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Work related road safety:

An analysis based on UK bus driver performance

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Abstract

The effects of age and experience on accident involvement for bus drivers was investigated, with special emphasis upon the first years of being an operator, using two methods. First, direct calculations between these variables were undertaken. Thereafter, a variant of the method of quasi-induced exposure (a ratio of culpable versus non-culpable accidents in the population) was used and referred to as the indirect method. These methods yielded fairly similar results, given that the samples used were drawn from the same population but only partly overlapping. It was found that experience had the strongest effect on accidents in the first year of driving, while age had a u-shaped association with accidents, i.e. young and old drivers had more accidents, something which was more apparent when experience was held constant. These results show that, for bus drivers, experience is initially more important than age, but after two or three years, the effect is small. Thereafter, age is the more discernible variable, although it is a very weak factor in predicting crash risk.

Keywords: crash, accident, culpability, bus driver, quasi-induced exposure

1. INTRODUCTION

Road traffic accidents, and the associated economical and social costs, are a major health problem in most countries today. Throughout accident research history, the search for predictors of accident involvement has been a central focus of investigation (see for example reference 1). Although a vast number of parameters (psychological, demographic, medical etc) have been tested (for reviews, see 2-6 and the meta-analysis 7) no strong associations have been found (e.g. 8).

Many organisations are concerned about the frequency with which their employees are involved in road traffic crashes, but there is, in comparison to car drivers, little published data to guide company policy and professional driver training. This paper aims to 1) re-visit two of the most persistently found accident predictors; age and experience but within a professional group of drivers that are less well understood compared with car drivers; that of bus operators and 2) we aim to consider methodological approaches to understanding crash risk that do not seem to have been studied before for any groups of professional drivers.

Bus drivers are a special group of professional drivers that differ markedly from the population of car drivers in ways that are likely to affect their crash risk. Firstly, bus drivers already hold a car driving licence before being granted a bus driver’s licence and also start driving a bus work at a later age than novice car drivers do. While it is possible that this is beneficial, currently there is no evidence to indicate that this is the case. On the contrary, no association has been found between years of holding a car driver licence and number of bus crashes (9).

Secondly, bus drivers have the added pressure of responsibility for passengers' lives driving large, heavy vehicles that are constantly pulling in and out of traffic, mostly in built-up areas. Thirdly, bus drivers have a much higher annual mileage than private motorists. Finally, organisational factors such as bus schedules are likely to exert a strong influence on their driving behaviour.

Age and experience are known to be predictive of road traffic collisions for car drivers (e.g. 10) but as these predictors are usually highly inter-correlated and are difficult to separate when investigating crash risk (11-14). For age, mileage adjusted crash risk declines with age but then rises again for drivers aged over 65 (15). This is thought to be due to physical and cognitive declines in older people and higher risk-taking in younger car drivers (16-18). Even limited driving experience has a major effect on road safety, as there is a disproportionately higher crash rate during the first year of driving for car drivers, particularly in the first few months after licensure (19). Mayhew et al (20) found larger decreases in crash risk amongst younger novices compared with older novices during the first few months of car driving. There is thus a reasonable literature on the effects of age and experience on crash involvement for private motorists, but little is known about whether these results can be generalised to professional drivers.

Turning to professionals, crash risk is greater for drivers who drive for work, even when taking into account their increased mileage (21). For bus operators, the same general findings as those pertaining to car drivers have emerged, although the literature is not as prolific. Generally, accident risk is found to decrease somewhat with increased age and experience, both having independent impacts (22), especially at the low end (23) although in some studies only one of these have been a significant predictor (9, 24, 25).

Although some effects of age and/or experience can almost always be found in crash risk calculations, there exists an inherent problem in such data; the matter of culpability for crashes, which is often not taken into consideration. As all drivers are exposed to events that are due to other drivers' behaviour, studies that use all crashes as the dependent measure, instead of culpable ones, probably underestimate the effects of their independent variables (studies which have found this effect include 26-29).

Regarding source methodology, many studies use official accident data to examine crash risk (e.g. 12, 18, 22, 30). These databases most often have the advantages of being large and collected over a long time period, but under-reporting and various biases have been shown to exist by many authors (e.g. 31-38). Other studies are limited by small sample sizes (e.g. 39), while the extremely popular self-report measure of crashes is seriously flawed in various ways (15, 29, 40-45).

Company fleet crash data on the other hand have advantages over official archives, and are probably more complete than other sources (42). However, they may suffer from other problems. Data are often collected for insurance purposes and are concerned with policies and claims rather than crash and driver characteristics. Here, the problem of culpability returns, because even though such data may be available, the correctness of the criterion and the actual coding may not be accurate.

