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Josef Schumann
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The University of Michigan
Transportation Research Institute
Ann Arbor, Michigan 48109-2150
U.S.A.

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16. Abstract

This analysis of accident data was designed to replicate and extend an earlier analysis that investigated the effects of different types of driver-side mirrors on lane-change accidents (Luoma, Sivak, and Flannagan, 1995). The present analysis was based on 3,038 lane-change accidents that occurred in Great Britain between 1989 and 1992. Mirror information for the most popular car models in Great Britain was collected to identify different types of exterior mirrors.

Data analysis was based on the odds ratio of cars with different types of driver-side mirrors (plane or convex) being involved in a lane-change accident to the driver side. Because all cars were equipped with the same type of passenger-side mirror (convex), lane-change accidents to the passenger side served as baseline data to control for exposure.

The results can be summarized as follows:

(1) Convex driver-side mirrors do not increase the risk of being involved in lane-change accidents to the driver side.

(2) Consistent with the findings of Luoma et al. (1995), accident data for the largest cars revealed a tendency, albeit not statistically significant, for a decrease in lane-change accidents to the driver side when equipped with convex driver-side mirrors.

(3) Convex driver-side mirrors tended to be beneficial for the highest risk groups—the youngest and the oldest drivers.

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CONTENTS

INTRODUCTION

While driving an automobile, most of the driver's visual attention has to be in the direction of travel. However, because of high traffic density, multilane highways, and varying traffic flow, monitoring the area behind the car is also important. Therefore, interior and exterior rearview mirrors are used to monitor the traffic behind the car without the necessity to turn the head and thereby to divert attention from the forward view. One of the main disagreements concerning rearview mirrors centers on how to deal with a blind zone that appears diagonally to the driver side close to the car when using a plane exterior driver-side mirror. Convex mirrors reduce this blind zone, but at the cost of minifying the image, which may cause the driver to misjudge speed and distance of an approaching vehicle (for a discussion see Flannagan and Sivak, 1993).

One driving maneuver in which the adequate interpretation of information about the traffic behind the vehicle is particularly important is changing lanes. Not detecting a nearby car in the adjacent lane, or erroneously estimating an approaching car's distance and speed, can lead to a lane-change accident. U.S. accident data (Wang and Knipling, 1994) from the 1991 General Estimates System (GES) and Fatal Accident Reporting System (FARS) reveal that there were 244,000 lane-change accidents (4% of all crashes), resulting in 225 fatalities (0.5%). A high percentage of those accidents occurred during daytime (77%) and without adverse weather conditions (85%). Although lane-change accidents cannot be attributed to the improper use of rearview mirrors alone, the lack of adequate processing of visual information to initiate a lane-change maneuver seems to have some influence on the accident history. According to an analysis of a limited sample of CDS (Crashworthiness Data System) and GES lane-change accident data, a high percentage of the accident-causing drivers did not see the other vehicle prior to the impact (Chovan, Tijerina, Alexander, and Hendricks, 1994, p. 15). Failing to detect the other vehicle can result from information-gathering errors related to the use of mirrors. In a task analysis of the lane-change maneuver, McKnight and Adams (1970) identified two tasks prior to lane changing related to the use of rearview mirrors:

(1) check rearview mirrors for rear-approaching traffic, and

(2) look out of window to check blind zone, moving head enough to see around blind zone.

An analysis of accident data caused by vehicles equipped with different types of driver-side mirrors could reveal whether the mirror type has any effect on the frequencies of lane-change accidents. Such an analysis was performed by Luoma, Sivak, and Flannagan (1995) on 407 accidents in Finland, where the regulations (in contrast to the U.S. regulations) allow the use of nonplanar driver-side mirrors. Comparing different types of driver-side mirrors (plane, convex, multiradius), Luoma et al. (1995) found a tendency for a decrease in the accident frequency for lane-change accidents to the driver side with passenger cars equipped with nonplanar driver-side exterior mirrors. A drawback of their study, however, was the relatively small sample size, which resulted in a low statistical power of their analysis. Consequently, the main purpose for this study was to replicate the analysis of Luoma et al. (1995) with a larger sample, and to include an additional analysis concerning different driver age groups.

