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MIRROR-MOUNTED TURN SIGNALS AND TRAFFIC SAFETY

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16. Abstract

Previous studies have shown that mirror-mounted turn signals have advantages over conventional turn signals in terms of their geometric visibility and conspicuity in several important situations. This study was designed to (1) develop methods for evaluating the effects of mirror-mounted turn signals on both the frequency and severity of relevant crashes, and (2) provide an illustrative application of these approaches.

We presented arguments suggesting that a viable approach involves a longitudinal comparison of the crash experience of vehicle models that had an abrupt year-to-year change from 0% to 100% installation. Several crash scenarios were identified that might be sensitive to the presence of mirror-mounted turn signals, including changing lanes, merging, making turns, and leaving a parked position.

We identified 13 vehicle models in the U.S. that had the desirable abrupt change in the installation of mirror-mounted turn signals. An illustrative analysis was then performed on the crash experience of these 13 vehicle models using the North Carolina crash database. The results indicate a tendency for vehicles with mirror-mounted turn signals to be less likely involved in turn-signal-related crashes, but the effect was not statistically significant. Furthermore, the results were inconclusive concerning the possibility of a reduction in crash severity for vehicles with mirror-mounted turn signals.

As manufacturers adopt mirror-mounted turn signals on more vehicle models, the target population of vehicles for a crash analysis will increase. At that point, the approach illustrated in this report could be used to perform a more definitive analysis of the safety benefits of mirror-mounted turn signals.

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Introduction

Mirror-mounted turn signals are turn signal repeaters mounted in or on the outside mirror housing. There are several common types of these signals. One type (through-the-glass) has light sources mounted behind the mirror surface and is only visible from the rear of the mirror. A second type (wrap-around) uses light sources to the side and on the front of a mirror, and is visible from a wider range of positions behind, adjacent to, and in front of the vehicle. A third type (belly-mounted) uses light sources below the mirror, and is also visible from behind, adjacent to, and in front of the vehicle.

We performed two previous studies related to the potential benefits of mirror-mounted turn signals. The first study (Reed and Flannagan, 2003) examined the potential for mirror-mounted turn signals to improve the geometric visibility of turn signals. Measurements of mirror location and window geometry were made on a large sample of passenger cars and light trucks. These data were combined with data on driver eye locations to assess the relative visibility of mirror-mounted and conventional turn signals. Simulations were conducted to examine the potential for signals to be obstructed when a driver looks laterally through the passenger-side window. The results indicated that mirror-mounted turn signals are visible from a wider range of geometric conditions than are conventional turn signals. Furthermore, mirror-mounted turn signals are generally closer to the viewing driver's forward-directed line of sight than conventional turn signals when the viewing driver's vehicle is in or near the blind zone. The report concluded that mirror-mounted turn signals improve the geometric visibility of turn signals in the adjacent-vehicle scenario that is believed to precede many lane-change/merge crashes.

The second study (Schumann, Sivak, Flannagan, and Schoettle, 2003) evaluated the potential benefits of the reduced eccentricity of mirror-mounted turn signals on the conspicuity of signals. Specifically, that study evaluated the effect of the eccentricity of a signal on its detectability under bright sunshine, while subjects performed a concurrent central visual task. Two levels of eccentricity were tested: 45° (representing a conventional turn signal when the observer is in the adjacent lane and just behind the signaling vehicle), and 30° (representing a mirror-mounted turn signal in the same

situation). Indeed, the results tended to favor lower eccentricity, and thus by implication also mirror-mounted turn signals.

In summary, the results of our previous two studies showed that mirror-mounted turn signals have advantages in terms of both geometric visibility and detectability. The present study was designed to explore several approaches for evaluating the potential safety benefits of mirror-mounted turn signals. These approaches were then applied to the North Carolina crash database. Because there are not enough relevant data available yet for a definitive analysis, this application should be viewed as an illustration of a more definitive analysis to be performed once more data are available.