There are many ways to assess the crash risk associated with different types of road user. Often, the driver is used as the unit of analysis and age, experience and crashes over a certain period of time is correlated, which can be called a direct analysis. However, as crashes are rather rare, the statistical power of such an analysis is often low. An alternative to this method is to start with crashes, and compare the characteristics of the drivers with those of the general driving population. However, using all drivers as comparison is crude, and will probably lead to confounding of different effects, like that of exposure. Therefore, several researchers have suggested using what is called induced exposure techniques on accident data, producing relative risk ratios, where the number of non-culpable accidents is used as an index of exposure. This method is based on the assumption that in two-vehicle crashes there is a driver who is responsible for the collision and that the second driver is selected randomly from the driving population (46, 47). The culpable and non-culpable drivers can thereafter be compared for various characteristics. This method has the advantages of not having to ascertain the exact population of drivers, or their exposure, as crashes are used as the unit of analysis, and other crashes used an exposure proxy. Furthermore, the use of pairs of drivers from the same crash means that many environmental variables of interest are held constant. A variant of this method, which is called quasi-induced exposure (see 47-49), calculates crash risk as a ratio of responsible drivers divided by the proportion of non-responsible in each group (defined by whatever variable is of interest, age for example), then the groups' risk ratios can be compared. If these differ, it can be said that there is an effect of the grouping variable.

The common approach for the induced method is that you cannot get all relevant data for the population, but instead compare the data of two groups. However, despite its popularity, this type of method does not seem to have been validated, and some results would seem to indicate that induced and direct techniques can yield different results, even when the same data is used (9). Also, for the data in the present study, it has been shown that the assignment of responsiblity is too lenient, with a substantial percent of bus drivers' being categorized as not at fault in accidents when they were probably active participants in the crash (57). Such erroneous coding may have serious repercussions for the induced method, but probably very small effects if associations with predictors are calculated directly for culpable accidents only. Therefore, it was decided to use both the direct and indirect methods to study the effects of age and experience upon the accident rates of bus drivers, and compare results between these methods.

To summarize, this study aimed to investigate the role of age and bus driving experience on crash risk when taking into account culpability, with special emphasis on the first year of employment with a bus company, using two different methods of analysing crash risk.

2. METHOD

2.1 Data

2.1.1 Source, coding and arrangement

A major UK bus company supplied data for the present study. Information about all their crashes and passenger falls was gathered and entered into an incident database. Some driver characteristics, such as age and length of employment, were also available. A further advantage was that all incidents are reported and attributed to a particular driver, no matter how minor. This is due to a strictly adhered to company policy that all vehicles are checked at the start and end of each shift. Each crash is coded by the driver according to several different categories. Culpability was assigned by the depot manager and the insurance team (for further details see the Appendix). In the present study, three levels of responsibility were available; Partly, Solely and Not responsible.

The data could be analysed taking the driver or crash as the unit of analysis. Unfortunately, the available sets for these two different types of analysis were not exactly the same, mainly due to the practical problems of extracting data for such large datasets.

2.1.2 Direct data

Samples of drivers were drawn from five regions. Available for each driver was date of birth, date of commencement of employment and number of crashes between 2001-2005 (the period for which this information was available) at the three different levels of culpability. However, only the culpable accidents were used (both categories of partly and solely responsible added together). Descriptive data for these are shown in Table 1. It should be noted that both age and experience in the accident sample are lower using the indirect method compared with the direct sample (Table 1 and 2). . For the indirect sample, it can be seen that mean age does not differ between culpability levels, while experience does.

Tables 1-2 about here

2.1.3 Induced data

The bus company operates from 121 depots in the UK and the induced analysis included all crashes that occurred throughout these depots from December 2000 to June 2003[1], except passenger falls and those where details about the crash and culpability were not complete (see Table 2). The accidents of 12,244 bus drivers aged between 18 – 64 years who had been in service from one month to 35 years were analysed. Information about driver's sex was not available, but, as can be seen from the direct data of sample 1 (Table 1) almost all of these bus drivers are male.

2.1.4 Direct method calculations

The direct method uses the individual driver as the unit of analysis, computing the effects of age and experience on accident rate. Also, the drivers with little experience could be singled out for further analysis. Furthermore, the trend over time in accident liability could be tracked by dividing the sample into groups with differing experience and calculating the mean number of accidents for each year between the groups using t-test analyses.

The results for different groups could also be compared with the risk ratios of the indirect method (see next section), for groups contructed according to the same principles (e.g. an age band). If results of the two methods were similar, this would mean that the known error in coding for culpability was random for the two variables of interest here (age and experience), because the direct method does not involve the Not responsible accidents (where the coding is partly erroneous, as shown in 57).

2.1.5 Indirect/induced method calculations

In the present paper, the drivers in accidents were not pairs from the same accident, as most were car drivers and thus not really comparable to the population of interest. Similarly, single-vehicle accidents were included, that are, of course assumed to be

[1] The direct and indirect samples were thus not the same (although there must have been some overlap), due to organisational factors; the indirect sample was already compiled by the company, while the direct

culpable. Therefore, the present analyses violated one of the assumptions of quasi-induced exposure, and thus introduced an unknown amount of error into the calculations. However, for a population of bus drivers, the use of pairs of drivers from the same accident are probably not that important, because the main purpose of this part of the method is to hold constant factors like time of day. Here car drivers probably differ a lot in their exposure compared with bus drivers (49). Risk exposure for bus drivers at work is much more standardized, as they have less choice concerning routes, time of day, type of vehicle etc than the car driving population. Therefore, it was not expected that there would be any significant violation of the assumption of non-culpable drivers as a random sample of the population. However, the risk ratios computed here cannot be compared to those of the quasi-induced method, as the numbers of drivers assigned to responsible and not responsible categories are not necessarily equally distributed. A higher percentage of drivers in the responsible category will therefore bias the risk ratios towards high values. Consequently, the analysis can only yield results that can be used for comparisons between groups (e.g. the ratio is lower for older drivers). It should be noted that the analysis is based on collisions, so that drivers may appear in the data more than once if they have been involved in multiple collisions within the time period.