METHOD

Accident data

The accident data were taken from the STATS19 database for 1989-1992. This database contains information on all road accidents reported to the police in Great Britain involving injury or death. Since 1989, data also include the Vehicle Registration Mark of accident-involved vehicles, which enables extraction of information concerning vehicle make, model, and year (Broughton, 1996). The STATS19 database allows the distinction between two classes of accidents that are of special interest for this analysis: lane-change accidents to the left and lane-change accidents to the right (Great Britain Department of Transport, 1993, p. 122). Each year, over 300,000 accidents were reported involving cars (including vans), with about 4,000 accidents classified as lane-change accidents (Great Britain Department of Transport, 1993, Table 44).

Mirror data

Information on exterior rearview mirrors was obtained by a survey that was sent to car companies with a market share of new registrations in Great Britain of at least 2% (American Automobile Manufacturers Association, 1994). This survey inquired about the type of rearview mirrors on the most popular models. The actual questionnaire is reproduced in the Appendix. The questions concerned (1) type, (2) radius, and (3) size of both exterior mirrors. In addition, wheelbase information (as an indicator of the vehicle size) was also requested.

Mirror information was obtained from the following car manufacturers:

Ford: Fiesta (1989-1992), Sierra (1987-1992), Escort/Orion (1984-1992)

GM: Cavalier (1985-93), Astra (1985-1993), Nova (1985-1993)

Honda: Civic (1984-1995)

Renault : 19 (1989-1992)

Rover: Mini (1985-1993), Metro (1985-93), Maestro/Montego (1985-93), 200 (1985-1993)

VW: Golf (1984-1992), Passat (1984-1992)

Ford, GM, and Rover had a combined market share of about 50% in Great Britain with the above models for the examined period (American Automobile Manufacturers Association, 1994).

Data analysis

All models were equipped with convex passenger-side mirrors, and either plane or convex driver-side mirrors. Multiradius mirrors were not included in the analysis because of a lack of mirror-type information from car manufacturers using this type of exterior mirror.

Both data sets were based on model year. If there were mirror design changes during a model year, the accident data for that vehicle model in that year were excluded from the data analysis.

The data analysis was based on a comparison of the frequencies of lane-change accidents to the driver side for vehicles equipped with different types of driver-side mirrors, while the frequencies of lane-change accidents to the passenger side were used as controls. Because the passenger-side mirrors were the same for all vehicles, accidents to the passenger side should provide an index of exposure (Luoma et al., 1995). The proportions of lane-change accidents (i.e., the frequencies of lane-change accidents to the driver side vs. the frequencies of lane-change accidents to the passenger side) can be analysed for the two different driver-side mirror types (i.e., plane vs. convex mirrors) by utilizing two-way contingency tables. Results can be expressed as an odds ratio (Agresti, 1990).

A simple example should clarify this analysis. Table 1 shows a fictitious example of lane-change accident frequencies to both sides for two different types of driver-side mirrors (A and B).

Table 1: 2x2 contingency table.

	lane-change accident to:	
	driver side	passenger side
mirror type A	40 [D_A]	50 [P_A]
mirror type B	60 [D_B]	50 [P_B]

A Pearson chi-square test (Agresti, 1990, p. 47) can be used to examine the effect of the mirror type on lane-change accidents to the driver side. For this example, θ, the odds ratio of being involved in a driver's side lane-change accident with mirror type A compared to mirror type B, is:

$$\theta = \frac{\left(\dfrac{D_A}{P_A}\right)}{\left(\dfrac{D_B}{P_B}\right)} = \frac{\left(\dfrac{40}{50}\right)}{\left(\dfrac{60}{50}\right)} = 0.67 \qquad (1)$$

This means that the likelihood of a lane-change accident to the driver side with the mirror type A is 0.67 times as high as with the mirror type B. This odds ratio can be transformed into an effectiveness measure, E, as follows (Luoma et al., 1995):

$$E = 100 * \left(\frac{\left(\dfrac{D_A}{P_A}\right)}{\left(\dfrac{D_B}{P_B}\right)} - 1 \right) = -33.3 \qquad (2)$$

For our example, the mirror type A resulted in a 33% decrease in driver-side accidents, compared to cars equipped with mirror type B.

RESULTS

STATS19 lane-change accident data

Accident data for cars with mirror information consisted of 3,117 cases. The final data sample consisted of 3,038 cases, because 79 accidents with drunk-driver involvement (2.5%) were excluded from the data analysis. From the 3,038 cases, 61.6% were coded as a lane change to the driver side and 38.4% as a lane change to the passenger side.[1]

Mirror information

The reported car models were equipped only with plane or convex driver-side mirrors, and convex passenger-side mirrors. For three models, information on mirror dimension was not available. Table 2 summarizes the data.

