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Short paper

Passenger-side rear-view mirrors: driver behavior and safety

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Abstract

Passenger-side rear-view mirrors (PRMs) have been standard equipment on motor vehicles sold in the US for many years, although they are not required by the federal motor vehicle safety standards. Numerous studies documented both the apparent need for PRMs (to overcome visual obstructions) and their apparent value (by increasing visual access to the passenger-side rear). In addition, surveys of drivers have found a general appreciation of the importance of sampling visual information from the rear. Very little can be found, however, regarding the actual safety benefit of PRMs. A review of the research literature and several initial studies (driver observation and accident-data analysis), suggest that PRMs may not be associated with any substantial accident prevention, perhaps because they are not consistently used. Implications and research directions will be discussed.

Relevance to Industry

PRMs should have been a success story, having been carefully developed through research to provide important information for safe driving. The apparent failure of PRMs to reduce accident rates in practice illustrates a potential problem with designing and deploying safety features or devices without empirical assessment of normal user behavior.

Keywords: Driver behavior; Mirror; Accident data; Traffic safety

1. Introduction

Studies of transportation accidents repeatedly have shown that human behavior—rather than environmental conditions or vehicle function—is the primary contributor to accidents (Treat, 1980; Ayres et al., 1993). Many approaches are used to address human limitations and errors on the part of vehicle operators and pedestrians, from changes in vehicle and roadway design to encouragement and enforcement of safe behavior. Nevertheless, it is estimated that more than a million people die each year in motor vehicle accidents, with injuries in the tens of millions (Ross, 1999). The toll is

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rising most quickly in developing countries, with higher casualty rates (per vehicle) than in industrialized countries.

Assessment of the safety value of simple and practical interventions can play an important role in allocating scarce funds for public safety. Compared to major changes in transportation infrastructure (e.g., new roadways) or large-scale education efforts, vehicle design requirements (for new vehicles, or as retrofits for existing vehicles) may offer reasonably cost-effective solutions that compensate for human limitations. The success of such changes, however, may depend heavily on how drivers use them.

As an example, in this paper, we evaluate the safety benefit provided by passenger-side rear-view mirrors (PRMs). It is widely recognized, and demonstrated in research studies, that driver-side and interior rearview mirrors often do not provide drivers with a complete view of the area to the rear and passenger side of a vehicle. PRMs have been standard equipment on motor vehicles sold in the US for many years, although they are not required by the federal motor vehicle safety standards. Numerous studies documented both the apparent need for PRMs (to overcome visual obstructions; e.g., Burger, 1974) and their apparent value (by increasing visual access to the passenger-side rear). In addition, surveys of drivers have found a general appreciation of the importance of sampling visual information from the rear (Smith et al., 1978).

On the other hand, it is also clear that there are trade-offs associated with the provision of PRMs. Flat-surface PRMs do not provide a sufficiently wide field of view for the driver (Mourant and Donohue, 1979) and convex PRMs are associated with errors in distance estimation, even after adaptation (Flannagan et al., 1996, 1997). A limited degree of convex curvature appears to be better than a flat mirror, according to on-road research (Mortimer, 1971) and accident data (Luoma et al., 1995). In addition, there are problems related to glare from the reflections of headlights of following vehicles at night (Flannagan, 1988), and PRMs can cause serious or fatal injuries to pedestrians and cyclists (particularly PRMs on larger vehicles such as trucks and buses; GAO Business Services, 1978).

2. Accident data

Very little can be found, however, regarding the actual safety benefit of PRMs with respect to preventing accidents. Mortimer and VanderMey (1971) performed a study of accident data for driver-side mirrors, at a time when very few cars had PRMs (but all had driver-side mirrors). In a sample of 18 accidents involving passing or lane changes for which faulty rear vision was judged to be involved, left- and right-side accidents were equally likely. This could suggest that the presence of an outside rearview mirror (driver's side) did not reduce accidents.