2.2 Statistical methods

Two main problems for the present study was a need to find comparable statistics for the two different methods, and that the effects were not necessarily linear. Also, the two predictor variables were expected to be strongly correlated.

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samples had to be manually extracted from the main database by a researcher at a later date.

Although not commonly used in accident research currently, the Pearson correlation and multiple regression analyses were deemed suitable for the direct method, as most variables were fairly normally distributed, with experience being the only exception. Here, there was a fairly strong positive skew, indicating that many drivers only stay in the job for a rather short period of time. Therefore, t-tests were used to compare different groups of drivers, according to age and experience.

For the indirect sample, risk ratios were calculated between the culpable and non-culpable accidents, for groups formed with the same cut-off values for age and experience as for the direct calculations. The result is a measure of differences in accident-causing tendencies between groups. A ratio of 1 means that a group of drivers are equally involved in responsible and non-responsible crashes.

Given that measures of risk for groups defined in the same way had been calculated for both the direct and the indirect samples, these could be compared on a common scale, after standardization of values.

3. RESULTS

3.1 Direct calculations

Age and number of years of employment were correlated with the number of responsible accidents in a five-year period for all samples. As the associations were rather similar between samples, they were pooled into one. For this group, correlations for responsible accidents with age and experience are shown in Table 3. Thereafter, it was tested whether experience had any long-term effect by excluding accidents in the first year of driving for the company. It was found that the correlation with accidents for the whole period (2001-2005) was significant for up to four years. With more than five years experience, at the beginning of 2001, r was -.051 (N=1302, ns). As could be expected, the reverse exclusion process had the opposite effect; the correlation between accidents and experience was strongest for the drivers with less than one year of service at the start of 2001.

Experience was therefore further analysed by dividing the direct sample by years of experience and calculating the mean number of responsible accidents for each available calender year. The strongest effects were found for the first two years of driving (see Figure 1 and Table 4). Therefore, these were singled out and compared with the same groups from the induced data set (Figures 2-3).

As age and experience correlated .366 (N=2153, $p<.0001$), multiple regressions were run with these variables as predictors of responsible accidents. For the whole period (2001-2005), both were significant ($p<.0001$, beta for experience -.150, age .106, R=.152, N=2153). Results for each year in isolation were very similar. It is worth noting here that the age trend was positive.

However, dividing the sample into different age groups and comparing their means revealed that there was actually a higher risk for drivers under 25 years of age (see Figure 4), a negative initial trend. As this group was very small (N=24), this difference was only significant at $p<.05$ in comparison with the three next groupings, while against all other drivers it was not significant.

Table 3 and Figure 1 about here

3.3 Indirect calculations: Risk ratios

3.3.1 Total time period

Risk ratios were first computed for every year of experience. There was a marked decline during the first two years of driving (for both culpability categories), which were significantly different from later years, using a chi2 test (see Table 5). The later differences were not significant, due to dwindling Ns with the longer time periods. This would seem to pinpoint the effect of experience within the first years or so. Therefore, results are shown for the first five years, and compared to the findings of the direct method for drivers with less than one year's experience at the beginning of 2001 (Figure 2). This could also be calculated for up to six years, when the first year is deleted (this comparison uses the drivers with more than one but less than 2 year's experience).

Figure 3 and Table 5 about here

3.3.3 Comparisons of direct and indirect results

Figures 2 and 3 show the results for experience from the direct and indirect samples, with different starting points. It can be seen that for the first comparison (one to five years of experience), the results were very similar, while for the second, they were less similar. Thereafter, the risk ratios computed for age groups (responsible accidents divided by not responsible for each age group) can also be seen in Figures 4 and 5, and Table 6. The trends in these sets of data would seem to be fairly similar, with a correlation of .800 ($N=9$, $p<.05$).

Figures 2-5 and Table 6 about here

4. DISCUSSION

The main findings of this study indicate that, overall, there was an initial negative, and thereafter a weak positive effect of age on bus driver accidents, and a somewhat stronger initial, negative effect of experience, for both calculation methods. It therefore appears that lack of experience of driving a bus is more influential than age in its contribution to risk for crashes at first, but that age after a few years is still influential although rather weak, while experience no longer contributes to the change in crash risk.

It can also be concluded that the induced method does seem to yield similar results to the direct calculations, despite the violations against the assumptions of the original method (e.g. violation of the driver pair assumption). The method used to compare risk ratios and direct calculations of means for similarly constructed groups would seem to be a new contribution to the debate. It is therefore important to point out what can actually be concluded from these standardized values. As the basic values are in different units, the size of the two values for example, the first year of experience, cannot be directly compared with each other. However, they can both be compared to the other values within the same variable, and it can therefore be concluded that both methods indicate that the risk is twice as high in the first year of driving as in the second year of driving.