Methodological Considerations

Vehicle samples

The ideal analysis would compare the crash experience of vehicles of the same model and year, differing only in whether they are equipped with mirror-mounted turn signals. Consequently, the most desirable approach would be to examine vehicles that offer mirror-mounted turn signals as an option, provided that it is possible to identify which vehicles are which. However, because information about mirror-mounted turn signals is not coded in the vehicle identification numbers (VINs), this is not a viable option.

A more practical approach involves identifying vehicle models that had an abrupt change in the availability of mirror-mounted turn signals, from 0% (not available at all) to 100% (standard equipment) from one year to the next. In this approach, several model years prior to the change would be compared to several model years following the change. An inherent concern with this approach is that, in addition to the vehicle difference of interest, often there are other vehicle differences across model years. This, however, can be partially controlled for by examining not only changes in the frequency of crash types of interest but also changes in other (control) crash types.

Crash scenarios

Mirror-mounted turn signals can be expected to be beneficial in reducing the frequency and/or severity of crashes that were precipitated by drivers in other vehicles who did not see an energized conventional turn signal, such as crashes while changing lanes, merging, making turns, and leaving a parked position. Such crashes (see Table 1) account for a total of about 17% of all U.S. crashes (NHTSA, 2005).

Table 1
Percentages of crashes that are expected to be sensitive to turn signals (NHTSA, 2005). The data are for 2004.

Pre-crash maneuver	% of all crashes
Changing lanes	3.2
Merging	0.5
Turning right	2.9
Turning left	10.2
Leaving a parked position	0.3

Complicating the matter is the fact that U.S. drivers do not use turn signals as often as they should. In an observational study, Papacostas (1984) found that at urban intersections 25 to 40% of drivers turning left did not properly use turn signals. Similarly, the results from a naturalistic driving study by LeBlanc et al. (2006) indicate that 20% of drivers changing lanes on freeways and ramps do not use their turn signals; the analogous percentage for surface roads was 36%. A recent survey of self reported usage (Response Insurance, 2006) found that turn signals are used less often by men than by women, and less often by younger drivers than by older drivers.

The general underuse of turn signals is of obvious importance, because the effectiveness of any turn signal is zero if not used. Consequently, the lower the usage rate of turn signals, the lower the expected benefits of supplemental, mirror-mounted turn signals. However, because of the technological novelty and appeal of mirror-mounted turn signals, they might lead to more frequent use of turn signals. Such a behavioral change would then be an indirect positive consequence of having mirror-mounted turn signals.

As indicated above, if the two vehicle groups were to differ only in whether they have mirror-mounted turn signals, we could concentrate on the above-indicated crash scenarios. However, because a realistic analysis would compare different model years of the same vehicle model, we need to use an additional crash scenario to control for other changes in the vehicle equipment (and driver population) over these intervening years.

Such a control crash scenario would be a scenario that is not expected to be affected by the presence of mirror-mounted turn signals (e.g., crashes when going straight ahead).

Crash severity

Mirror-mounted turn signals have the potential to influence both the frequency and severity of certain crashes (if mirror-mounted turn signals are detected sooner than conventional turn signals). Consequently, it would be instructive to examine not only the frequency of crashes but also their severity.

Illustrative Application

Vehicle samples

We contacted several mirror manufacturers to provide us with preliminary information about vehicle models/years that offered mirror-mounted turn signals as standard equipment. This preliminary information was then presented to vehicle manufacturers for confirmation. Vehicle manufacturers were also queried as to the availability of mirror-mounted turn signals as optional equipment for preceding model years of the same vehicle. Based on this survey, we identified 13 vehicle models that had an abrupt change from 0% to 100% installation of mirror-mounted turn signals from one model year to the next. These vehicles, and the respective model years, are listed in Table 2.

Table 2
Vehicle samples.