Table 2. Summary of questionnaire data on exterior mirrors.

Driver-side mirror			Radius convex passenger-side mirror (mm)[2]	Car wheelbase (cm)
Type	Radius (mm)	Size (mm) [width x height]		
plane	∞	(150-176) x (90-100)	≈1400 (±200)[3]	234-263
convex	≈1400 (±200)	(142-172) x (75-101)	≈1400 (±200)	204-261

[1] To avoid ambiguity, accident data in this report were coded as occurring to the driver or passenger side, because the data came from Great Britain with left-hand drive.

[2] Mirror dimensions for the passenger-side mirrors were the same as for the driver-side mirrors.

[3] Some of the manufacturers provided an average and a range of convexities, indicated by ±200.

Convex vs. plane driver-side mirrors

Figure 1 shows the number of lane-change accidents to each side for the two different mirror types.

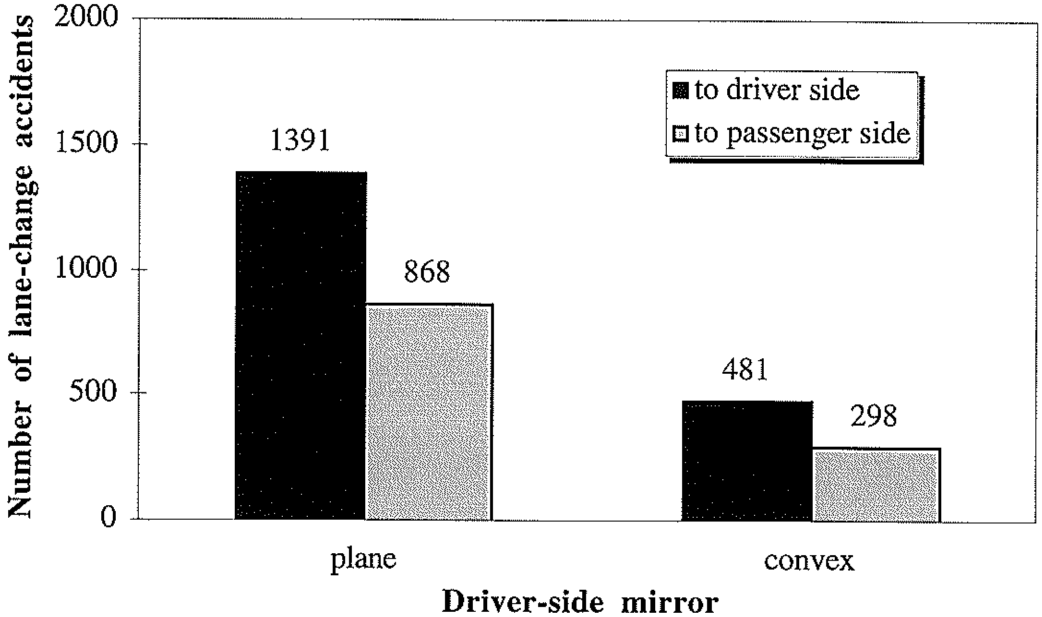

Figure 1. Number of lane-change accidents to each side by type of driver-side mirror.

A Pearson chi-square test revealed no significant differences in the frequency of lane-change accidents with the two different mirror types, $\chi^2(1) = 0.007$, $p = .933$.

To compare lane-change accidents with the data from Luoma et al. (1995), who used only midsize cars in their sample, we divided the data into three car-size groups (small, compact, and midsize cars) as follows:

(1) small: Metro, Mini, Civic, Nova, and Fiesta (car wheelbase < 245 cm);

(2) compact: Escort, Orion, Golf, Maestro, Rover 200, Astra, Renault 19 (car wheelbase between 245 and 255 cm);

(3) midsize[4]: Cavalier, Passat, Sierra, Montego (car wheelbase > 255 cm).

Figure 2 shows the number of lane-change accidents to each side for the two different mirror types by the different car-size groups.

[4] Of the car models involved in the present study, only the midsize cars Cavalier, Passat, and Sierra were also part of the data set of Luoma et al. (1995).