There are a number of methodological limitations to the present study that need to be considered. Firstly it is reasonable to assume that many of the employees with greater crash involvement will tend to leave the company (56), although no such effect could be found for Swedish bus drivers by af Wåhlberg (9). If this situation were the case, for the present bus company, this would lead to over-estimations of the effects, especially for experience, in the indirect data, while the direct sample would probably under-estimate them instead. However, the differences between methods were small, so there does not seem to be a case for suspecting an attrition effect.

Secondly, assigning culpability was jointly undertaken by depot managers and the insurance company (see Appendix). As there are a large number of depots from which the data was gathered, a large degree of error variance is to be expected from this source. As no inter-rater reliability assessments were undertaken, this facet remains an unknown.

Thirdly, it is possible that new drivers may be allocated less favourable routes and shifts compared with their longer serving peers, making their exposure qualitatively worse. However, the policy for bus company is the opposite to this. Depot managers are encouraged to ensure that in the early weeks of driving for the company, new drivers are given ‘nursery routes’. Therefore, the estimates of the impact of experience on accidents calculated here are, if anything, underestimations.

Fourthly, it is estimated by the bus company that about a third of the new drivers actually have some experience from other companies when they are hired. The experience effects found here are therefore underestimates of the actual ones.

The induced exposure technique assumes that non-culpable accidents are directly related to exposure and can be used as a proxy for it. As has been shown for the present data, this is not always the case (57). Also, Sagberg (51) added mileage and age as further predictors in his calculations using this method, with considerable effects (52).

Inexperience in the form of lack of knowledge about hazards and the appropriate vehicle handling skills to allow the driver to manoeuvre safely may result in the driver taking unnecessary risks in unknown situations (53-55). At present, the average newly recruited trainee bus driver with the present bus company receives about two weeks instruction on vehicle handling skills training and hazard awareness in one of the company's driving schools, in common with many other professional driver training courses. Apart from a test of the two methods of analysing crash risk and finding that there is little to chose between them when considering professional driver accidents, the implications of the present data suggests that the most fruitful targets for training of bus drivers would be to focus on novice drivers, regardless of age. There is also the suggestion that older drivers may need a refresher driver training course to mitigate risk.

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Appendix

Assignment of culpability by the Bus Company

After a collision, the bus driver completes a report with 6 boxes to tick for road type categories and 7 boxes to describe the road features where the collision took place. The driver can only tick one of these boxes for each of the sections and they are given no guidance about the circumstances under which they must respond to different boxes. There is no miscellaneous box. The accident report must also contain a diagram to describe what happened.

This report is forwarded to the depot manager who completes an 'Opinion Memo'. The manager looks at the driver's report, considers local knowledge and looks at the diagram. He/She then sends the Opinion memo to an in-house insurance team. They gather all the evidence, which includes the driver's report, the memo, witness reports, police reports, photographs (if available - drivers all have a disposable camera in the cab). The insurance team then either agree or disagree with the opinion memo. Culpability is assigned at this point and the information loaded on to the database. There are about 40 - 60,000 records each year.

Table 1: Descriptive data for the driver samples in the direct analysis. N, sex (percent males), age and experience (time since employment) on 2001-01-01 in years, and number of accidents at each level of responsibility (mean/std). Note that in the analyses, the five samples were added (total sample), as were the Partly and Solely responsible accident categories.

Sample	N	Sex	Age	Experience	Not responsible	Partly responsible	Solely responsible
1	407	95%	46.2/9.1	9.8/9.1	2.72/2.33	0.32/0.60	2.34/2.11
2	628	-	46.0/8.7	11.5/9.5	2.66/2.25	0.27/0.53	2.18/1.96
3	141	-	46.5/8.7	12.6/8.7	3.69/3.10	0.34/0.57	2.14/2.33
4	460	-	47.3/9.0	9.5/8.3	2.08/1.78	0.34/0.64	2.03/2.06
5	518	-	46.0/9.7	9.2/9.0	2.26/2.27	0.29/0.57	1.89/2.07

Table 2: Descriptive data for the accident sample of the indirect analysis. Number of incidents, age and experience (mean/std), for different levels of culpability. Note that in the analyses, the Partly and Solely responsible accident categories were added.

Accidents sample	N	Age	Experience
All	15100	42.8/10.8	6.1/7.6
Not responsible	7448 (49.3%)	42.9/10.6	6.7/7.7
Partly responsible	1422 (9.4%)	42.5/10.8	5.7/7.2
Solely responsible	6230 (41.3%)	42.9/11.2	5.5/7.5

Table 3: The correlations between age, experience and number of responsible accidents in each of five years and for the whole period, for the total direct sample. N=

	2001	2002	2003	2004	2005	2001-2005
Age	-.002	.003	.022	.072***	.064**	.051*
Experience	-.137***	-.058**	-.087***	-.012	-.031	-.116***

* p<.05, ** p<.01, ***p<.001

Table 4: The years in which there were significant differences ($p<.05$, independent t-tests) between differently experienced groups (see Figure 1).

