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OVERTAKING ROAD-ACCIDENTS: DIFFERENCES IN MANOEUVRE AS A FUNCTION OF DRIVER AGE*

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Abstract—Nine-hundred and seventy-three police road-accident files describing overtaking accidents were sampled from the headquarters of Nottinghamshire Constabulary, England, for the years 1989–1993. Salient facts were extracted from each case, including the exact manoeuvre involved, the principle explanatory factors, the driver(s) most at fault, and the drivers' ages. Two kinds of reliability measure for case interpretations indicated high levels of consistency. Two induced exposure measures were used, comparing driver involvement in a given type of overtaking accident with involvement in overtaking accidents in general, and comparing the age profiles of the drivers most at fault with those of the other drivers involved. Ten types of overtaking accident were distinguished, and three are discussed in detail: collision with a right-turning vehicle (the most common injury-accident for overtakers), which tends to occur either because a young driver makes a faulty overtaking decision, or an older driver makes a faulty right turn; head-on collision, which affects all age groups roughly in proportion to exposure; and the 'return-and-lose-control' accident, which is associated particularly with young drivers. The study illustrates the 'structured judgement method' of accident causation research, in which human interpreters are used to ascribe causes and processes to individual cases, but orthodox research techniques are used to standardise procedures, and to assess and ensure reliability.

Keywords—Accident causation, Overtaking, Police records, Methodology

INTRODUCTION

This paper has two objectives: to show how police accident files can be analysed effectively using a mixture of human interpretation and standard quantitative research techniques, and to report on the different ways in which inappropriate overtaking can lead to road accidents.

Research on overtaking accidents is comparatively rare, even though the accidents themselves are quite common and typically fairly serious. They accounted for 7.9% of fatal road accidents in the county of Nottinghamshire, England, during the period 1989–1992 inclusive, and their 'accident severity index' (the proportion of cases resulting in deaths or serious injuries) is over 20%. Drivers themselves, when asked, rate overtaking as a dangerous manoeuvre (Harris, 1988) and, of course, they have little opportunity to learn and practise it in driving lessons. Groeger and Clegg (1994), in their video analysis of manoeuvres in over 550 hours of driving tuition, showed that practising overtaking typically comprises only 5% of all manoeuvres in lessons, and many of these occasions only involve the overtaking of either stationary or slow moving vehicles. It therefore seems hardly surprising that not only inexperienced but also experienced drivers are at risk of becoming involved in overtaking accidents.

The interval judgements required for overtaking have been studied using test tracks and roadside observation (Crawford, 1963), while a more psychophysical approach was taken by Björkman (1963), who studied drivers' perceptions regarding the meeting point of their car with an oncoming car, using a marked test track. He found that drivers expect to meet an oncoming vehicle halfway, regardless of its speed, suggesting problems with speed perception. In a further study based on Björkman's work, however, Brehmer (1990) found support for an alternative perceptual strategy. Here drivers did not seem to assume that the mid-point between vehicles would be the meeting point, but rather made variable errors in estimating the meeting point which showed regression

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towards the mean (which also happened to be the mid-point in Björkman's study—hence his result). Brehmer also predicted that accident rates will depend on the distribution of vehicle speeds. Any road environment with a greater variability of speeds and other factors will be more prone to accidents, which may be part of the reason why overtaking accidents are a particular problem on single-carriageway trunk roads, where vehicle occupant deaths are at their highest (PACTS, 1994).

In the United States, early research was conducted by Farber and Silver (1967). Their main conclusions were that drivers are able to make good judgements regarding the *distance* of an oncoming car, but are unable to respond effectively to the oncoming vehicle's *speed*. This is because the rate of change of angle has to exceed 0.2 degrees per second before a driver can distinguish a faster from a slower closing speed, and in the passing situation this threshold is not crossed until just before meeting an oncoming vehicle. Investigating a different process, Farber (1969) observed drivers overtaking at night and in daylight. Drivers were more conservative in their overtaking decision-making during the hours of darkness, although in darkness there was greater variability caused by individual differences. Unfortunately, the study used covert observation, so data regarding the characteristics of the drivers were not obtained.

More recently, further work has been done on drivers' behaviour on the road. Wilson and Best (1982) identified several strategies used in overtaking manoeuvres on an observed stretch of rural A road in England with a 60 mph limit. Examples included 'flying overtakes' (no braking beforehand to follow the vehicle in front), 'piggy-back overtakes' (following another overtaker), 'multiple overtakes' (passing more than one vehicle) and 'accelerative overtakes' (increasing velocity throughout the manoeuvre). All strategies involved using very small gaps, which increased proximity to the *overtaken* vehicle in two ways. Firstly, there was marked evidence of 'lane sharing' with the overtaken vehicle, i.e. not moving fully over the centre line. Secondly, cutting in on the overtaken vehicle was common. Wilson and Best's approach, but not Crawford's, considers the crucial interaction with the vehicle(s) being overtaken and not just relationships with oncoming traffic. Any action which increases a driver's proximity to the vehicle being overtaken "increases geometrical risk" according to Wilson and Best. This conclusion is in contrast to Crawford's original work which, to a great extent, ignored the same direction cohort, and even recommended cutting in as an appropriate response to increase headway in relation to oncoming traffic. Wilson and Best also proposed the idea of the "inertial driver"—one who is essentially unwilling to change speed, maintaining speed to the last possible moment before braking to follow. Once overtaking is commenced by such drivers, they leave it until the last possible moment before returning to their own side of the road.

Wilson and Greensmith (1983) returned to the theme of the "inertial driver" in their multivariate analysis of drivers' accident status in relation to observed driving patterns, gender and exposure. They report that accident-involved drivers drive more quickly "…and move around continually (especially overtaking) in traffic". The typical inertial driver differs from his high-exposure accident-free counterpart, in that he seems unwilling to change speeds in response to conditions by using gear changes, deceleration or braking.

Further observational work was carried out by Harris et al. (1986) using video recordings. Findings included the observation that heavy goods vehicle (HGV) drivers are particularly likely to use right-turn filter lanes as overtaking lanes, and that drivers of high power-to-weight ratio vehicles seem safer overtakers. Harris (1988) moved on to examine drivers' beliefs about overtaking, identifying another key form of overtaking accident never simulated on a test track—overtaking at intersections.