2.1. Method

As a first step toward assessing the accident reduction attributable to the introduction of PRMs, we performed an analysis of reports of fatal accidents in the US. Data were obtained from the Fatal Accident Reporting System (maintained by the National Highway Traffic Safety Administration) for all fatal motor vehicle accidents reported in the US in 1999 (the most recent year with data available at the time of the analysis). We examined data for fatal accidents involving sideswipes between vehicles moving in the same direction (a type of accident included in the coding system); this is a class of accident that would occur during lane changes and for which PRMs could prove helpful for drivers. If PRMs in actual usage tend to help drivers avoid fatal same-direction sideswipes (by preventing collision or reducing severity), then these accidents should constitute a smaller percentage of all fatal accidents involving recent model-year cars (from the last decade or so, when PRMs have become ubiquitous in the US) than for older model-year cars (when PRMs were only an option). The data do not contain information about the presence or absence of a PRM on a vehicle, so model year was used as a substitute.

2.2. Results

In 1999, there were approximately 93,000 vehicles involved in a total of approximately 37,000 fatal motor vehicle accidents in the US (with close to 42,000 fatalities). Sideswipes between vehicles moving in the same direction accounted for 1.54% of all vehicles involved in fatal accidents. Fig. 1 shows the results for the number of vehicles involved in fatal accidents in 1999 involving cars with model years 1960–2000. Aside from some high variability in the earliest model years, for which there were few accidents overall, there is no indication that fatal same-direction sideswipes declined across model years; the trend line actually increases slightly. This pattern becomes even clearer when the analysis is restricted to model years beginning with 1970 (Fig. 2); over the period 1970–2000, same-direction sideswipes increased significantly as an annual percentage ($t = 2.19$, $p < 0.05$).

A similar pattern of results (significant regression with positive slope) was obtained for fatal accidents in 1994 (not shown). In addition, it was found that vehicles in same-direction sideswipes (not broken down by model year) increased as a percentage of all fatal-accident-involved vehicles across the period from 1994–2002 (from 1.3% in 1994 to 1.8% in 2002). Thus, these data offer no evidence that the addition of PRMs to motor vehicles have prevented a substantial number of fatal accidents in the US—either PRMs are not potentially helpful for avoiding same-direction sideswipes, or they are not used effectively.

3. Driver behavior

Given that PRMs can provide drivers with a view of a portion of the side-rear environment that is not available with other mirrors, why might PRMs not contribute more to accident prevention? In most situations, the information that a PRM could provide is also available if the driver turns her head to look at the passenger side and rear. Perhaps drivers are no more likely to seek crucial information from a PRM than they are to turn and look in the appropriate direction if the vehicle lacks a PRM. Indeed, there is some evidence that drivers do not make optimal use of resources available for safe lane changing. Inexperienced drivers, particularly, are less likely to use mirrors (Mourant and Rockwell, 1972). Drivers in early studies were found to be more reluctant to use PRMs than driver-side mirrors because of the greater effort needed for head and eye movements, leading to suggestions for mounting PRMs on the front passenger-side fender (where they could be

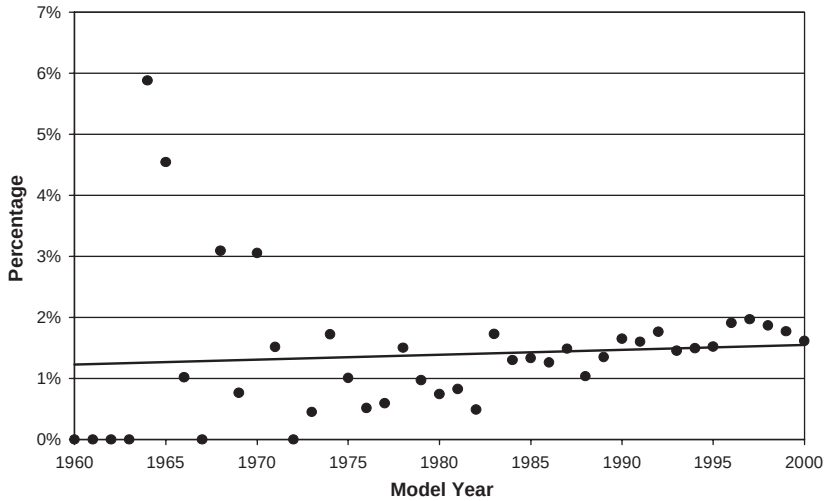

Fig. 1. Fatal same-direction sideswipes as percent of all fatal accidents. Data from 1999 for model years 1960–2000.

