EFFECTS OF DRIVER-SIDE MIRROR TYPE ON LANE-CHANGE ACCIDENTS

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15. Abstract

This quasi-experiment was designed to investigate the effects of the type of driver-side mirror on lane-change accidents. The analysis was based on 407 accidents reported from 1987 to 1992 to Finnish insurance companies, for vehicles with passenger-side convex mirrors and one of three types of driver-side mirrors (flat, convex, or multiradius).

The results showed that there was no difference between the multiradius and convex mirrors in the frequencies of lane-change accidents to the left. Compared to the flat mirror, the mean effect of the multiradius and convex mirror was a 22% decrease. The 95% confidence interval ranged from a 51% decrease to a 25% increase. This result was not related to driver characteristics or driving conditions.

In conclusion, the multiradius and convex driver-side mirrors, in comparison to the flat mirror, are more likely to reduce than increase lane-change accidents. A theoretical implication of this study is that minimizing the blind spot is likely to be more important than providing an undistorted image of objects. From a practical point of view, the present findings support the use of multiradius and convex driver-side mirrors.

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CONTENTS

INTRODUCTION

According to a 1987 estimate by the Swiss Information Centre for Prevention of Accidents, 8% of all road accidents (12% on limited-access roadways) are attributed to insufficient visibility provided by rearview mirrors (Bockelmann, 1991). To see vehicles in the adjacent lanes, cars are equipped with a driver-side and often also a passenger-side exterior mirror, and with an interior mirror. In the U.S.A., driver-side mirrors are flat, while in Europe they are either flat, convex, or multiradius.

The potential advantages and disadvantages of the various types of driver-side mirrors have been discussed for a long time. In summary, for a given mirror area, the blind spot with a convex or a multiradius mirror is smaller than with a flat mirror. On the other hand, images in convex or multiradius mirrors are minified and, therefore, it has been argued, the estimation of distances and relative speeds of cars approaching from behind is more difficult. This problem concerns especially convex mirrors with small radii, because the radii of the central parts of actual multiradius mirrors are relatively large.

Recently, Helmers, Flannagan, Sivak, Owens, Battle, and Sato (1992) concluded that the available data "are inconclusive about the differential effect of flat and convex mirrors on behavior and decisions" (see also, Bowles, 1969; Walraven and Michon, 1969; and Mortimer, 1971). Helmers, et al. (1992) also carried out a simulation experiment, which evaluated the effects of three types of driver-side, exterior mirrors (flat, convex, or multiradius) on drivers' response times for detection of cars at near distances behind in the left adjacent lane. The shortest response times were for the multiradius mirror, which had no blind spot and, consequently, did not require any large supplemental head movements for collection of information. On the other hand, the longest response times were obtained with the flat mirror, which required large head movements in a large proportion of trials.

However, Helmers, et al. (1992) indicated that the results from their laboratory study should be validated by carrying out experiments in real traffic. Such a validation is needed because the experimental setup did not allow for evaluating possible disadvantages of convex and multiradius mirrors, such as the difficulty in distance and speed estimation.

In many respects, the ultimate validation of a laboratory study is a study investigating accident frequencies. Consequently, the present quasi-experimental study was designed to evaluate the effects of three types of driver-side mirrors on lane-change accidents. Lane-change accidents were investigated because they are, perhaps, the type of accident most likely to be influenced by the driver's use of exterior mirrors. The analysis was based on Finnish data. Finland is, apparently, unique in having both (1) information on accidents when changing lanes to the left or to the right, and (2) a variety of driver-side rearview mirrors.

MATERIAL AND METHOD

This study used two databases: (1) road accidents reported to Finnish insurance companies, and (2) information on rearview mirrors.

Accident data

The data included lane-change accidents in Finland between 1987 and 1992 that were reported to the Finnish insurance companies. This database is uniquely suitable for this kind of study because of three features. First, starting in 1987, the accident classification includes two groups that are of special interest in this study, lane-change accidents to the left and lane-change accidents to the right. Second, the database includes information on vehicle make, model, and the first year of use. Third, it includes all road accidents that led to indemnities on the basis of a mandatory, third party, liability insurance of motor vehicles. The database covers about 70% of all traffic accidents and about 75 to 85% of injury accidents (Road and Waterways Administration, 1988). The most frequent accident types that are not included are pedestrian and bicyclist accidents, and single vehicle accidents without injuries (Road and Waterways Administration, 1988; Finnish Motor Insurers' Centre, 1993). However, those accidents were not of interest in this study. In addition, the database indicates the responsible party for the accident, and several background variables.