There has also been relevant work on perceptions of the road environment and its influence on accidents. Hills (1980), for example, concluded that failures in judgement of oncoming traffic speed were the inevitable result of innate limitations in the human perceptual apparatus, which cannot detect the very small changes in visual image size associated with directly oncoming vehicles. Also drivers show little or no reduction in speed in conditions of reduced visibility caused by road geometry, for example. This has an obvious bearing on the large numbers of overtaking accidents occurring in the vicinity of bends, dips in the road and hill crests. Hills attributes the acceptance of risk-taking behaviour in such conditions to the high probability and, therefore, expectancy that there will be no obstruction. Fuller (1992) calls this phenomenon "learned riskiness". Summala (1980) conducted research showing that when overtaking is prohibited on a section of road, it can improve safety margins in various ways, not only by reducing the accidents involving overtaking per se, but also by increasing following distances and distances from the centre line, as drivers are no longer positioning themselves for possible overtaking opportunities.

These studies notwithstanding, there seems to be a relative dearth of overtaking research, which may be due, in part, to the special difficulties of studying this kind of manoeuvre. It is not easy to reproduce accurately in simulators or on test tracks, and failures are hard to observe and film as they are not strongly associated with particular locations, and they occur at speed over a considerable length of road.

One possibility is the use of multi-disciplinary accident investigation (MDAI) teams that travel to accident sites straight away to collect data. However, in a review of the work of MDAI research worldwide, Grayson and Hakkert (1987) point out several disadvantages to such a method. Operational costs are very high, and only a small number of accidents can be studied. There is a bias towards injury accidents, owing to the notification procedure, and the accidents sampled are bound to be of a heterogeneous nature. Despite the vast amount of information collected in such work, "definitive conclusions are very limited" and have been applied mainly to vehicle design and engineering efforts rather than human behaviour and road design. According to Grayson and Hakkert, these limitations tend to disappear "if an in-depth but not immediate response on-the-spot approach is taken". They also point out that any in-depth technique is only really useful if applied to specific problems rather than a large heterogeneous sample of cases.

Some studies have applied in-depth techniques to secondary data sources, such as police reports, interviews and questionnaires. Fell (1976) was amongst the first to claim that an "accident causal schema" could be constructed from such sources. Malaterre (1990) used police reports to classify and analyse accidents, and later to identify prototype cases. However, his sample was quite small (115 cases) and was also heterogeneous. He concluded by saying that more precise analysis needed to be carried out from complete police accident reports, with all their different types of information, especially for the purpose of designing driver aids which require the driver's needs to be defined accurately in different situations.

Clarke et al. (1995a, 1998) analysed police road-accident files on right-turn junction accidents, and introduced the techniques of sequence analysis and computation rule-finding (using machine learning 'genetic' algorithms) to pick out the distinctive features of accidents turning onto or off major roads; those of younger and older drivers; those that resulted in injury or in damage only; and so on. However, some of the 'richness' of the case information was inevitably lost when coding files for computer analysis, and so for the present project it was decided to place more emphasis on the interpretation of causal patterns by the human coders, and to save the powers of the computer for the later stages of storing, sifting and aggregating explanatory models of individual cases.

In most forms of research, there is a balance to be struck between the judgement and experience of the investigator as a source of insight, and the additional findings that may be possible with objective instrumental methods. Too much reliance on human interpretation can lead to bias and a neglect of computationally complex issues. But too much reliance on formalised objective methods, on the other hand, can mean sacrificing subtlety, flexibility, speed and intelligibility. To take a very crude example, if you wanted a method for determining the sense of this present text, you could (a) read it, or ask someone else to do so and to summarise its meaning; or (b) write a suite of text interpretation programs, and let them process it. The former approach is far more effective than the latter, notwithstanding the enormous effort that has gone into AI text interpretation, and the real strides that have been made. A human reader detects things that no other device or procedure yet can, and does so in a different way—more quickly and flexibly, more 'holistically', more receptively to other knowledge about the domain in question, and yet, remarkably, without any real awareness of the process involved. By comparison, a mechanical text reader is slow, rigid and error prone.

So much is obvious. However, we typically overlook the fact that much the same applies to the interpretation of specialised texts like accident case files. Here, too, the human reader has the advantage over algorithmic methods in many respects, and the causal 'sense' of each accident is usually abundantly clear from case documents that have been constructed precisely to make it so. Sadly, though, the history of psychology and allied disciplines has left us fearful of any approach that might seem less than completely mechanical and objective. As a result we often neglect the most straightforward solutions to our most pressing problems.

Human judgement can provide the key to effective case-based research, but only if it is properly organised and disciplined to maximise reliability and validity. We use the phrase 'structured judgement methodology' for an approach which uses judgement as the main source of causal inference, but also employs conventional techniques from experimental psychology to standardise procedures and to assess and improve reliability.

Earlier studies carried out in our laboratory showed that detailed interactions between causal factors only come out clearly if the sample is confined to a single type of accident. It was felt that one of the drawbacks of previous in-depth studies had been their reliance on heterogeneous groups of accidents (e.g. Carsten et al., 1989; Malaterre, 1990). Overtaking accidents were chosen partly because their relative inaccessibility by standard methods makes them a particularly suitable test-bed for this new approach to accident causation research. Overtaking was defined as the situation whereby any moving vehicle passes, or attempts to pass, another that is moving in the same direction, or is standing temporarily with a running engine. Nearside passing or 'undertaking' was included in this definition, but accidents were excluded if they involved the overtaking of vehicles which were parked, or on dual carriageway roads with a central reservation. As the method relies largely on the human interpretation of case reports, the construction of explanations, typologies and models was not based on any particular theory, but generated primarily from the data themselves. Only injury accidents were sampled, as the records of damage-only accidents contain less detail.

Our enquiry into real cases of overtaking accidents began by asking whether different sub-types of accident exist, and whether they occur for different reasons and with different groups of drivers.

METHOD

Case selection

The reference numbers of all overtaking injury accidents in the county of Nottinghamshire, England, for the years 1991–1993 which met the above criteria were identified from the Nottinghamshire County Council Accident Investigation Unit database. There were 795 cases in all. The corresponding case files were then borrowed from the headquarters of Nottinghamshire County Constabulary, photocopied, examined, interpreted and then returned.

