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16. Abstract

This study was designed to evaluate whether dedicated stop lamps, in comparison to stop lamps that are functionally combined with tail or turn signals, provide additional safety benefits at night. The analysis compared the frequencies of rear-end collisions in which the vehicles were struck to those collisions in which the same vehicles were the striking ones. The analysis used 1999-2003 Florida and North Carolina crash data. The vehicle sample consisted of 38 passenger car models for the years 1994-2003.

Overall, the results include a statistically significant pattern that suggests a beneficial effect of dedicated stop lamps. However, the results are complex and further analyses should be done to better understand the possible effect of dedicated versus combined stop lamps.

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Contents

Introduction

Rear-end collisions are one of the most frequent road-collision types. In the U.S., rear-end collisions currently account for about 30% of all crashes (NHTSA, 2004). Specifically, in 2003, there were 1,871,000 rear-end collisions, including 2,076 with fatalities, 638,000 with injuries, and 1,299,000 with property damage only (NHTSA, 2004).

Although we do not have a complete understanding of all factors involved in rear-end collisions, we do know that driver inattention is one of the key contributors (e.g., Lee et al., 2002). Consequently, any circumstance that increases the likelihood of a driver noticing energized stop lamps on a preceding vehicle is likely to decrease the risk of rear-end collisions.

In their comprehensive review, Moore and Rumar (1999) listed several aspects of rear lighting that might decrease the likelihood of detecting stop signals. One such aspect is of interest here: Brake signals may sometimes be masked by other signals. The center high mounted stop lamp (CHMSL) was introduced partly to address this problem by spatially separating the stop signal from the other rear signals.

In addition to this unambiguous indication via CHMSLs that the preceding vehicle is braking, some cars are also equipped with dedicated stop lamps. The principle of dedicated stop lamps is the same as that of CHMSLs. Specifically, by having at least one lamp on each side of the vehicle dedicated to the brake function, these lamps provide an additional cue to the following driver in situations where the tail lamps are energized (e.g., at night). This cue is not provided by lamps that functionally combine the stop and tail functions. As pointed out by Mortimer (1970), dedicated stop lamps provide redundancy in coding: the stop signal can be discerned by an increased number of energized lamps (in addition to the difference in intensity between stop lamps and tail lamps).

In reviewing the rear-signaling literature, Henderson et al. (1983) concluded that spatial separation of stop lights from other signals results in shorter reaction times. However, the results of the reviewed studies did not provide direct safety evidence for the benefits of dedicated stop lamps.

The potential masking effect of tail lights has also been investigated in connection with daytime running lights (DRLs) because low beams, with simultaneously energized tail lamps, are sometimes used as DRLs. On the basis of the review of the effects of DRLs on road safety, Elvik et al. (2003) concluded that these concerns are generally unfounded. However, there is evidence to suggest that the masking of tail lights may adversely affect rear-end collisions.

Pirtala (2002) evaluated potential benefits of dedicated stop lamps in comparison with other types of stop lamps in terms of the risk of being struck in a rear-end collision. The study was conducted in Finland, where the mandatory use of DRLs was introduced in 1982 for rural areas and in 1997 for urban areas. The use of DRLs raised the question of whether rear-end accident risk would increase, because low beams (accompanied by energized tail lamps) were frequently used as DRLs, and, therefore, the brake signals might be more difficult to detect. Pirtala (2002) found that the vehicle models with dedicated stop lamps were less frequently struck in rear-end collisions than those with combined lighting functions. Specifically, his first dataset of urban crashes in 1987-92 showed a decrease of 24%, and the second dataset of urban and rural crashes in 1993-98 showed a decrease of 22%. However, the effects of the gradual introduction of CHMSLs during the data collection period were not examined.

The present study was designed to evaluate whether dedicated stop lamps provide safety benefits at night. Based on the discussion above, we hypothesized that dedicated stop lamps might decrease the likelihood of being struck in rear-end collisions at night. (In the U.S., tail lamps are generally not energized during the daytime. Consequently, the likelihood of being struck in rear-end collisions during the daytime should be approximately the same for systems with and without dedicated stop lamps.)

Method

Rear lamp data

Based on the results of Pirtala (2002), we preselected a sample of vehicle models that we expected would include various rear-lighting configurations. The actual information on the configurations was obtained by e-mail inquiries to the vehicle manufacturers. This information was supplemented with visits to two car dealerships. The specific question of interest was whether, for the particular model year, (1) at least one lamp on each side of the vehicle was dedicated to the brake function or (2) each stop lamp was functionally combined with tail lamp(s) or turn signal(s). The study was limited to the conventional lamps, and the CHMSLs were not included.

The sample of vehicle models consisted of 38 full-size, mid-size, and compact passenger cars. The model years included were from 1994 to 2003 (if a model was available on the market). The sample included the following models (in alphabetical order): BMW 3 and 5 series; Buick Century and Regal; Chevrolet Impala, Lumina, and Malibu; Chrysler Cirrus; Dodge Stratus; Ford Contour and Taurus; Honda Accord; Mercedes-Benz C and E series sedans; Mercury Mystique and Sable; Oldsmobile Achieva, Aurora, Cutlass, and Intrigue; Plymouth Breeze; Pontiac Grand Am and Grand Prix; Saab 900, 9000, 9-3, and 9-5; Toyota Camry; Volkswagen Golf, Jetta sedan, and Passat; and Volvo 40, 60, 70, 80, 850, 940, and 960.

