident liability down to that of drivers who would have met that standard anyway.

There is also the question of whether it is fair and cost-effective to attempt to target a group of relatively unsafe drivers. Possible reasons for such targeting include the following.

- A group whose standard of driving is relatively unsafe might be more susceptible to improvement by training and practice. For example, its members might have skill and knowledge deficiencies that could be remedied.

- A high-accident group imposes higher costs on other members of society (including those who become involved in the group's accidents).

- A group whose excess accidents are explained by high exposure offers more scope than a low-accident group for reducing the road accident total.
The fact remains, however, that it may be possible to obtain greater or more cost-effective road safety benefits by improving training and practice for drivers in general, or by tackling the wider aspects of the licensing system so as to reduce risk and control behaviour during the early months of post-test driving. Baughan and Simpson (2002) provide a review of some attempts to achieve such changes in other countries.

Conclusions

- The results of statistical modelling indicate that high-faults people tend to be intrinsically less safe as drivers during the first six months of post-test driving, implying (though not providing absolute proof) that they would have more accidents than low-faults people if they were to decide to drive the same mileage and to drive as often at night.

- High-faults people tend to drive fewer miles in the first six months after the test, drive less often the dark, and be slightly older than low-faults people. These differences tend to reduce the actual accident involvement of high-faults people. There is no relation between number of faults and actual accidents for men, and only a rather weak one for women.

- There is no test failure threshold for total driving faults that identifies a group of men who will have more accidents than the rest during the first six months of unsupervised driving. For women, there are cut-off points that identify higher accident groups.

- The higher-faults, higher-accident group of women have fewer accidents than the men in any 'number of faults group'.

- Any move to tighten the failure criterion so as to fail a high-faults group of people whose driving is relatively unsafe would have to be defended against the argument that, in practice, high-faults men do limit their driving, or have it limited by factors outside their control, such that they do not actually have more accidents.

- The above conclusions are not changed if low-speed manoeuvring accidents, or accidents for which the respondent feels little responsibility, are excluded from the analysis.

- The survey showed that, in addition to the difference in mileage, age, and driving in the dark, high-faults drivers tended to rate their driving as relatively slow, and relatively poor. They also tended to have more hours of professional instruction than low-faults people, fewer hours of pre-test driving supervised by a friend or relative, and to have taken more driving tests than low-faults people.

- The survey provides no good evidence to support the setting of separate failure criteria for subcategories of driving fault.
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