All case files were checked against the selection criteria. Approximately 3% were excluded because they had been wrongly coded, or did not fit our definition of overtaking, for example. This left 769 accidents in the initial sample. Each case was designated either 'A grade' (containing a high level of detail allowing a full interpretation of events), or 'B grade' (where the overall level of information, e.g. from independent witnesses, was lower).

This initial sample produced 206 A grade cases, and a further 204 were subsequently obtained from the records held on microfiche at Nottinghamshire County Council for the years 1989–1990, making the sample up to 973 cases overall. No B grade cases were extracted for 1989–1990.

Case interpretation

Each case file was read in detail by two interpreters who were both experienced researchers (and experienced drivers), and any difficulties resolved in consultation with the third member of the team. The procedures for interpreting and summarising each case file had been developed and piloted at an earlier stage of the project (Clarke et al., 1994). Three main items of information were used to represent the circumstances of each accident: (1) a 'story-line', or narrative description of the sequence of events; (2) a sketch plan of the accident scene; and (3) a list of explanatory factors.

Standard conventions for creating the story-lines and sketch plans were drawn up after repeated examination of the materials in the pilot study. The story-line was always written from the viewpoint of 'Driver 1', the driver mainly at fault, for example, although much consideration was also given to other drivers' actions and intentions at this stage. All available facts were incorporated, including information from witnesses when this was felt to be reliable. Discrepancies were sometimes found between the statements of the drivers involved and those of independent witnesses, on the question of the driver's speed for example. But a consensus usually emerged from the witnesses, which was often backed up by police investigations of skid marks and vehicle damage, so unequivocal conclusions about the accident circumstances could usually be drawn. The sketch plans were also produced in standardised form using computer-graphic templates of road layouts and vehicles.

The possible 'explanatory factors' for each case were coded from a standardised list developed during the pilot study. (The attending police officers' summary of 'CONFACS', or contributory factors, drawn from a police coding scheme, was also recorded, but not used in the analysis here as it is intended mainly just to capture the first impressions of the officers at the scene.) Our coding frame covered the main causes which could be attributed to overtaking accidents, ranging from the road environment, through vehicle and driver characteristics, to specific driver behaviours. It had been repeatedly refined in order to capture the specific characteristics of overtaking cases, so driver judgements concerning distances to bends and other road features were distinguished in some detail, for example. Written definitions of each explanatory factor and its appropriate circumstances of use were drawn up to assist the case interpreters. Only factors which appeared to have contributed to the accident were recorded as 'explanatory factors'. Others, which were present but incidental, as perhaps a wet road or defective tyres could be on some occasions, were coded separately.

The distinction between features which have a causal role and those which are merely present, especially when made case by case, is an unusual feature of 'structured judgement methodology'. Most methods of accident causation research, or come to that, most scientific investigations in any field, would identify causal factors by statistical association, or concomitant variation. *A* would be picked out as a cause of *B* only if, by and large, they both occurred in the same cases and were both absent from the same cases. No distinction would normally be possible between the cases where *A* was present in a causal role, and those where *A* was present but incidental. This is part of the reason why exposure and baseline effects are such a problem in conventional accident-causation studies. We cannot tell whether a common feature of accidents is a causal factor, unless we know whether it is equally common in comparable but accident-free cases, and there is usually no record of the latter. However, this is to assume that the ascription of causes is always problematic. In structured judgement methodology, by contrast, it is assumed that the causal powers (Harré and Madden, 1975) of many of the objects in the driving situation are familiar, and their causal role in individual cases can often be judged with reasonable confidence. For instance, an accident in which a car swerves and loses control as it completes an overtaking manoeuvre may have been (at least partly) caused by bald tyres on the overtaking car. But an accident in which an overtaking car, without attempting to change speed or direction, is hit in the side by an emerging vehicle as it passes a side road, must have been due to other factors, even if the overtaker's tyres were bald. (The most likely causes in this case would be failure of observation by the emerging driver, and lack of care by the overtaker in choosing where to pass.)

The coding frame for explanatory factors was organised hierarchically, with specific driver actions and behaviours grouped under the broad headings of misinterpretation, ignorance, carelessness, misjudgement and deliberate risk taking. This allowed a given action to be represented in different ways, depending on the driving process which gave rise to it. For example, a simple failure to observe could arise for various reasons, including carelessness, misjudgement or deliberate risk taking. It is important to distinguish between collisions which might appear similar but arise for quite different reasons. The necessary distinctions turned out to be quite straightforward given the level of detail found in the police interviews and witness statements. This stage of case interpretation is similar to Malaterre's (1990) "task and error analysis", which attempted to find out which factors led to failures in the "function event sequence" before building prototypes of the 10 most frequent "function failure categories" and four "antecedents".

Two studies were conducted to gauge the reliability of the interpretation process in all its aspects, including the construction of story-lines and sketch plans. These gave very satisfactory results which are reported elsewhere in detail (Clarke et al., 1995b, 1996). For instance, similarity ratings for different interpreters' versions of the same case had a mean of 6.26 (0.84) on a seven-point scale, whereas similarity between interpretations of different cases by the same coder was rated at 2.30 (1.55), and of different cases by different coders at 2.38 (1.46). Standard deviations are shown in parentheses. This much difference between different-case pairs and same-case pairs is equivalent to an 'effect size' of 2.68, and in experimental work any effect size above 0.8 is conventionally classified as a large experimental effect.

The standardised case descriptions consisting of factual details such as the time and place of the accident; the narrative story-line; the sketch plan; and the relevant explanatory factors, were input to a customised FILEMAKER PRO database. Figure 1 shows just the layout of the standard 'data entry screen', although a variety of other formats were set up as well for other data-entry, calculation and display purposes. Once all the cases had been entered in this way the process of hypothesis creation and testing could begin in earnest, using the search routines in the database to identify contrasting sub-groups of cases typifying different kinds of driver (or vehicle, or road layout, or countless other features and combinations of features). Each sub-group of case descriptions was then re-read repeatedly and in detail, combing out possible common accident mechanisms, re-grouping or further dividing the sets of cases, and re-iterating through the process until stable and consistent conclusions were reached.

The resulting 973 case descriptions and interpretations then made up the 'Nottingham Accident Database for Overtaking' (NAD/O) for use in an ongoing series of analyses and studies, of which this paper represents the first part.