Mirror data

Information on exterior mirrors was obtained by a mail survey. The survey form was sent to Finnish car importers. The questions concerned features of certain makes and models they imported. Specifically, the following information was requested by make, model, and model year for both exterior mirrors: (1) type (flat, convex, or multiradius), (2) radius, if applicable, and (3) area. In addition, the wheelbase, as an indicator of the vehicle size, was requested.

At the beginning of the study, it was assumed that all cars in Finland were equipped with convex exterior mirrors on both sides, except some recent models of Saab and Volvo that are equipped with multiradius mirrors. Therefore, we selected a sample including certain models of Saab and Volvo and other, similar vehicles in terms of size, price, and body type (sedans, hatchbacks, and wagons).

The survey involved fifteen makes with model years from 1984, if applicable. However, representatives of five makes did not respond. Information for one of those makes was later received directly from a representative of the manufacturer. The final set included information on the following makes, models, and model years:

Audi 80, 90 (1988-92), 100, 200 (1984-92)
BMW 300, 500 (1984-92)
Citroen CX (1987-88)
Ford Scorpio (1984-92), Sierra (1984-90)
Honda Accord (1984-92)
Opel Ascona (1984-88), Omega (1986-92), Record (1984-87), Vectra (1988-92)
Peugeot 405, 505 (1987-92)
Saab 900 (1984-92), 9000 (1985-92)
Toyota Camry, Carina II (1984-92)
Volkswagen Passat (1988-92)
Volvo 200, 700 (1984-92)

Data analysis

The two databases were compatible, except for the fact that the accident database included information on the first year of use, while the type of the exterior mirror was classified by model year. Because many car manufacturers introduce new models prior to the beginning of the corresponding calendar year, accidents to vehicles that were put in use in the year in which design changes affected the mirrors were excluded from the analysis.

The analysis was based on a comparison of the frequencies of lane-change accidents to the left for vehicles equipped with different types of left-side (driver-side) mirror, while the frequencies of lane-change accidents to the right were used as controls. Thus, if the types of the right-side (passenger-side) mirror of two vehicle groups are similar, then the effect of the type of the left-side mirror was calculated from accident frequencies using the formula

$$E = 100 \text{ x } \left(\frac{L_1}{\frac{R_1}{R_2} \text{ x } L_2} - 1\right) \qquad (1)$$

where

E = effect (%) of the mirror of type 1 compared to the mirror of type 2
L_1 = number of accidents to the left for cars with the left-side mirror type 1
R_1 = number of accidents to the right for cars with the left-side mirror type 1
L_2 = number of accidents to the left for cars with the left-side mirror type 2
R_2 = number of accidents to the right for cars with the left-side mirror type 2

The expression in the denominator is the number of accidents to the left that would be expected for cars equipped with mirror type 1 if that mirror would have been similar to type 2. This prediction is based on three main assumptions.

First, the proportions of attempted lane changes in the two directions are assumed to be similar in both vehicle groups.

Second, the relative risk of lane-change accidents to the left and right in each vehicle group is affected by the exterior mirrors, but not by possible differences in other vehicular factors. In other words, this assumption postulates that there are no particular vehicular factors in one vehicle group that would selectively increase or decrease the risk of having accidents to the left or right. Furthermore, if the left-side mirror has an effect of frequencies on lane-change accidents, it is assumed that it would influence only the frequency of accidents to the left.

Third, the relative risk of lane-change accidents to the left and right in each vehicle group is not affected by possible differences in driver characteristics and driving conditions. There is no a priori reason to believe that this would not be the case. Nevertheless, the accident data were crosstabulated by nine background factors, including driver characteristics, time of accidents, environmental conditions, and vehicle age.

RESULTS

Accidents

Data consisted of lane-change accidents in which a car with a right-side convex mirror had changed lanes. Primary data included 462 accidents. However, only accidents with the lane-changing driver fully at fault (89.0% of all accidents), and with no drunk driver involvement (98.7% of all accidents), were selected for further analyses. Consequently, the final data included 407 accidents. In those accidents, 51.6% involved a lane change to the left and 48.4% a lane change to the right.

Mirrors

The survey revealed that in Finland there is a wider variety of left-side mirrors on cars than was expected. Vehicles with convex mirrors on the right side were classified into three categories, according to the type of the left-side mirror: (1) a multiradius mirror, (2) a convex mirror, and (3) a flat mirror. In addition, there was a fourth vehicle group that had a flat mirror on both sides, but this group was not included in the analyses. Table 1 summarizes the data concerning exterior mirrors and car wheelbase of the selected cars.