Crash data

We used 1999-2003 crash data for Florida (Department of Highway Safety and Motor Vehicles Florida, 2005) and North Carolina (University of North Carolina, 2005). These databases include all reportable traffic crashes (fatal, injury, and property damage) in those states.

Frequencies were computed for vehicles involved in rear-end collisions (defined by the first harmful event) involving two vehicles in which one vehicle was driving at a slower speed or slowing down or stopping in traffic, or in which the front vehicle was turning. The vehicle identification number (VIN) was decoded to get specific vehicle models. If the point of impact (in Florida data) or contact point (in North Carolina data) was in the rear of the vehicle, it was assumed that the vehicle was *struck* by a following vehicle. Analogously, if the point of impact or contact point was in front of the vehicle, it was assumed that the vehicle in question was the *striking* vehicle. The analysis was conducted separately for daytime and nighttime data. The collisions that occurred during dawn and dusk periods were excluded from the analyses. To avoid complex collision configurations, the included vehicles had damage only in the front or rear area (but not in both areas). Moreover, if the struck vehicle had a trailer, the collision was not included.

Data analysis

The analysis was based on a comparison of the frequencies of rear-end collisions in which the vehicles were struck, while the frequencies of rear-end collisions in which the vehicles were striking were used as controls. Because the signaling systems of the striking vehicle are unlikely to affect collision frequency, they should provide an index of exposure. Consequently, the ratio of the frequencies of being struck and striking was assumed to indicate the likelihood of being struck in rear-end collisions.

In addition, we assumed that, in *daylight*, there should be no difference in the likelihood of being struck between the two rear-lighting configurations. This assumption was based on the following considerations. First, in the daytime the tail lamps are normally not on before the driver of the leading vehicle brakes (and not on after braking either.) Second, the physical appearance of stop lamps is likely to be about the same in both model groups because of the federal regulations that specify the required luminous intensity values.

Based on the above assumptions, we computed, for each rear-lighting configuration, the ratio of the nighttime and daytime struck/striking odds as an index of whether vehicles with that type of lighting fared better or worse than would be expected in nighttime lighting conditions. We then calculated the ratio of these ratios to quantify any differences between the two vehicle types.

Results

Table 1 shows the frequencies of struck and striking vehicles in rear-end collisions in Florida and North Carolina and the totals for both states by ambient lighting and rear-lighting configuration.

Table 1
Frequency of struck and striking vehicles in rear-end collisions
by ambient lighting and rear-lighting configuration.

Rear-lighting configuration	Collision type	Florida		North Carolina		Total	
		Daytime	Nighttime	Daytime	Nighttime	Daytime	Nighttime
Dedicated stop lamps	Struck	709	254	355	53	1,064	307
	Striking	518	215	195	33	713	248
No dedicated stop lamps	Struck	8,920	2,868	5,193	916	14,113	3,784
	Striking	8,393	2,499	3,978	615	12,371	3,114

The ratio of odds ratios is 0.80 for Florida, 0.77 for North Carolina, and 0.78 for the total data. For example, the ratio of odds ratios for the total data was computed as follows:

$$\underbrace{\left[\underbrace{(\underbrace{307}_{\text{Struck}}/\underbrace{248}_{\text{Striking}})}_{\text{Nighttime}} / \underbrace{(\underbrace{1{,}064}_{\text{Struck}}/\underbrace{713}_{\text{Striking}})}_{\text{Daytime}}\right]}_{\text{Dedicated stop lamps}} / \underbrace{\left[\underbrace{(\underbrace{3{,}784}_{\text{Struck}}/\underbrace{3{,}114}_{\text{Striking}})}_{\text{Nighttime}} / \underbrace{(\underbrace{14{,}113}_{\text{Struck}}/\underbrace{12{,}371}_{\text{Striking}})}_{\text{Daytime}}\right]}_{\text{No dedicated stop lamps}} = 0.78.$$

Given that all three ratios of odds ratios are less than 1, the data suggest that the rate at which vehicles with dedicated stop lamps are struck at night is lower than the corresponding rate for vehicles with no dedicated stop lamps (a decrease of 22% for the total sample). To evaluate whether this parameter was significantly different from 1.0, we fit a hierarchical log linear model. This analysis showed a statistically significant three-way interaction (nighttime/daytime by dedicated/no dedicated stop lamps by struck/striking vehicle), $\chi^2(1) = 6.00$, $p = .014$, implying that the obtained ratio of odds ratios (0.78) was indeed statistically different from 1.

Discussion

This study investigated potential effects of dedicated stop lamps on rear-end collisions. Specifically, the analysis compared the frequencies of rear-end collisions in which vehicles were struck by the type of rear-lighting configuration, while the frequencies of rear-end collisions in which the same vehicles were the striking ones were used as controls. In addition, we assumed that in daylight the likelihood of being struck in rear-end collisions should be approximately the same for the two lighting configurations.