RESULTS

Typology of overtaking manoeuvres

After repeated reviews of the database, the following 10 groups of overtaking manoeuvres were chosen as best representing the distinctions present in the sample of cases. Each type has a short name for use in tables and figures.

Type 1	Right turn	Collision between an overtaking vehicle and an overtaken vehicle which turns right
Type 2	Head on	A head-on collision with a vehicle travelling in the opposite direction
Type 3	Swipe	Side-swiping a vehicle which is being overtaken

Record number	NJ1543/92/464	**Grade of Info.**	A
		No. of Statements	4
Severity	Serious	x	Independent witnesses
			Vehicles examined
Date	1/7/92	x	Sketch map
			Photographs
Day	Wednesday	x	Licence records

Time 24hrs	12:42		**Type O/T**	2
Road Type	B class		**Entry 1-6 options**	Flying overtake Multiple overtake Piggy back
Speed limit	60			
Area		Rural	**Police cf's**	38
Weather, Road conditions		rain, wet	**Lighting**	Daylight
Junction type, control		none	**Driver age, sex**	1- M,23 2- M,33
Types of vehicle	1- Vauxhall Cavalier 2- Escort van			
Drivers familiar ?		yes, both	**Casualties**	1 -bruising to chest 2- severe lacerations and broken ribs
Passengers age, sex, relation		none		
Previous Convictions		SP30 speeding	**Charges**	DWDC

Fig. 1. (*continued opposite*)

Type 4	Cut in	Hitting a vehicle either in front or behind when returning to a gap after overtaking
Type 5	Lose after	Losing control after returning to the nearside following an overtake
Type 5.1	Lose during	Losing control while carrying out the overtake
Type 6	Junction	An overtaker colliding with a vehicle emerging from a junction
Type 7	Nearside	A vehicle overtaking on the nearside (undertaking) and hitting another
Type 8	Avoidance	Colliding as a result of avoiding action following another driver's risky overtaking manoeuvre
Type 0	Miscellaneous	Unclassifiable/miscellaneous

The whole sample of 973 A and B grade cases was then re-examined in detail to identify the main features associated with each manoeuvre. In most cases the primary blame for the accident could clearly be apportioned either to the overtaker/undertaker, or else to another driver (who typically turned into the path of an overtaker). In 16% of cases, more than one driver appeared to be at fault. Table 1 shows the distribution of blame over the 10 types of overtaking accidents. This paper concentrates on Types 1 (Right turn), 2 (Head on) and 5 (Lose control), as they are the most common ways in which an overtaker error causes a serious accident.

Explanatory factors in the 10 types of overtaking accident

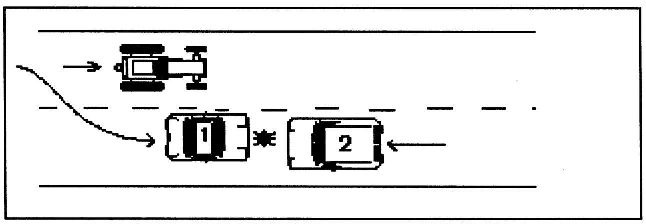
The 10 overtaking manoeuvre types were examined in relation to the main categories in the explanatory factors coding template (see Table 2). Note that more than one factor may apply in a given case.

The tendency is for Type 1, overtaking a right

Prose account

It was just after mid day on a summer weekday. The roads were wet from previous heavy rainfall. The driver [M 33] of a Vauxhall Cavalier (1) was driving along a rural B road with 60 mph limit. He had travelled that day from Perth with 2 or 3 stops but was used to driving long distances and was familiar with the road. As he came round a slight right hand bend, he came up behind a slow moving tractor. He slowed down behind it and started to overtake as there was a straight stretch of road ahead. However, a van (2) driven by [M 23] was coming in the opposite direction only some 30 metres away. The van driver was not aware that the Cavalier was behind the tractor until it pulled out to overtake. The van driver braked and began weaving and pulled over to the nearside of the road but could not avoid a head on collision with the car which braked at the last minute. Both cars were badly damaged at the front but not written off. Driver 1 was bruised and cannot remember the details of the accident but he was not detained in hospital. Driver 2 suffered broken ribs and severe lacerations and bruises and was detained. Driver 1, who may have fallen asleep momentarily as he approached the tractor , was convicted of driving without due care and attention.

Map



Minimum Set of Explanations Driver 1:
DC3 Tired / fatigued
C2.3 Poor observation ; no continuity of observation

Other factors present Wet road

Hazard perceived only at last moment by Driver 2

Avoiding Action ? Driver 2 braked hard

Comments / Quotes

Q: Where had you travelled from that day?
A: Perth
Q: Had you driven non-stop?
A: No, I'd had 2 or 3 breaks
Q: Is it possible you fell asleep as some time as you approached the tractor?
A: I wouldn't have thought so, I do 35-40,000 miles a year at present and I haven't had a problem with tiredness before.

Primary blame Overtaker / Undertaker

Fig. 1. An example 'data entry screen' from the FILEMAKER PRO database.

turner, to involve poor observation, whereas Type 2, head on, involves more misjudgement together with poor observation. Type 5, the 'return and lose control accident', is characterised by misjudgement and excess speed before and during the manoeuvre.

Induced exposure measures

In order to relate the 10 types of overtaking accidents meaningfully to the age of the driver primarily at fault, some account must be taken of exposure effects. This was done in two ways.

Firstly, the age range in the sample (16–81 years) was divided into 10 equally spaced bands, which were cross tabulated against the 10 manoeuvre types. For each combination of an age group and a manoeuvre, the 'standard normal residual' (Colgan and Smith, 1978) was calculated (see Table 3). 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 ± 1.009 is approximately equivalent to a significance level of $p < 0.05$. As with Chi-squared

Table 1. Distribution of blame in 10 types of overtaking accidents

	Type	Overtaker at fault	Other at fault	Combined fault	Total
1	Right turn	144	122	74	340
2	Head on	150	1	7	158
3	Swipe	76	9	10	95
4	Cut in	26	0	3	29
5	Lose after	43	0	0	43
5.1	Lose during	33	0	2	35
6	Junction	13	17	25	55
7	Nearside	34	82	24	140
8	Avoidance	37	4	7	48
0	Miscellaneous	15	12	3	30
	Totals	571	247	155	973

the calculation involves differences of observed from expected numbers of observations as a proportion of expectation, so the critical value is independent of sample size. In this case it provides us with a kind of indirect exposure measure, in that it picks out groups of drivers who are disproportionately involved in a particular type of overtaking accident, relative to their involvement in overtaking accidents in general, which stands for their exposure to driving situations in which hazardous overtaking occurs.