Table 1
Mirrors and car wheelbase by vehicle group.

Vehicle group	Left-side mirror/ right-side mirror	Radius of the left-side mirror (mm)	Radius of the right-side mirror (mm)	Mirror area (cm^2)§	Car wheelbase (cm)
1	Multiradius/Convex	2,000 and 140-800*	2,000$^{\Delta}$	153-158	252-277
2	Convex/Convex	1,400-2,000$^{\Delta}$	1,400-2,000$^{\Delta}$	122-158	245-285
3	Flat/Convex	∞	1,400-2,500$^{\Delta}$	144-194	254-276

* Radius of the progressively reducing part.

Δ Radius information covers only 55% of models.

§ For the models with available information, the correlation coefficient between the mirror area and the mirror width was r = .81.

Effect of the type of mirror on accidents

Figure 1 shows the frequencies of lane-change accidents to the left and right, by type of left-side mirror.

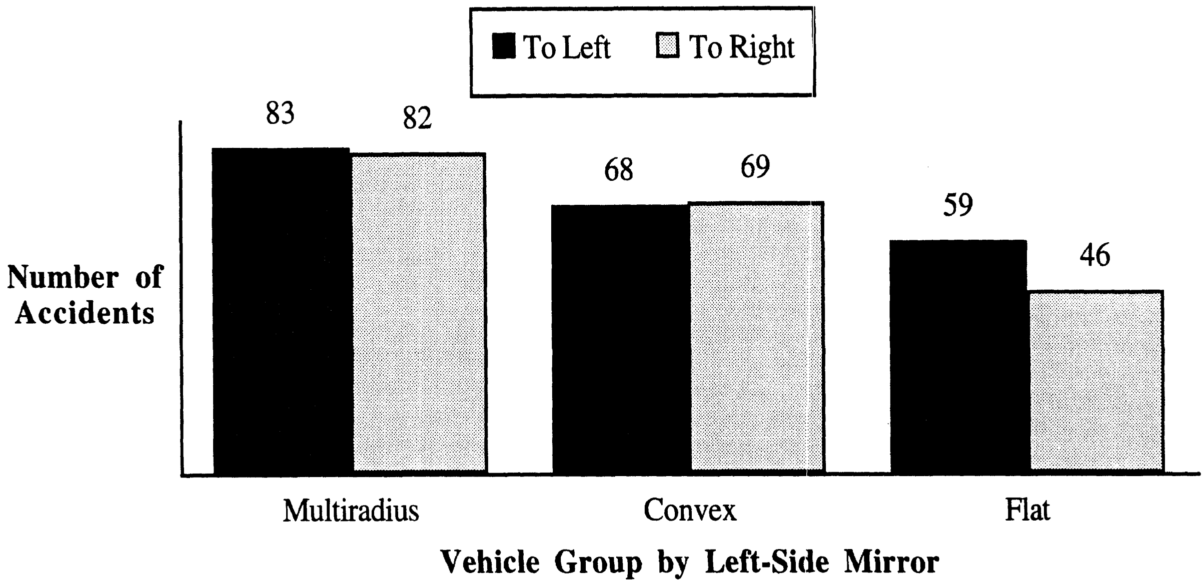

Figure 1. Frequency of lane-change accidents by type of left-side mirror.

The only evident difference is that for flat mirrors the relative frequency of lane-change accidents to the left versus to the right was higher than for multiradius or convex mirrors. Using the formula (1), the mean effect of multiradius and convex mirrors compared to flat mirrors was a 22% decrease. The present accident data are not strong enough to reject the null hypothesis that there is no effect of mirrors on accidents at the conventional .05 level of significance. A test of the proportion of rightward versus leftward accidents for vehicles with multiradius or convex versus flat mirrors yields χ^2 (1) = 1.20, p = .27. The 95% confidence interval (Fleiss, 1981, pp. 71-74) ranged from a 51% decrease to a 25% increase.

Background variables

To investigate whether there were any differences in driver characteristics or driving conditions that may have affected the relative numbers of left- and right-side accidents, we tabulated the data by nine background variables. Table 2 shows that none of the background variables appears to be related to the relative involvement in lane-change accidents to the left or right in the way that would invalidate the comparison of lane-change accidents.

Table 2
Background variables for lane change accidents to the left and right, by left-side mirror type.