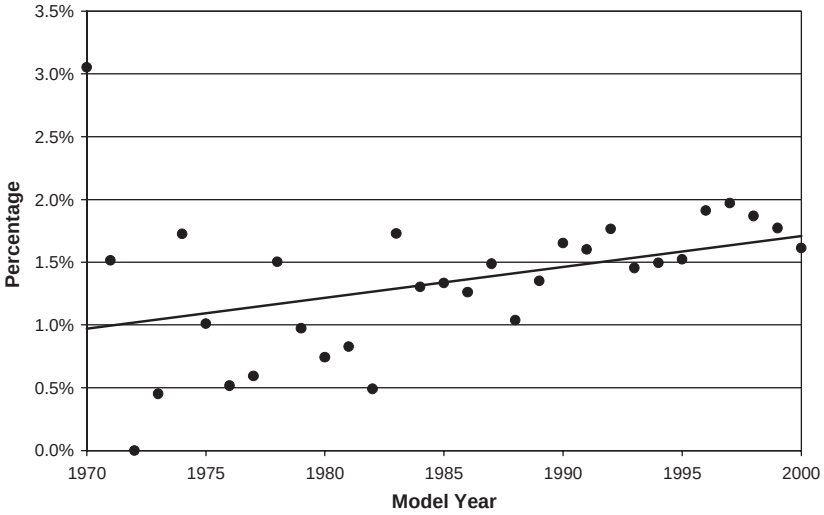

Fig. 2. Fatal same-direction sideswipes as percent of all fatal accidents. Data from 1999 for model years 1970–2000.

seen without having to turn so far to the side rather than on or just in front of the door, Nagata and Kuriyama, 1985). Hetrick (1997) found that 8% of drivers did not signal before making lane changes, and over half of the remainder did not signal until after beginning their maneuver, making it difficult for other drivers to avoid them in a conflict.

We have made unobtrusive observations of (unsuspecting) drivers approaching and conducting rightward lane changes (toward the passenger side of the vehicle in the US). Many drivers did not look to either the PRM or the passenger-side rear before or during a rightward lane change. These observations, however, were difficult to make reliably.

In order to document driver looking behavior, eye and/or head movements can be studied with video cameras or other devices mounted inside vehicles. In a recent study, 16 drivers used an instrumented vehicle (an SUV loaned to them for the study) during their normal commuting (Lee et al., 2003), and recorded data for over 8000 lane changes. Analysis of a subset of 29 rightward lane changes (out of 500 that were selected to emphasize those when approaching a slower-moving vehicle ahead, and with vehicles fairly close in adjacent lanes, thus more demanding) indicated that the driver looked toward the PRM on only 6 of 29 occasions (21%) during the last 3 s prior to the lane change, and only 5 (14%) looked toward the passenger-side blind spot, compared with 16 (55%) who looked toward the interior rearview mirror; unfortunately, the report does not specify overlap, e.g., how many looked either toward the PRM or the blind spot or both. Nevertheless, those findings suggest that drivers often fail to gather potentially useful information about adjacent-lane traffic before making rightward lane changes.

3.1. Method

In order to gather additional data on visual information sampling during rightward lane changes, we conducted a small-scale roadway study. Eight subjects were recruited (6 male, 2 female; ages 23, 29, 31, 39, 39, 39, 45, and 50); they were told that the study was concerned with driving behavior, specifically posture and seating position. They were asked to drive their own cars (all with PRMs) for the study, with video cameras installed to record their behavior. This assured that they would be comfortably familiar with the vehicle they used; all of the subjects had been driving their vehicles for at least 2 months, and

most for at least a year. During a 6.5 mile course in daylight on local urban streets, subjects were asked by the in-car experimenter to make various lane changes, both leftward and rightward, using their judgment to make the maneuvers safely. Subjects were not told about the specific aims of the study until afterwards.