Group	1><2 years	2><3 years	>3 years (N=1585)
<1 year (N=220)	2001	2001, 2002	2001, 2002, 2003
1><2 years (N=218)	-	ns	2001, 2002
2><3 years =N=189)		-	2001, 2003

Table 6: The effect of experience in the accident sample. Chi2 values for the differences in risk ratio for each of the first three years of experience versus all later years (maximum 35). All df=3.

Variable	N	1	N	2	N	3
Accidents	15100	229.4*****	10934	22.6****	8828	3.41

**** p <.0001, ***** p<.00001

Table 6: t-values for differences between age groups in the total direct sample (as shown in Figure 4). Independent t-tests.

Group	25-30 years (N=89)	30-35 years (N=182)	35-40 years (N=261)	40-45 years (N=301)	45-50 years (N=370)	50-55 years (N=523)	55-60 years (N=348)	>60 years (N=29)
<25 years (N=24)	t=2.2*	t=2.5*	2.0	1.2	2.6**	1.5	0.9	0.9
25-30 years (N=89)		0.3	-0.3	-1.4	0.6	-1.3	-2.0*	-1.0
30-35 years (N=182)			-0.7	-2.1*	0.4	-2.1*	-3.0**	-1.3
35-40 years (N=261)				-1.6	1.2	-1.5	-2.5*	-0.8
40-45 years (N=301)					3.0**	0.4	-0.9	-0.1
45-50 years (N=370)						-3.1**	-4.1***	-1.4
50-55 years (N=523)							-1.4	-0.2
55-60 years (N=348)								0.3

* p<.05, ** p<.01, *** p>.001

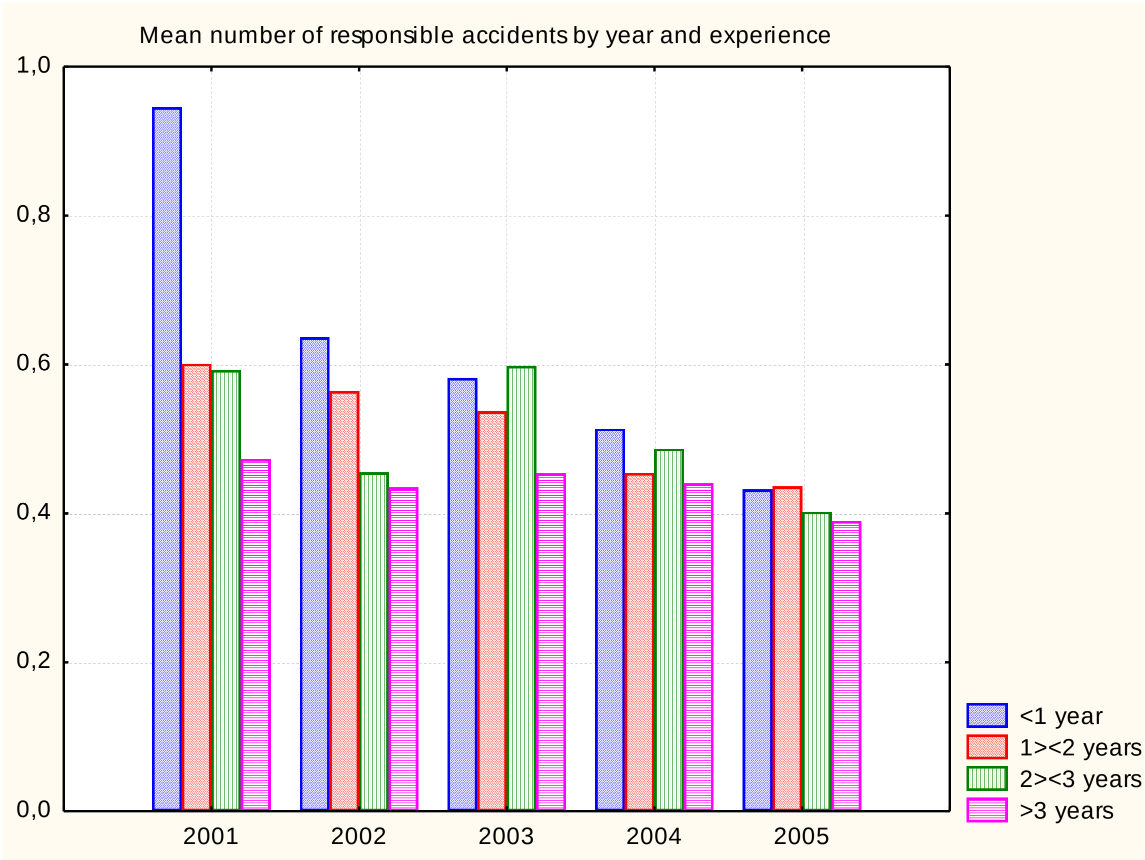

Figure 1: The mean number of responsible accidents 2001-2005 of drivers with differing amounts of experience as of 2000-01-01, for the direct sample (N=220+218+189+1584).