Variable	Type of left-side mirror					
	Multiradius		Convex		Flat	
	Left	Right	Left	Right	Left	Right
Driver sex (%)						
Male	77.1	82.9	79.4	75.4	81.4	87.0
Female	22.9	17.1	20.6	24.6	18.6	13.0
Driver age (years)						
Mean	39.6	40.9	42.1	40.0	36.1	36.1
Standard deviation	12.8	14.4	13.2	12.7	13.7	11.0
Month (%)						
January-March	28.9	30.5	30.9	29.0	32.2	34.8
April-June	19.3	24.4	19.1	18.8	22.0	17.4
July-September	24.1	23.2	23.5	21.7	28.8	26.1
October-December	27.7	22.0	26.5	30.5	16.9	21.7
Day of the week (%)						
Monday-Thursday	71.1	54.9	55.9	62.3	59.3	52.2
Friday-Sunday	28.9	45.1	44.1	37.7	40.7	47.8
Time of day (%)						
12.00 am - 05.59 am	9.6	8.5	10.3	11.6	6.8	10.9
06.00 am - 11.59 am	21.7	29.3	29.4	26.1	30.5	30.4
12.00 pm - 05.59 pm	54.2	50.0	44.1	52.2	42.4	41.3
06.00 pm - 11.59 pm	14.5	12.2	16.2	10.1	20.3	17.4
Area (%)						
Urban	89.2	96.3	92.6	92.8	89.8	87.0
Rural	10.8	3.7	7.4	7.2	10.2	13.0
Light conditions (%)						
Daylight	72.0	77.9	73.4	79.1	73.7	67.4
Twilight, dark, or dark but lighted	28.0	22.1	26.6	20.9	26.3	32.6
Road conditions (%)						
Dry	54.7	62.3	56.9	61.9	60.7	51.1
Wet	29.3	14.3	18.5	17.9	19.6	20.0
Snowy or icy	16.0	23.4	24.6	20.9	19.6	28.9
Vehicle age (years)						
Mean	3.1	2.4	2.9	2.2	2.5	2.9
Standard deviation	1.9	1.8	2.2	1.5	1.9	2.0

DISCUSSION

This study was designed to investigate the effects of three types of driver-side mirrors on lane-change accidents. Specifically, the analysis compared the frequencies of lane-change accidents to the left for vehicle groups equipped with different types of driver-side (left-side) mirrors, while the frequencies of lane-change accidents to the right were used as controls. The study was based on road accidents reported to Finnish insurance companies, and information on rear-view mirrors was collected by a survey sent to Finnish car importers. The accident data consisted of 407 lane-change accidents to cars with a convex mirror on the right side in which the cars with a known mirror had changed lanes. Vehicles were classified into three categories according to the type of driver-side mirror: (1) a multiradius mirror, (2) a convex mirror, and (3) a flat mirror.

The results showed that there was no difference between the multiradius and convex mirrors in the proportions of leftward versus rightward lane-change accidents. Therefore, further analyses focused on effects of multiradius and convex mirrors compared to flat mirrors. The mean effect of multiradius plus convex mirrors compared to flat mirrors is a 22% decrease in lane-change accidents to the left. The 95% confidence interval of the effect is from a 51% reduction to a 25% increase. In other words, the mean effect is relatively large, but, because of the small sample size, the uncertainty is also relatively large. However, the present results do offer moderate evidence for a beneficial effect. The best estimate of the magnitude of that benefit based on the present data, if it is accurate, is large enough to be of considerable practical importance (i.e., a 22% reduction).

In comparison to the results of Helmers et al. (1992), the present study did not reveal any difference between the effectiveness of multiradius and convex mirrors, while Helmers' et al. results showed that the mean difference in reaction times between multiradius and convex mirrors was almost as much as between convex and flat mirrors. In the study by Helmers et al., however, the radii of the convex mirror and the central part of the multiradius mirror were equivalent, while the mean radius of the convex mirrors of the present study was likely smaller than the radius of the multiradius mirrors (see Table 1). In addition, a change in the frequency of lane-change accidents (the topic of interest in the present study) is only one of many possible consequences of a rearview mirror. In contrast, the study of Helmers et al. (1992) evaluated a more general aspect of driver performance—driver reaction time. Consequently, there is no fundamental disagreement between the results of Helmers et al. (1992) and those of the present study.

In conclusion, the multiradius and convex driver-side mirrors, in comparison to the flat mirror, are more likely to reduce than increase lane-change accidents. A theoretical implication of this study is that minimizing the blind spot area by exterior mirrors is likely to be more important than providing an undistorted image. From a practical point of view, the present findings support the use of multiradius and convex driver-side mirrors.

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