Type 1 (Right turn) accidents are relatively common for all age groups, with no group achieving significant relative differences. With the Type 2 (Head on) accident, the story is a little different. This is a type of accident in which two groups, aged 43–48 and 69–74 years, are under-represented, and the oldest group, aged 75–81 years, is over-represented. The Type 5 (Lose control) accident is a problem for younger drivers, with the older age groups showing a clear tendency not to demonstrate it.

A second type of induced exposure measure allows driver age and accident types to be examined in a different way using a procedure like that originally proposed by Thorpe (1964), and later developed by Carr (1969) and Haight (1973). The age of 'Driver 1'—the person primarily to blame, usually the overtaker, was compared with age of 'Driver 2', the other driver involved in the collision. Figure 2 shows the result for accident Type 5 (Lose control).

For this type of accident, we can see that the youngest age band in particular (16–22 years of age) includes a much greater proportion of Driver 1s than Driver 2s, suggesting that the involvement of the younger drivers in this kind of accident is not just a result of exposure, which would affect both parties to an accident equally. This pattern has already reversed by the time the third age band is reached, suggesting that drivers of 29 and over are relatively more often on the roads in circumstances where this

Table 2. Explanatory factors in 10 types of overtaking accidents

Factor	Type 1 Right turn	Type 2 Head on	Type 3 Swipe	Type 4 Cut in	Type 5 Lose after	Type 5.1 Lose during	Type 6 Junction	Type 7 Nearside	Type 8 Avoidance	Type 0 Misc.
Poor observation	262	95	52	11	7	5	50	114	13	18
	(77.1)	(60.1)	(54.7)	(37.9)	(16.3)	(14.3)	(89.3)	(81.4)	(27.1)	(60.0)
Inexperience	85	44	14	4	14	10	17	22	8	6
	(25.0)	(27.8)	(14.7)	(13.8)	(32.6)	(28.6)	(30.9)	(15.7)	(16.7)	(20.0)
Misjudgement	14	83	10	15	41	21	5	7	16	4
	(4.1)	(52.5)	(10.5)	(51.7)	(95.3)	(60.0)	(9.1)	(5.0)	(33.3)	(13.3)
Excess speed	52	50	11	5	27	17	14	13	8	5
	(15.3)	(31.6)	(11.6)	(17.2)	(62.8)	(48.6)	(25.5)	(9.3)	(16.7)	(16.7)
Total	340	158	95	29	43	35	55	140	48	30

Percentages are in parentheses. These do not necessarily sum to 100 as the categories are not mutually exclusive.

Table 3. Standard normal residuals for 10 types of overtaking accident and 10 age bands of driver most at fault

Age group	Age (years)	Type 1 Right turn	Type 2 Head on	Type 3 Swipe	Type 4 Cut in	Type 5 Lose after	Type 5.1 Lose during	Type 6 Junction	Type 7 Nearside	Type 8 Avoidance	Type 0 Misc.
1	16–22	0.089	0.909	−0.70	0.159	**1.408**	−0.24	−0.02	**−1.27**	−0.68	0.57
2	23–29	0.018	−0.07	0.855	**−1.11**	**1.05**	**3.59**	−0.59	**−1.05**	−0.73	**−1.37**
3	30–35	−0.78	0.198	0.735	0.435	−0.03	**−1.29**	−0.57	**1.38**	−0.49	0.66
4	36–42	0.874	−0.35	−0.91	**1.534**	**−1.28**	−0.93	0.417	−0.26	**1.05**	−0.55
5	43–48	0.368	**−1.17**	0.051	0.334	**−1.15**	−0.89	**1.70**	−0.44	0.752	**1.604**
6	49–55	0.684	0.243	−0.73	0.559	−0.97	−0.72	**1.589**	**1.077**	0.512	0.352
7	56–61	0.129	−0.07	0.836	−0.87	−0.35	**−1.06**	**−1.33**	0.740	**1.109**	0.139
8	62–68	0.695	−0.47	−0.35	−0.76	**−1.04**	−0.93	−0.29	0.888	**1.554**	−0.81
9	69–74	0.133	**−1.19**	0.686	−0.46	−0.62	−0.56	−0.70	**2.517**	**1.451**	−0.49
10	75–81	−0.61	**1.177**	−0.57	−0.36	−0.49	−0.44	−0.55	**1.422**	−0.40	−0.39

Figures exceeding ± 1.009 (shown in bold type) are equivalent to a significance level of $p < 0.05$.

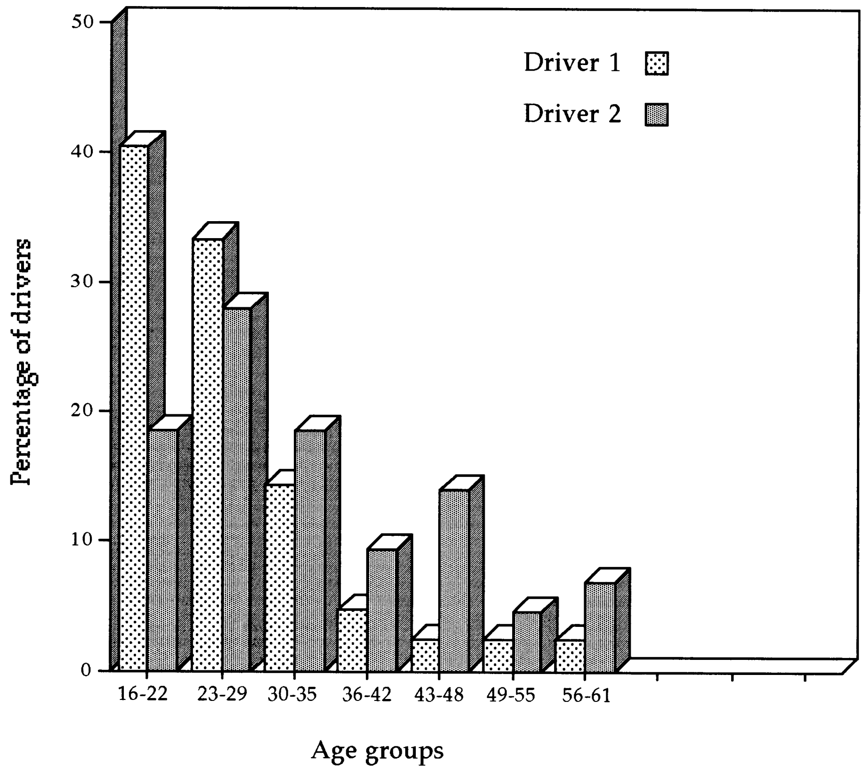


Fig. 2. Type 5 (Lose control) accidents—percentage of drivers mainly at fault (Driver 1) in each age band, and of other drivers involved (Driver 2).

kind of accident happens to them than they are involved in causing it.