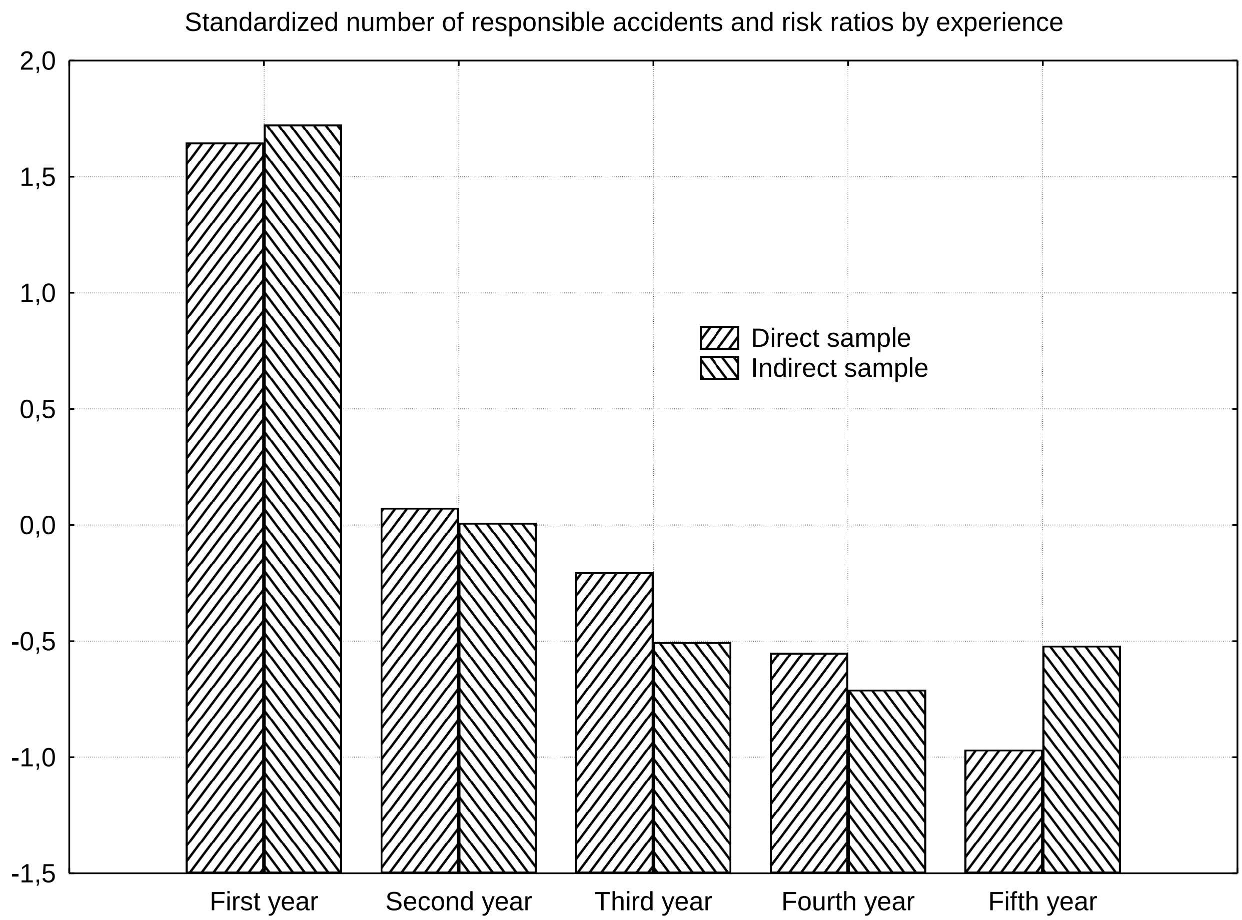

Figure 2: A comparison between the results for direct and indirect calculations of the influence of experience on accident liability. The mean number of responsible accidents and the risk ratios (responsible/not responsible accidents), in the drivers' first and later years (both standardized). The correlation between means and risk ratios was .912 (N=5, p<.05).