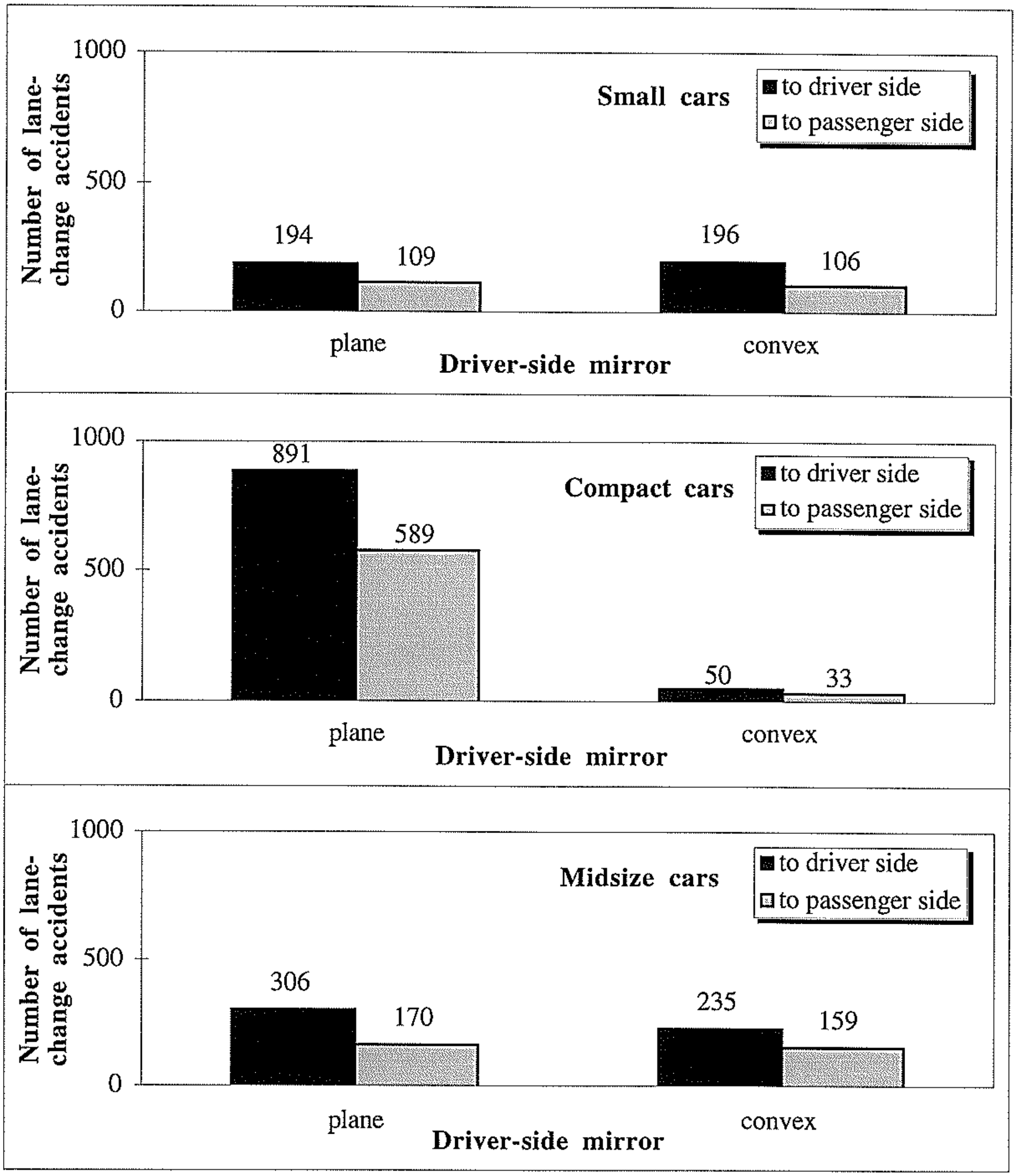

Figure 2. Number of lane-change accidents to each side by type of driver-side mirror for different car-size groups.

Figure 3 shows the effectiveness measure (see Formula 2, p. 5) for each car-size group. Lane-change accidents for each car group were not significantly affected by the type of the mirror (at the conventional .05 level of significance). However, as was the case with the data from Luoma et al. (1995), accidents with midsize cars showed a tendency for proportionally fewer lane-change accidents to the driver side for cars equipped with convex versus plane driver-side mirrors, $\chi^2(1) = 1.98$, $p = .16$. The 95% confidence interval (Agresti, 1990) ranged from a 38% decrease to an 8% increase.