For accident Types 1 and 2 (Right turn and Head on), there was a smaller, but still noticeable disproportion between Driver 1s and Driver 2s in the first age band. This shows that young drivers (16–22 years) are more involved in overtaking right turners, and head-on collisions while overtaking, than would be expected from their numbers on the road. However, this does not show up so clearly in the standard normal residual measure above. That is dominated by the higher involvement of young drivers in overtaking accidents in general, and does not pick up their particular involvement in the Right turn and Head on types.

Both types of measure, the standard normal residuals and the comparison of Driver 1s and Driver 2s, were intended to show accident involvement corrected for possible exposure effects. The two measures are positively correlated ($r=0.54$, $t=6.4$, $p<0.05$, one-tailed). For the purpose of the correlation, the proportions for Driver 1 (D_1) and Driver 2 (D_2) in the second exposure measure were reduced to a single 'differential index': $(D_1-D_2)/(D_1+D_2)$. This index was calculated for every combination of age band and accident type. It runs from 1.0 when all drivers involved in that type of accident and age band are Driver 1s (most at fault), through 0.0 when the numbers of Driver 1s and Driver 2s are equal, to -1.0 when the combination of age band and accident type contains only Driver 2s, meaning that no drivers in that age band are at fault in that type of accident. Table 4 shows the proportions of Driver 1s and Driver 2s, in each combination of age band and accident type, as a single 'differential index'. The correlation of the two exposure measures, for each accident type in turn, is shown at the foot of Table 4.

Overall, the two measures correlate well. However, there are some anomalies. Considering the accident types separately, the correlation between measures does not always reach significance. This occurs notably in accident Types 1 (Right turn) and 5.1 (Lose during). In the case of accident Type 1, this may be due to the relative diversity of accident types remaining in this large group. With drivers under 22, for example, this type of overtaking accident often involves excess speed. Multiple overtakes tend to be involved, where the driver passes a line of traffic and collides with a right turner at the front. There is also evidence of recklessness or racing as a feature of this group. Drivers aged 56 and over, by contrast, tend to be involved in Type 1 (Right turn) accidents when moving off, U-turning or overtaking into the path of a vehicle which is already overtaking

Table 4. Relative proportions of Driver 1 (most at fault) and Driver 2 (other involved) in each age band, for each accident type. Also, for each accident type, the correlation between these indices of relative proportions and the standard normal residuals (Table 3), with associated *t* values

Age group	Age (years)	Type 1 Right turn	Type 2 Head on	Type 3 Swipe	Type 4 Cut in	Type 5 Lose after	Type 5.1 Lose during	Type 6 Junction	Type 7 Nearside	Type 8 Avoidance	Type 0 Misc.
1	16–22	0.041	0.312	−0.33	−0.39	0.277	0.028	0.07	−0.12	−0.45	0.04
2	23–29	0.022	0.017	0.089	0.130	0.032	0.222	−0.23	0.055	−0.33	0.44
3	30–35	−0.07	0.082	0.133	0.391	−0.07	−0.11	0	0.083	−0.39	−0.09
4	36–42	0.069	−0.06	−0.23	−0.06	−0.25	−0.42	0.183	0.011	0.108	0.111
5	43–48	0.083	−0.39	0.168	1	−0.62	−0.2	0.655	−0.12	0.153	0.294
6	49–55	0.084	−0.09	−0.41	−0.01	−0.16	−0.16	0.277	0.11	−0.61	0.49
7	56–61	0.017	0.017	0.219	0	−0.49	−1	−1	0.346	1	0.015
8	62–68	0.029	−0.03	−0.22	−1	0	−1	−0.41	0.227	0.44	0
9	69–74	−0.23	−1	0.111	−1	0	0	−1	1	1	0
10	75–81	1	−0.11	0	0	0	0	0	0.231	−1	0
$r=$		−0.36	0.7*	0.76*	0.312	0.608*	0.499	0.811*	0.784*	0.792*	−0.01
$t=$		−1.098	2.77	3.33	0.93	2.17	1.63	3.92	3.57	3.67	−0.03

*Indicates $p < 0.05$.

them, suggesting observational errors. Where these older drivers are overtaking a slower moving vehicle, it is often a farm vehicle or an HGV. Quite commonly, the indicator on the right-turning vehicle is masked by the glare of sunlight. There is very little involvement of excess speed in this age group.

Profiles of accident involvement

Each age group can be described according to the 'profile' of their involvement across the 10 accident types. Figure 3Fig. 4 show the profiles for the youngest two age groups combined (16–29 years) and the oldest three age groups combined (62–81 years). Such age-specific summaries may be of particular use to road safety officers, as they can highlight particular hazards and errors associated with young drivers (or other target groups).

DISCUSSION

Overtaking is a complex manoeuvre which can fail in a number of different ways. Each sub-type of overtaking accident has its own associated causes, and type of driver.