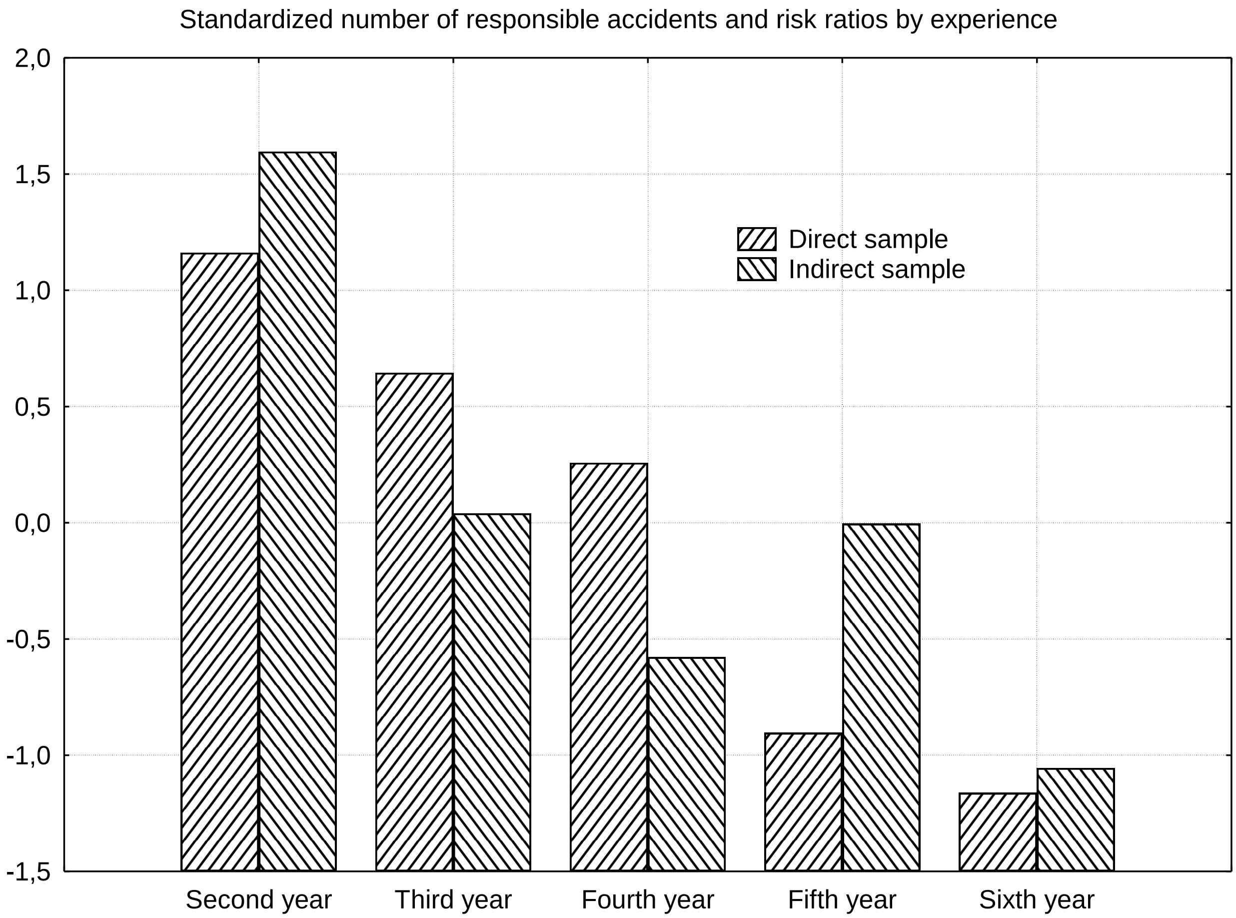

Figure 3: A comparison between the results for direct and indirect calculations of the influence of experience on accident liability. The mean number of responsible accidents and the risk ratios (responsible/not responsible accidents), in the drivers' second and later years (both standardized). The correlation between means and risk ratios was .619 (N=5, p>.05).