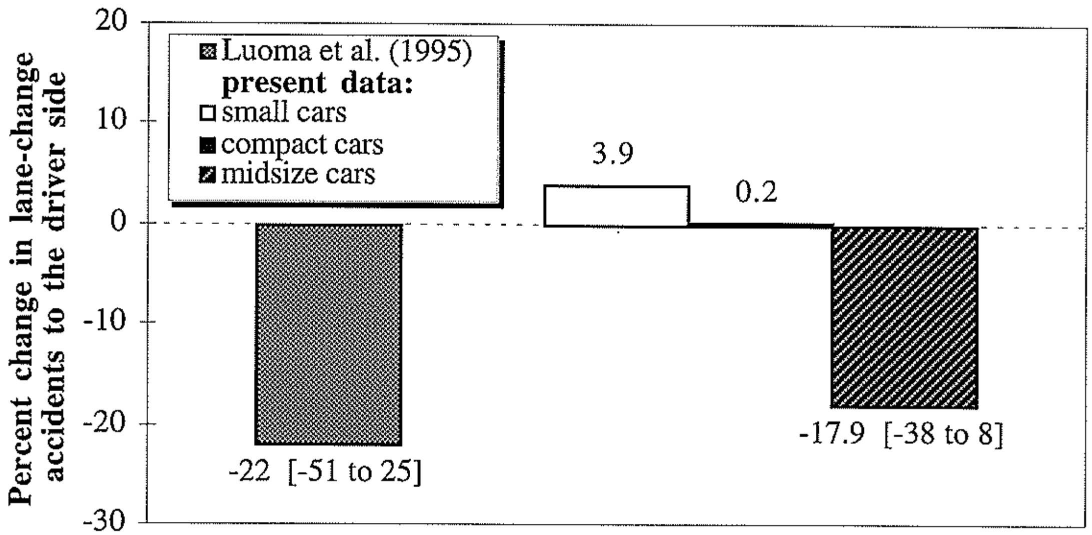

Figure 3. Effectiveness measures for convex versus plane driver-side mirrors by car size, with respect to the frequency of lane-change accidents to the driver side (95% confidence interval in brackets).

Because car size might have an influence on the size of the exterior mirrors, and consequently on the driver's field of view, we calculated the ratio of viewing angles (for the driver-side and passenger-side mirrors) by car-size groups (using formulas discussed by Platzer, 1994). However, as can be seen in Figure 4, the ratios are unaffected by the car size because larger cars tended to have larger mirrors on both sides.

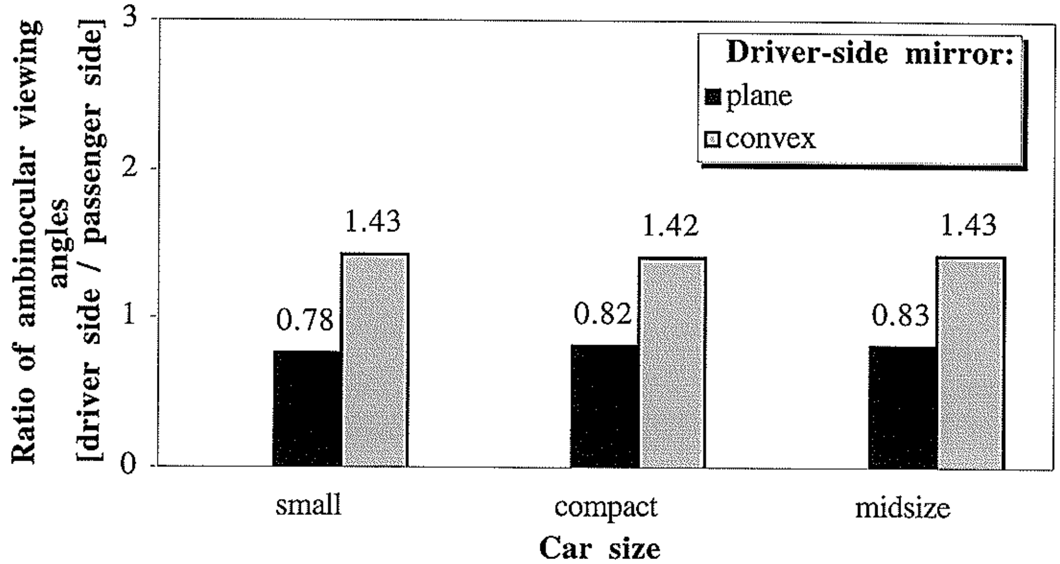

Figure 4. Ratio of viewing angles for different car sizes.