The main results indicated that, on average, the tendency for models with dedicated stop lamps to be struck at night is 22% lower than for models without dedicated stop lamps. The effect was statistically significant.

However, an additional analysis showed that the price of the vehicles was directly related to the ratio of being struck vs. being the striking vehicle. This may be due to a reporting bias. For example, owners of more expensive models may be more likely to report a collision in which their vehicle is struck than the owners of less expensive vehicles. Alternatively, drivers of more expensive cars could be less likely to be involved in rear-ending other vehicles. However, neither a reporting bias nor a differential tendency to rear-end other vehicles should have an effect on the main finding, because such effects would be cancelled out by taking nighttime to daytime ratios.

The present results support the earlier finding of Pirtala (2002). As a matter of fact, the magnitude of the obtained effect was very close to the results obtained by Pirtala (2002), although that study dealt with both daytime and nighttime collisions (with tail lights in Finland usually being on in daylight). In comparison with the effects of CHMSLs [a 4% reduction in relevant crashes according to Kahane and Hertz, (1998)], the estimated effects of dedicated stop lamps are large.

This study focused on a single factor of rear-lighting configurations that may covary with other characteristics. For example, compared to the models with no dedicated stop lamps, the models with dedicated stop lamps are more likely to have dedicated turn signals. Moreover, in the U.S. the color of dedicated rear turn signals can be red or amber, while they are always red when combined with other functions.

Although we assume that for rear-end collisions the information provided by turn signals is of relatively minor importance compared to the information from stop signals, turn-signal information is likely to have some effect on the likelihood of rear-end collisions. Further research should investigate these issues more comprehensively.

It is important to point out that this was not a controlled experiment, but a quasi-experiment in which several potentially relevant parameters were not controlled for. The following are three such examples. First, in the daytime, the struck vs. striking ratio differed by rear-lighting group. This ratio was 1.49 for the vehicles with dedicated stop lamps and 1.14 for the vehicles without dedicated stop lamps. Second, there was a substantial difference in the mean purchase price of the two vehicle groups. Specifically, the mean of the minimum and maximum factory-suggested retail price in 1999 (or in the closest year that a model was available) averaged $32,000 for the vehicles with dedicated stop lamps and $25,000 for the vehicles without dedicated stop lamps (The Automobile Red Book, 2004). Third, as the vehicle price increased, so did the struck vs. striking ratio (possibly because of either an increase in reporting of collisions in which the subject vehicle is struck or a decrease in the tendency to rear-end other vehicles with increasing value of the vehicle). Although it is not apparent how any of these factors could have influenced the main finding, their possible effects cannot be fully ruled out.

Overall, the results include a statistically significant pattern that suggests a beneficial effect of dedicated stop lamps. However, the results are complex and further analyses should be done to better understand the possible effect of dedicated versus combined stop lamps.

References

The Automobile Red Book (2004). *PRIMEDIA price digests' official used car valuations (cars, light trucks, SUVs, vans, Region A), 94*(5). Overland Park, KS: Primedia Business Directories & Books.

Department of Highway Safety and Motor Vehicles Florida. (2005). *Florida Crash Data, 2003*. Tallahassee, FL: Author

Elvik, R., Christensen, P., Fjeld Olsen, S. (2003). *Daytime running lights: A systematic review of effects on road safety* (Report No. 688/2003). Oslo: Institute of Transport Economics.

Henderson, R.L., Sivak, M., Olson, P.L., and Elliot, W.M. (1983). *Motor vehicle rear lighting and signalling* (SAE Technical Series Paper No. 830565). Warrendale: Society of Automotive Engineers.

Kahane, C.J. and Hertz, E. (1998). *The long term effectiveness of center high mounted stop lamps in passenger cars and trucks* (Report No. DOT HS 808 696). Washington, D.C.: National Highway Traffic Safety Administration.

Lee, S., Wierwille, W.W., and Klauer, S.G. (2002). *Enhanced rear lighting and signalling systems: Literature review and analysis of alternative system concepts* (Report No. DOT HS 809 425). Washington, D.C.: National Highway Traffic Safety Administration.

Moore, D.W. and Rumar, K. (1999). *Historical development and current effectiveness of rear lighting systems* (Technical Report No. UMTRI-99-31). Ann Arbor: The University of Michigan Transportation Research Institute.

Mortimer, R.G. (1970). *Automotive rear lighting and signaling research. Final report* (Report No. HSRI Report No. HuF-5). Ann Arbor: Highway Safety Research Institute.

NHTSA (National Highway Traffic Safety Administration). (2004). *Traffic safety facts 2003*. Washington, D.C.: Author.

Pirtala, P. *Jarruvalotyypin vaikutus peräänajoriskiin [Effect of stop lamp type on rear-end collision risk]* (Report No. 42). Tampere, Finland: The Tampere University of Technology, Traffic and Transportation Engineering.

University of North Carolina. (2005). *North Carolina Crash Data, 2003*. Chapel Hill, NC: University of North Carolina Highway Safety Research Center.