Two small video cameras were mounted in each subject's vehicle, both aimed at the driver's head. One camera was placed next to the center rearview mirror and the other was next to the PRM; the two images were captured on a single split-screen video recorder. Eye glance directions were coded from the videotapes by one viewer, and checked by a second viewer. Any differences between the two viewers were resolved by watching the corresponding section again and reaching consensus.

3.2. Results

The data of interest for this paper involve mirror use during rightward lane changes, with each of the 8 subjects making 10 such maneuvers upon request, yielding 80 observations. Overall, subjects looked at the inside rearview mirror on 97.5% of trials prior to rightward lane changes, but they looked at the PRM on only 65% of such trials.

Usage of the PRM varied substantially across subjects. Three subjects used both the inside rearview mirror and the PRM on every trial before making a rightward lane change. Another three subjects also used the inside mirror every time, but looked at the PRM on only half of the trials; these subjects presumably felt the inside mirror often gave them enough information for their maneuver. Finally, two subjects occasionally (1 in 10 trials) made a rightward lane change without checking either of the critical mirrors, and in general used the PRM infrequently (one never used the PRM, and one used it for only 2 of 10 trials).

After the driving, subjects were asked about their use of the mirrors during the study. Although all subjects looked at the inside rearview mirror on 9 or 10 of the 10 trials, one reported that he had never looked at that mirror when changing lanes, and another reported that he used that mirror only sometimes. For the PRM, one subject reported never having used it, despite having looked at it on all 10 trials, and the two subjects who reported almost never using it had looked at the PRM for 0 and 7 trials, respectively; another subject said they had almost always used it, but in fact looked at the PRM on only 2 of 10 trials. These findings suggest that self-reported mirror usage can be highly unreliable, even immediately after a driving episode.

4. Conclusions

It is clear from past research that looking forward and using an inside rearview mirror cannot always provide enough information for safe lane changes. Outside rearview mirrors have been carefully designed to make blind-spot information available while balancing trade-offs such as glare and limited field of view. Accident statistics, however, including the fatal accident data analyzed here, have failed to demonstrate a safety benefit for PRMs. Perhaps more detailed analyses, such as review of in-depth accident reports, will uncover such evidence. In the meantime, the question remains as to why PRMs might not yield substantial safety benefits.

One possibility is that, in actual practice, PRMs may not add to the information gathered by drivers; consequently, drivers may not feel a need to check PRMs often. In most vehicles, a PRM does not provide much information that would not also be available by turning and looking to the passenger-side rear. It could even be argued that the PRM, with its narrow field of view, is inferior to a direct look; some driving manuals recommend that the driver always make a direct look before initiating a lane change. A PRM could act as a convenience, allowing a driver to perform an initial check of conditions before using a direct look to verify that it is safe to maneuver. In heavy and fast-moving traffic, however, where lane-changing is made difficult by short following distances (Ayres et al., 2001), drivers may not have the luxury of using both a PRM and a direct look before initiating a lane change.

In cars without PRMs, drivers were found to look back to the right on somewhat more than half

of their rightward merges (Robinson et al., 1972). In our study, using cars equipped with PRMs, drivers checked their PRMs on somewhat more than half of the rightward lane changes. Lee et al. (2003) found PRM checking on only 21% of trials, but their subjects were driving a relatively unfamiliar vehicle, and their sample emphasized heavy traffic conditions when drivers may not have time to check the possibly redundant information in a PRM.

Another possibility is that, despite the sometimes valuable information available in a PRM, drivers may not feel a need to look there. There are numerous documented examples of frequent failure to use safety equipment (e.g., to use safety belts) or to drive at a safe speed for conditions (e.g., in fog or at night); such behavior might represent under-estimation of risk, or else a general tendency to act just adequately rather than safely (Ayres et al., 1998).

Thus, despite the promise of a simple device that appears to fill an informational need, PRMs may not substantially reduce accidents if they are not used, or if they are used instead of direct looking. Researchers are now seeking more advanced crash avoidance systems as solutions to lane-change safety (e.g., Hetrick, 1997; Lee et al., 2003).

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