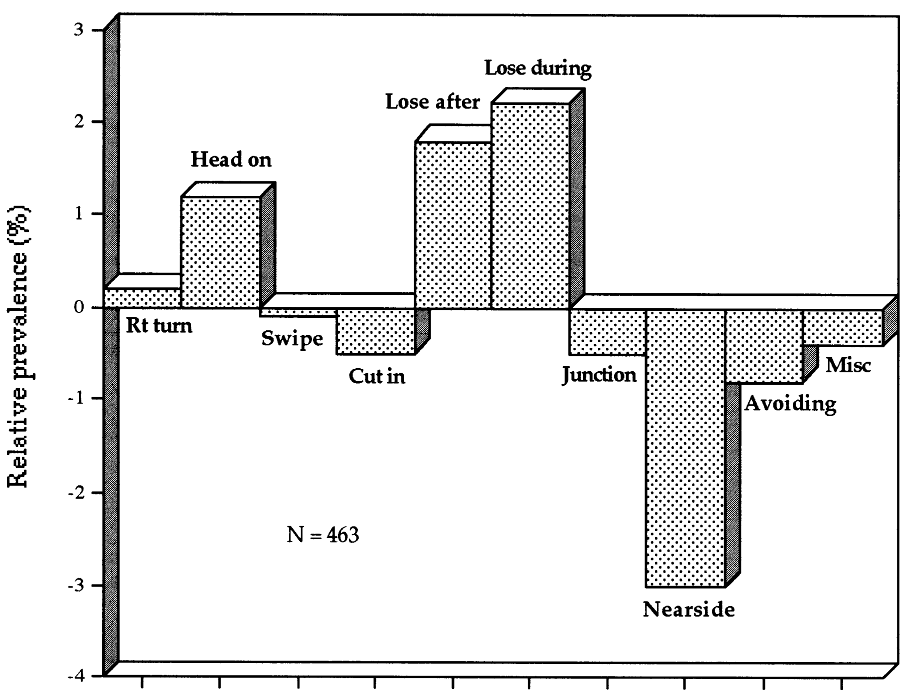


Fig. 3. Drivers aged 16–29 years. Percentage by which these drivers are over- or under-represented in each overtaking accident type, relative to the average prevalence of the type across all age groups.

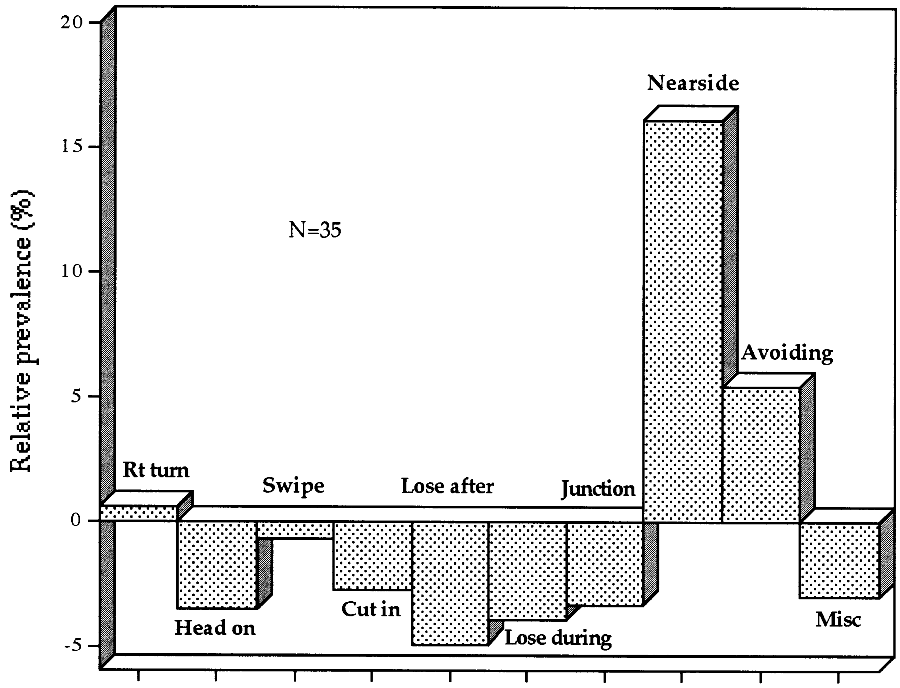


Fig. 4. Drivers aged 62–81 years. Percentage by which these drivers are over- or under-represented in each overtaking accident type, relative to the average prevalence of the type across all age groups.

The most frequent error made by overtaking drivers in this sample of injury accidents was overtaking a vehicle that was turning right. This was the case for all ages and types of driver, whether considered as a whole sample or split into more specific age groups. Initial statistical tests showed no differences with regard to the age of the main involved driver. However, when the details of these accidents were examined more closely, important differences began to emerge between the ways in which younger and older drivers came to be involved in collisions between overtakers and right-turners. At its simplest, this kind of accident tended to occur either because a young driver made a faulty overtaking decision, or an older driver made a faulty right turn.

With the Type 2 (Head on) accidents, all age bands were found in about the proportion expected from exposure considerations alone. None of the standard residuals were greater than ± 1.18, whereas seven of the other accident types produce a residual of at least 1.4. Examination of other material in the case files suggests that the key problems here are, firstly, that drivers of all ages misjudge the speed of the traffic they *are following* (or possibly the acceleration of their own vehicle) rather than the speed of oncoming vehicles. Statements like the following are common. One driver said in a police statement "I thought I had enough time to get around it" and another said "I didn't expect it to take that long to overtake the car". Secondly, the drivers appear to misjudge how much clear road will be needed to get past the vehicle being overtaken. The distance required for overtaking a vehicle travelling at 50 mph is quite considerable, yet interviews with involved drivers suggest that they picture the manoeuvre as putting them slightly ahead of the overtaken vehicle's initial position. They seem to imagine the overtaking of a moving vehicle in terms of the time and distance needed to overtake a stationary one, like the driver who said "I couldn't see any headlights coming the other way so I indicated to overtake the bus thinking I could sort of nip out and get in front of it".

Perhaps surprisingly, the Type 4 (Cut in) accident is under-represented for one of the younger groups of drivers, and over-represented for an older group.

Type 5 accidents, where the driver loses control on returning to the nearside after completing the overtake, are a particular problem for younger drivers. Such accidents can prove very serious, as the loss of control can cause the vehicle to either collide broadside-on with opposing traffic, or leave the road and collide with trees, walls, ditches and so on. However, it should be noted that the problem stems from faulty choices of timing and speed for the overtaking manoeuvre, not a lack of vehicle control skills as such.