Make and model	Type of mirror-mounted turn signal	Model years with 0% mirror-mounted turn signals	Model years with 100% mirror-mounted turn signals
Cadillac DeVille DTS	through-the-glass	2000-2002	2003-2004
Cadillac Escalade	through-the-glass	2002	2003-2004
Cadillac Escalade EXT	through-the-glass	2002	2003-2004
GMC Yukon Denali	through-the-glass	2000-2002	2003-2004
GMC Yukon Denali XL	through-the-glass	2000-2002	2003-2004
Mercedes Benz C-Class	wrap-around	1993-1998	1999-2006
Mercedes Benz CLK-Class	wrap-around	1997-1999	2000-2006
Mercedes Benz E-Class	wrap-around	1995-1998	1999-2006
Mercedes Benz M-Class	wrap-around	1997-2001	2002-2006
Mercedes Benz S-Class	wrap-around	1992-1997	1998-2006
Mercedes Benz SL-Class	wrap-around	1995-2000	2001-2006
Volkswagen New Beetle	wrap-around	2002	2004*
Volkswagen Passat	wrap-around	2002	2004*

*Mirror-mounted turn signals were introduced as standard equipment mid-year in 2003.

Crash database and crash scenarios

We used 1992-2005 North Carolina crash data (UNC, 2006) to compile crash frequencies for the selected vehicles.[1] This database includes all reportable North Carolina traffic crashes (fatal, injury, and property damage). The VINDICATOR User's Manual (IIHS, 2006) was employed to identify the appropriate series and model codes for each vehicle. These codes combine to form the VINDICATOR Variable 254, "make/model," and this variable was used to select the proper combinations of vehicle models, body styles, and model years from within the North Carolina crash database.

Crash frequencies were then tabulated for the following crash-related vehicle maneuvers (Variable 146 in the 2005 codebook): "changing lanes or merging" (Code 5), "making right turn" (Code 7), "making left turn" (Code 8), "leaving parked position" (Code 14), and "going straight ahead" (Code 4). All scenarios, except for "going straight ahead," are potentially sensitive to the presence of mirror-mounted turn signals. The "going straight ahead" scenario was used as a control (as discussed above).

Crash frequency

The influence of mirror-mounted turn signals on lane change crashes was evaluated by comparing the likelihood of signal-related crashes in relation to the likelihood of signal-unrelated crashes. Specifically, for each vehicle type (with and without mirror-mounted turn signals), we calculated the ratio of the frequencies of signal-related crashes to signal-unrelated crashes. In the final step, we compared these two ratios by creating an odds ratio: a ratio of signal-related crashes to signal-unrelated crashes for vehicles with mirror-mounted turn signals divided by an analogous ratio for vehicles without mirror-mounted turn signals.

An odds ratio of 1 would indicate no difference between the vehicle with and without mirror-mounted turn signals. An odds ratio of less than 1 would indicate an under-involvement in signal-related crashes of vehicles with mirror-mounted turn signals; conversely, an odds ratio of more than 1 would indicate an over-involvement in signal-related crashes of vehicles with mirror-mounted turn signals.

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[1] The 2006 model year vehicles were introduced in 2005. Therefore, the 2005 crash database includes some 2006 model year vehicles.

Crash severity

In addition to crash frequencies, we also examined the severity of crashes in two analyses. The first analysis subdivided the relevant crashes into those after which the vehicle in question was drivable and those where it was not (Variable 132). The second analysis subdivided the relevant crashes by injury severity (Variable 165).

Results

Crash frequency. The frequencies of signal-related and signal-unrelated crashes are presented in Table 3 for vehicles with and without mirror-mounted turn signals. The odds ratio for the data in Table 3 (383/850)/(624/1,301) is 0.94, indicating that the odds of vehicles with mirror-mounted turn signals being involved in signal-related crashes versus signal-unrelated crashes are lower than the corresponding odds for vehicles without mirror-mounted turn signals. However, the 95% confidence interval for the obtained odds ratio (0.81 to 1.10) includes 1, indicating that the odds ratio is statistically not different from 1.