Age effects

Figure 5 shows the effectiveness of convex driver-side mirrors for different age groups.[5] There was a significant decrease in driver-side lane-change accidents for the youngest age group (17-24 years; 35% decrease, $\chi^2(1) = 6.15$, $p = .01$) and a tendency in the same direction for the oldest age group (65+ years; 46% decrease, $\chi^2(1) = 2.28$, $p = .13$). Figure 6 lists the breakdown of car sizes by driver-age groups. This information indicates that the benefits of convex mirrors for the youngest and oldest drivers were not a consequence of them driving primarily midsize cars; indeed, the tendency was for them to drive fewer midsize cars.

The overall trend in effectiveness as a function of age, shown in Figure 5, indicates that convex mirrors might be effective for the two age groups with the highest accident risk (see Figure 7), the very young and the very old drivers.

[5] The data sample for this analysis was smaller than the original data sample (3,038 cases), because driver age was not available for all cases. It consisted of 2,927 cases and included accidents with drunk-driver involvement, because the drunk-driver information was not available for the driver-age classification.

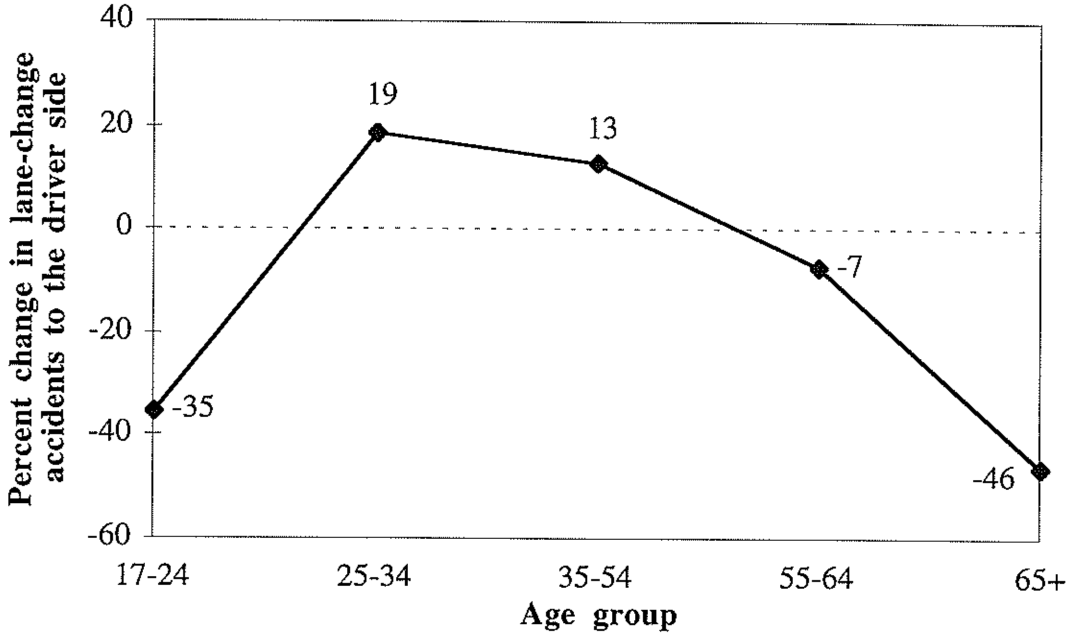

Figure 5. Effectiveness values for different age groups of convex versus plane driver-side mirrors with respect to the frequency of lane-change accidents to the driver side.

