UMTRI-2004-14

VISIBILITY AND REAR-END COLLISIONS INVOLVING LIGHT VEHICLES AND TRUCKS

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Report No. UMTRI-2004-14
June 2004

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTRI-2004-14		

4. Title and Subtitle	
Visibility and rear-end collisions involving light vehicles and trucks	5. Report Date June 2004
	6. Performing Organization Code 302753
7. Author(s) John M. Sullivan and Michael J. Flannagan	8. Performing Organization Report No. UMTRI-2004-14
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Road Ann Arbor, MI 48109-2150 U.S.A	10. Work Unit no. (TRAIS)
	11. Contracts or Grant No.
12. Sponsoring Agency Name and Address The University of Michigan Industry Affiliation Program for Human Factors in Transportation Safety	13. Type of Report and Period Covered
	14. Sponsoring Agency Code

15. Supplementary Notes

The Affiliation Program currently includes AGC America, Autoliv, Automotive Lighting, Avery Dennison, BMW, DaimlerChrysler, DBM Reflex, Denso, Federal-Mogul, Ford, GE, General Motors, Gentex, Guide Corporation, Hella, Honda, Ichikoh Industries, Koito Manufacturing, Lang-Mekra North America, Magna International, Mitsubishi Motors, Muth, Nichia America, Nissan, North American Lighting, Olsa, OSRAM Sylvania, Philips Lighting, PPG Industries, Reflec USA, Reflexite, Renault, Samlip, Schefenacker International, Sisecam, Solutia Performance Films, Stanley Electric, TG North America, Toyota Technical Center USA, Valeo, Vidrio Plano, Visteon, 3M Personal Safety Products, and 3M Traffic Safety Systems.

Information about the Affiliation Program is available at: http://www.umich.edu/~industry/

16. Abstract

Rear-end collisions predominantly occur in the daytime under clear, unobstructed viewing conditions and usually involve a lead vehicle that is stopped at the time of collision. These facts suggest that driver inattention plays a significant causal role in rear-end collisions, and mitigation efforts have therefore focused largely on development of warning technologies to alert drivers of an impending crash. However, we note that this pattern of crash data should not lead to the conclusion that drivers have special difficulty avoiding rear-end collisions in broad daylight. Nor should it be concluded that other "environmental" factors do not influence driving behavior to increase rear-end crash risk. Crash frequency is determined both by the inherent risk in the driving task and by the frequency of driver exposure to conditions in which a crash is possible. When exposure level is equated across conditions which differ in ambient light level, we find that rear-end collisions appear to be more than twice as likely in darkness as in daylight, and are more influenced by light level than are either side-impact collisions or front-end collisions. An examination of vehicle type and role in rear-end crashes revealed that the incidence of fatal rear-end crashes involving a struck truck is nearly 9 times more likely in darkness than in light, suggesting that trucks are particularly difficult to see at night.

17. Key Words	18. Distribution Statement
rear-end collisions, visibility, conspicuity, trucks, daylight saving time	Unlimited

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
None	None	15	

Acknowledgements

Appreciation is extended to the members of the University of Michigan Industry Affiliation Program for Human Factors in Transportation Safety for support of this research. The current members of the Program are:

AGC America
Autoliv
Automotive Lighting
Avery Dennison
BMW
DaimlerChrysler
DBM Reflex
Denso
Federal-Mogul
Ford
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General Motors
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Honda
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Valeo
Vidrio Plano
Visteon
3M Personal Safety Products
3M Traffic Safety Systems

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Introduction

According to the NHTSA's General Estimates System, in 2001 there were an estimated 1.9 million police-reported rear-end crashes in the United States, representing about 30% of a total of 6.3 million crashes. In contrast, rear-end crashes comprised only about 5% of all fatal crashes in 2001, suggesting that while numerous, rear-end crashes are not especially lethal. Nonetheless, rear-end crashes represent a considerable national cost and there is keen interest in developing effective countermeasures to reduce the incidence of this type of crash.

A detailed breakdown of the causal analysis of crash data taken from the Indiana Tri-Level Study (Treat et al., 1979) suggested that, especially for circumstances in which the lead vehicle is stopped, the majority of rear-end collisions (approximately 68%) are caused by driver inattention or distraction (Knipling, Wang, & Yin, 1993). This analysis was further supported by a follow-up causal analysis of the 1991 National Accident Sampling System (NASS) Crashworthiness Data System (CDS) in which driver inattention was implicated in 66% (weighted) of the rear-end crashes (Knipling, Mironer et al., 1993). Notably, factors related to the environmental conditions (icy roads, fog, rain, obscured vision) appeared to play only a small causal role. Less than 10% of the Tri-Level cases and less than 4% of weighted cases taken from the analysis of the 1991 CDS data were attributed to environmental conditions. The apparently strong causal relationship between driver inattention and rear-end collision also appeared to be further supported by the fact that 77% of rear-end collisions occurred in daylight and 90% occurred on straight roadways (Knipling, Wang et al., 1993). Thus, the striking drivers in rear-end crashes appear to be completely unaware of their immediate peril despite the generally favorable environmental conditions. Mitigation efforts have thus focused largely on the development of warning technologies to alert inattentive drivers of impending crashes.