Type 6 (Junction) overtaking accidents seem to peak in the 43–55 years age range. Our data do not indicate why this should be. Type 7 (Nearside) and Type 8 (Avoidance) accidents follow a similar pattern, in being rare for the younger age groups, but relatively common for the older ones. The nearside accidents seem to be due to inattention and confusion regarding multi-lane roads and junctions in some cases, which may account for their association with older drivers. Avoidance accidents may happen to older drivers if they become more apprehensive, and start taking more frequent, or less appropriate, actions to avoid the overtaking movements of other vehicles. It may also be that their slower and more hesitant movements on the road frustrate other drivers into unwise overtakes, which then call for avoiding action.

As to methodology, it seems that the rich data contained in police accident files can provide detailed causal information relating to a type of accident that has traditionally proved difficult to study, highlighting differences within even this apparently uniform type of accident. The use of 'structured judgement methods' allows certain inferences to be made about individual accidents, particularly the identification of drivers most and less at fault, and of the specific manoeuvre involved, which would not be possible with objective statistical and computational processing of the accident files. These interpretations of case files have achieved good levels of reliability, opening the way for this approach to be used in greater depth to elucidate the mechanisms of overtaking accidents per se.

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REFERENCES

Björkman, M. (1963) An exploratory study of predictive judgements in a traffic situation. *Scandinavian Journal of Psychology* **4**, 65–77.

Brehmer, B. (1990) Variable errors set a limit to adaptation. *Ergonomics* **33**, 1231–1239.

Carr, B. R. (1969) A statistical analysis of rural Ontario traffic accidents using induced exposure data. *Accident Analysis and Prevention* **1**, 343–357.

Carsten, O. M. J., Tight, M. R. and Southwell, M. T. (1989) *Urban Accidents: Why Do They Happen*? AA Foundation for Road Safety, Fanum House, Hampshire, U.K.

Clarke, D. D., Forsyth, R. S. and Wright, R. L. (1995a) *The Analysis of Pre-accident Sequences*. Transport Research Laboratory, Crowthorne.

Clarke, D. D., Forsyth, R. S. and Wright, R. L. (1998) Behavioural factors in accidents at road junctions: the use of a genetic algorithm to extract descriptive rules from police case files. *Accident Analysis and Prevention.*

Clarke, D. D., Ward, P. J. and Jones, J. (1994) Causal mapping of selected road-accident cases: rationale, method and preliminary findings. In Grayson, G. B. (ed.), *Behavioural Research in Road Safety*, Vol. IV, Proceedings of a Seminar at Brunel University, 6–7 September 1993. Technical Report No. PA3035/94, pp. 24–36. Transport Research Laboratory, Crowthorne.

Clarke, D. D., Ward, P. J. and Jones, J. (1995b) Causal mapping of overtaking accidents. In: Grayson, G. B. (ed.), *Behavioural Research in Road Safety*, Vol. V, Proceedings of a Seminar at University of Nottingham, 6–7 September 1994. Technical Report No. PA3081/95, pp. 55–70. Transport Research Laboratory, Crowthorne.

Clarke, D. D., Ward, P. J. and Jones, J. (1996) A clear road ahead: beyond the problems of accident causation research. In: Grayson, G. B. (ed.), *Behavioural Research in Road Safety*, Vol. VI. Proceedings of a Seminar at Royal Holloway, University of London, 4–6 September 1995. Technical Report No. PA3138/96, pp. 1–19. Transport Research Laboratory, Crowthorne.

Colgan, P. W. and Smith, T. J. (1978) Multidimensional contingency table analysis. In: Colgan, P. W. (ed.), *Quantitative Ethology*, pp. 146–174. Wiley, New York.

Crawford, A. (1963) The overtaking driver. *Ergonomics* **6**, 153–170.

Farber, E. I. (1969) Passing behaviour on public highways under daytime and night-time conditions. *Highway Research Record* **292**, 11–23.

Farber, E. I. and Silver, C. A. (1967) Knowledge of oncoming car speed as determiner of drivers' passing behaviour. *Highway Research Record* **195**, 52–65.

Fell, J. C. (1976) A motor vehicle accident causal system: the human element. *Human Factors* **18**, 1, 85–94.

Fuller, R. (1992) Learned riskiness. *The Irish Journal of Psychology* **13**, 250–257.

Grayson, G. B. and Hakkert, A. S. (1987) Accident analysis and conflict behaviour. In: Rothengatter, J. and de Bruin, R. (eds.), *Road Users and Traffic Safety*, pp. 27–59. Van Gorcum, Assen, Netherlands.

Groeger, J. A. and Clegg B. A. (1994) Why isn't driver training contributing more to road safety? In: Grayson, G. B. (ed.), *Behavioural Research in Road Safety*, Vol. IV, Proceedings of a Seminar at Brunel University, 6–7 September 1993. Technical Report No. PA3035/94, pp. 61–68. Transport Research Laboratory, Crowthorne.

Haight, F. A. (1973) Induced exposure. *Accident Analysis and Prevention* **5**, 111–126.

Harré, R. and Madden, E. H. (1975) *Causal Powers: A Theory of Natural Necessity*. Blackwell, Oxford.

Harris, D., Brindle, L. R. and Muir, H. L. (1986) Driver overtaking behaviour—an observational study. In: Oborne, D. J. (ed.), *Contemporary Ergonomics*, pp. 98–102. Taylor&Francis, London.

Harris, D. (1988) The subjective probability of involvement in an overtaking accident in the vicinity of a junction. In: Rothengatter, J. A. and de Bruin, R. A. (eds.), *Road User Behaviour: Theory and Research*, pp. 163–168. Van Gorcum, Assen, Netherlands.

Hills, B. L. (1980) Vision, visibility and perception in driving. *Perception* **9**, 183–216.

Malaterre, G. (1990) Error analysis and in-depth accident studies. *Ergonomics* **33**, 1403–1421.

PACTS (1994) Press release and minutes from working party meeting 12/1/94. U.K. Parliamentary Advisory Council for Transport Safety.
Summala, H. (1980) How does it change safety margins if overtaking is prohibited?—A pilot study. *Accident Analysis and Prevention* **12**, 95–103.
Thorpe, J. A. (1964) Calculating relative involvement rates in accidents without determining exposure. *Australian Road Research* **2**, 1, 26–36.
Wilson, T. and Best, W. (1982) Driving strategies in overtaking. *Accident Analysis and Prevention* **14**, 179–185.
Wilson, T. and Greensmith, J. (1983) Multivariate analysis of the relationship between drivers' accident, sex and exposure status. *Human Factors* **25**, 303–312.