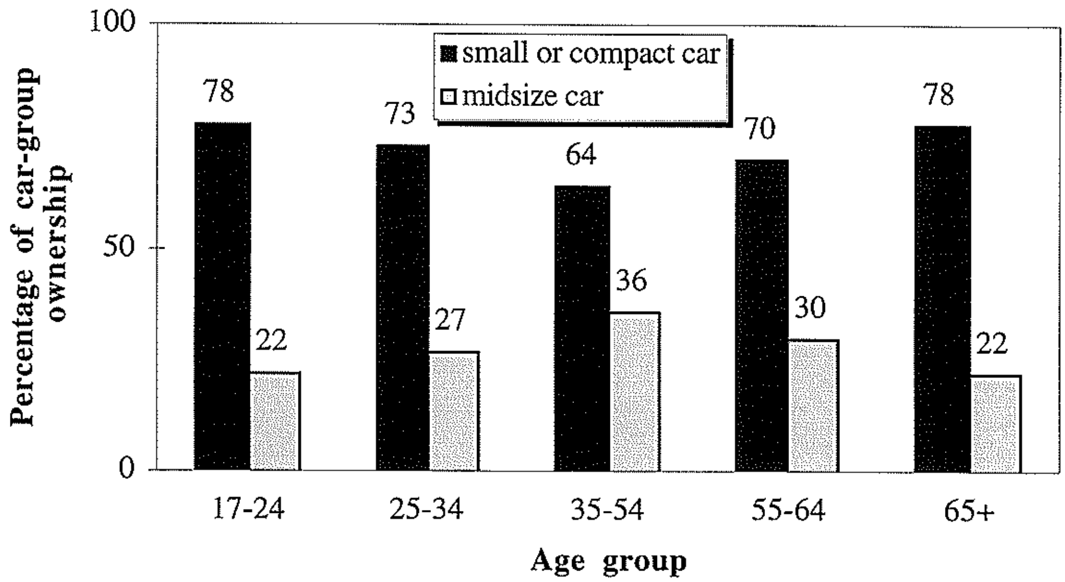

Figure 6. Car-size ownership by age group in the present data sample.

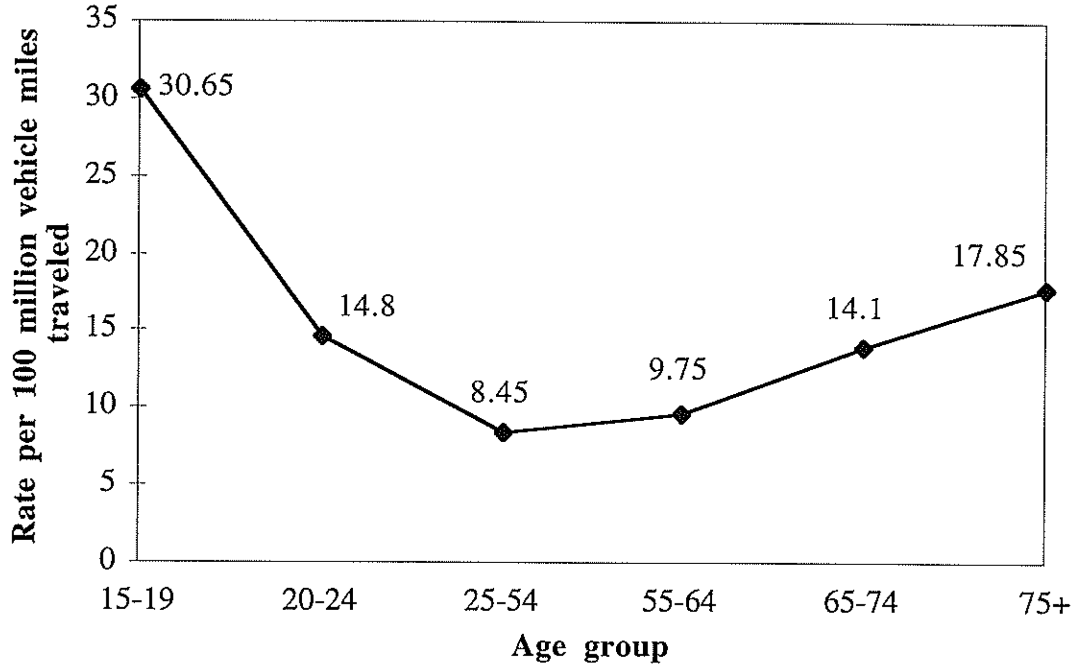

Figure 7. Lane-change accident involvement rate by driver-age group (adapted from Wang and Knipling, 1994, Figure 3.11).

DISCUSSION

Lane-change accidents can be affected by inadequate rearward vision. However, the ways in which the use of rearview mirrors influences lane changing cannot be directly inferred from accident data. A driver might simply not have used rearview mirrors, mirrors might have been adjusted suboptimally, or the information provided by rearview mirrors might have been insufficient or distorted. An analysis of lane-change accidents and their link to different types of exterior driver-side mirrors, therefore, cannot provide a complete answer concerning accident etiology, but it can furnish experts with suggestive tendencies.