Table 3
Frequencies of crashes by vehicle type and crash type.

Vehicle type	Crash type	
	Signal-related	Signal-unrelated
With mirror-mounted turn signals	383	850
Without mirror-mounted turn signals	624	1,301

Crash severity: drivability. For signal-related crashes, there was a tendency for crash-involved vehicles with mirror-mounted turn signals to be more likely drivable after the crash (76.4%) than those without (74.2%). However, for the signal-unrelated crashes (going straight ahead), there was also a tendency for crash-involved vehicles with mirror-mounted turn signals to be more likely drivable (69.1%) than those without (64.1%), and this reduction was greater than the corresponding reduction for signal-related crashes. (One possible explanation for this finding could be differential improvements over time in vehicle integrity for different angles of impact.)

Crash severity: injury severity. The distributions of the injury severity levels by vehicle type and crash type are shown in Table 4.

Table 4
Distributions of injury severity by vehicle type and crash type. The entries in each cell are percentages for vehicles with and without mirror-mounted turn signals, respectively.

Crash type	Property damage only	Possible injury	Nonincapa-citating injury	Incapacitating injury	Fatal injury
Signal-related	92.6/92.2	5.7/6.7	1.7/1.2	0.0/0.0	0.0/0.0
Signal-unrelated	87.2/84.5	10.0/11.5	1.9/3.4	1.0/0.4	0.0/0.2

For signal-related crashes, there was a slight reduction of all injury crashes for vehicles with mirror-mounted turn signals (from 7.8% to 7.4%). However, there was also a slight increase in nonincapacitating injuries for these vehicles (from 1.2% to 1.7%). Furthermore, for signal-unrelated crashes, there was also a reduction of all injury crashes for vehicles with mirror-mounted turn signals, and this reduction (from 15.5% to 12.8%) was greater than that for signal-related crashes. (Again, differential improvements over time in vehicle integrity for different angles of impact could account for the greater reduction of injuries in signal-unrelated crashes.)

In summary, the results of these illustrative crash-severity analyses are inconclusive concerning the possibility of a reduction in crash severity for vehicles with mirror-mounted turn signals.

Summary

Previous studies have shown that mirror-mounted turn signals have advantages over conventional turn signals in terms of their geometric visibility and conspicuity in several important situations (Reed and Flannagan, 2003; Schumann et al., 2003). Consequently, it is reasonable to expect some positive safety consequences. This study was designed to (1) develop methods for evaluating the effects of mirror-mounted turn signals on both the frequency and severity of relevant crashes, and (2) provide an illustrative application of these approaches.

From the methodological point of view, we presented arguments that suggest that a viable approach for evaluating the safety benefits of mirror-mounted turn signals involves a longitudinal comparison of the crash experience of vehicle models that had an abrupt year-to-year change from 0% to 100% installation. Several crash scenarios were identified that might be sensitive to the presence of mirror-mounted turn signals, including changing lanes, merging, making turns, and leaving a parked position. Furthermore, we argued that to control for other, unrelated changes over time in vehicles and drivers, another crash scenario that is unlikely to be affected by mirror-mounted turn signals (e.g., going straight ahead) needs to be tracked as well.

We identified 13 vehicle models in the U.S. that had the desirable abrupt change in the installation of mirror-mounted turn signals. An illustrative analysis was then performed on the crash experience of these 13 vehicle models using the North Carolina crash database. The results indicate a tendency for vehicles with mirror-mounted turn signals to be less likely involved in turn-signal-related crashes, but the effect was not statistically significant. Furthermore, the results were inconclusive concerning the possibility of a reduction in crash severity for vehicles with mirror-mounted turn signals.

As manufacturers adopt mirror-mounted turn signals on more vehicle models, the target population of vehicles for a crash analysis will increase. At that point, the approach illustrated in this report could be used to perform a more definitive analysis of the safety benefits of mirror-mounted turn signals.

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