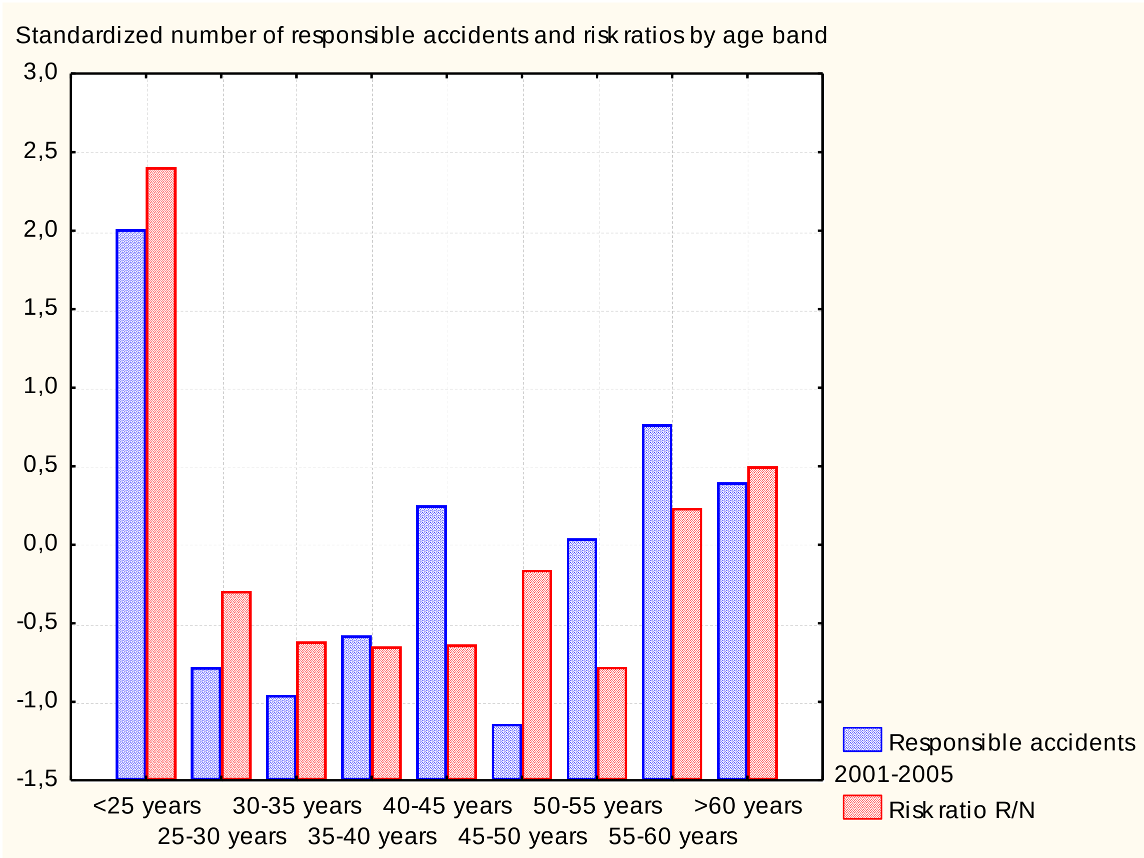

Figure 4: A comparison between the results for direct and indirect calculations of the influence of age on accident liability. The mean number of responsible accidents in 2001-2005, and the risk ratios (responsible/not responsible accidents), grouped according to age band (both standardized). The correlation between means and risk ratios was .800 (N=9, p<.05).

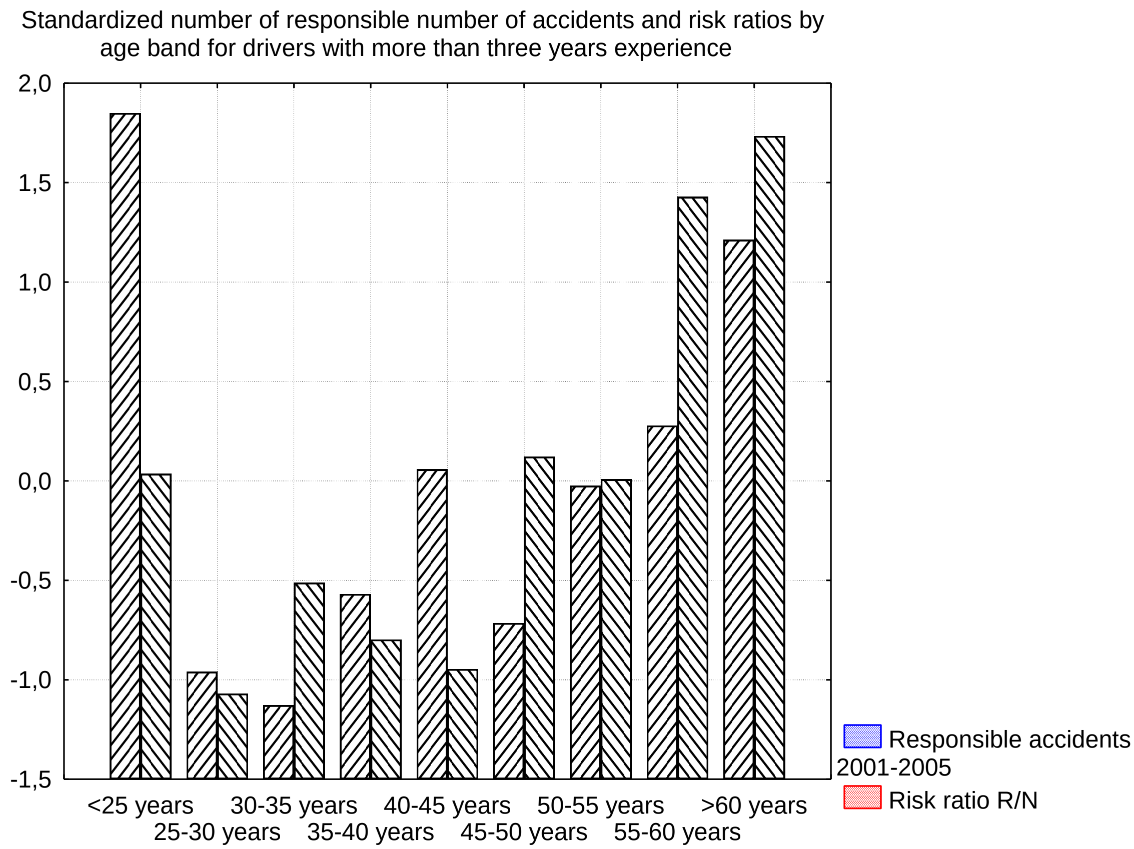

Figure 5: A comparison between the results for direct and indirect calculations of the influence of age on accident liability for experienced drivers. The mean number of responsible accidents in 2001-2005, and the risk ratios (responsible/not responsible accidents), grouped according to age band (both standardized). The correlation between means and risk ratios was .560 (N=9, p>.05). However, the calculation of responsible accidents for <25 years contained only six drivers.

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Lisa Dorn graduated with a BSc in Human Psychology in 1987 and was awarded a PhD on 'Individual and Group Difference in Driving Behaviour' in 1992, both from Aston University, UK. After several post-doctoral positions, Lisa was appointed as Director of the Driving Research Group at Cranfield University in 2001. Her research interests are driver training and the use of psychometrics for predicting driver behaviour and accidents.

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