One way to summarize the findings of the present study is to conclude that there is no evidence in the accident data from Great Britain that convex driver-side mirrors, compared to plane mirrors, increase the rate of lane-change accidents. The most often cited disadvantage of nonplanar rearview mirrors is a smaller virtual image compared to plane mirrors. This minification of images may lead to misestimations of the speed and distance of approaching cars. However, the accident data show no evidence for this (see Figures 1 and 3). The reasons for this might be that drivers rely not only on their exterior rearview mirrors, but also on their interior rearview mirror in gathering information about speed and distance of the rear-approaching traffic. Mortimer (1971) showed that the misestimation of speed and distance disappeared when nonplanar mirrors were used together with a plane interior rearview mirror. Furthermore, there is also some evidence that overestimation of distances with only a nonplanar driver-side mirror can be reduced (but maybe not eliminated) by learning (Flannagan, Sivak, and Traube, 1996).

The present data not only provide no support for the notion that convex mirrors contribute to lane-change accidents, but the data also suggest that convex mirrors might provide some benefit. The trend for a decrease in accidents with larger cars in the Finnish data of Luoma et al. (1995) was replicated with the present data from Great Britain (see Figure 3). Because of a larger sample size in the present analysis, the confidence interval was narrowed, from an interval ranging from a 51% decrease to a 25% increase in Luoma et al. (1995), to an interval ranging from a 38% decrease to an 8% increase in the present study.

The reasons that convex mirrors were only effective with larger cars remain unclear; however, one could speculate that, for large cars, the larger maximum eye-to-mirror distance allowed by the seat track increases the blind zone with plane mirrors. Calculations by Platzer (1995, Table 4) demonstrate a decrease in the field of view for driver-side plane mirrors, from 18.3 degrees for a forward seat position to 15.1 degrees for a back seat position, while the field of view for the passenger-side mirror remains approximately constant. Calculations based on a convex driver-side mirror (same size, 1400 mm convexity) lead to a proportionally smaller decrease in the field of view, from 30.2 degrees for a forward seat position to 27.1 degrees for the farthest seat position. Thus, the field of view with a plane mirror is more affected by different seat positions than the field of view with a convex mirror (18% decrease vs. 10% decrease). Because we could expect a larger maximum eye-to-mirror distance for larger cars, convex mirrors should be especially effective for larger cars, as our data seem to indicate (see Figure 3).

An interesting trend is apparent by looking at the driver-age distribution for lane-change accidents (see Figure 5). Evidently, convex driver-side mirrors were beneficial for the highest risk groups (see Figure 7), the youngest and the oldest drivers. A task analysis of lane-change maneuvers might be helpful in providing possible explanations for these age effects. According to a task analysis by McKnight and Adams (1970), two separate steps have to be performed by the driver in order to decide on a lane change: looking into the rearview mirrors to check approaching cars, and turning the head to check for vehicles in the blind zone. Both age groups might have difficulties in performing this second step, but for different reasons:

- the youngest drivers might be careless in performing this step, or might not have enough experience in doing blind-zone checking;
- the oldest drivers are more likely to have problems in turning their heads due to their reduced mobility (Sivak, Campbell, Schneider, Sprague, Streff, and Waller, 1995).

For both of these age groups, convex driver-side mirrors could be an effective means of reducing driver-side lane-change accidents, because they considerably reduce the blind zone.

To summarize, convex driver-side mirrors do not appear to increase the frequency of lane-change accidents. On the contrary, there is a tendency in the accident data suggesting that their advantages (a reduction in the blind zone) outweigh their possible disadvantages (a minification of the image). Multiradius mirrors, currently in use in several car models in Europe, could further improve safety of lane-change maneuvers, because they frequently combine a reduction in the blind zone with only minor minifications in the main part of the mirror.

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APPENDIX

UMTRI Mirror Study 1995

1. Make, model, and year[1]

....

2. Driver's side outside rearview mirror

- ❐ flat
- ❐ convex, radius .... mm
- ❐ multiradius:
  - • constant radius .... mm
  - • radius range [max - min] of progressive reducing part................... mm

Width x height of mirror: ....mm x ....mm

3. Passenger's side outside rearview mirror

- ❐ flat
- ❐ convex, radius .... mm
- ❐ multiradius:
  - • constant radius .... mm
  - • radius range [max - min] of progressive reducing part................... mm

Width x height of mirror: ....mm x ....mm

4. Wheelbase: .... cm

---

1) Please use another data sheet if the mirror type changed for this model during the period 1985-1993.