Care should be taken not to overinterpret these crash facts and draw conclusions from them about the role of human attention. For example, it should not be concluded that inattentiveness is more common during the daytime on straight roads. Instead, it must be recognized that there are more opportunities for rear end collisions during the daytime and on straight roadways. Rear-end collisions occur between a minimum of 2 vehicles: often one following another down a roadway at relatively close proximity. This circumstance is obviously less likely to occur at 03:00 h than at 17:00 h. Thus traffic density surely contributes to the observed pattern of rear-end crashes and should not be mistaken for drivers' attentional processes. While it is appropriate and practical to design countermeasures engineered to match the circumstances in which rear-end collisions frequently occur, the frequency statistics alone do not establish what characteristics of the driving situation affect a driver's performance to increase the risk of a rear-end collision.

This report takes a closer look at the role of ambient light in fatal rear-end collisions by analyzing the distribution of these crashes across the annual daylight saving time (DST) transitions. The technique examines the change in the distribution of fatal crashes during periods just before and just after DST changeovers at times of day that transition from darkness to daylight and vice versa. In comparing crash data from a 1-hour clock window across the DST transition, we assumed that levels of many factors known to play a role in fatal crashes remain relatively constant, leaving ambient light level as a quasi-independent variable. For example, in the Detroit area the 1-hour period between 19:30 h and 20:30 h is dark before the spring changeover to DST, and light afterwards. An important assumption in this analysis is that traffic conditions (and hence, crash opportunities) are the same in the weeks immediately before and after the changeover to and from DST, because traffic is principally governed by clock time rather than by the position of the sun in the sky. Observed differences in crash levels between these 2 periods are thus likely to be related to the difference in ambient light level, and may be used to quantify the effect of light in fatal crashes.

Past analyses of increased crash risk in the dark have focused primarily on fatal pedestrian crashes, which are about 4 times more likely in the dark than in daylight (Sullivan & Flannagan, 1999, 2001). A small, but reliable, heightened risk was also observed in these analyses for fatal crashes between motor vehicles (1.3 times more likely in the dark). In the current analysis, we follow up this finding by examining changes in the patterns of collisions between motor vehicles with special focus on disaggregating the crashes by collision type and with particular interest in rear-end collisions. Although environmental factors have been causally linked to only small numbers of rear-end crashes, they may nevertheless play a role in elevating the risk of rear-end crashes as long as factors related to crash opportunity are similar.

Method

Crash data from the Fatality Analysis Reporting System (FARS) of the National Highway Traffic Safety Administration (NHTSA) were selected from the 15-year period from 1987 to 2001. Cases selected for analysis straddled the daylight saving time changeover periods in time windows that abruptly changed from dark to light (or light to dark) across the time change. To perform the DST analysis, the exact start and end of civil twilight was computed for the dates of the spring and fall adjustments for DST for each county in 47 of the contiguous United States, for each of the 15 years covered in this analysis. Counties in states that do not observe DST, as well as counties split across time zones, were excluded (e.g., all counties of Arizona and 77 of Illinois).

Using the county times of the start and end of civil twilight, crash-record clock times were recoded to indicate if the crash occurred in the 1-hour interval just after the end of civil twilight in the evening. As shown in Figure 1, in the spring, this interval is dark before DST and light (or twilight) after the DST changeover. In the fall, the interval is light before the DST changeover, and dark following it. For the present analysis, crash records were taken from 5 weeks before and 5 weeks after the evening transitions in both the spring and fall, and tagged as falling into either a light or a dark period. We note that, although there is a dark/light transition in the morning, the same procedure could *not* be applied directly to the morning. The 5-week morning intervals straddling the DST changeover contain a mixture of both daylight and darkness (see Figure 2). As the figure illustrates, in the 5-week period before the spring transition in the morning, light levels are nearly dark at the beginning and lighten as the DST transition date is reached. After the transition, the light level changes from dark to light. Inclusion of these morning crash data over the 5 weeks before and after the DST transition would wash out the light level difference, because crashes in the dark and light periods would not be adequately segregated. (For a more detailed analysis of crash rates and light levels in morning crash transitions, see Sullivan and Flannagan, 1999.)

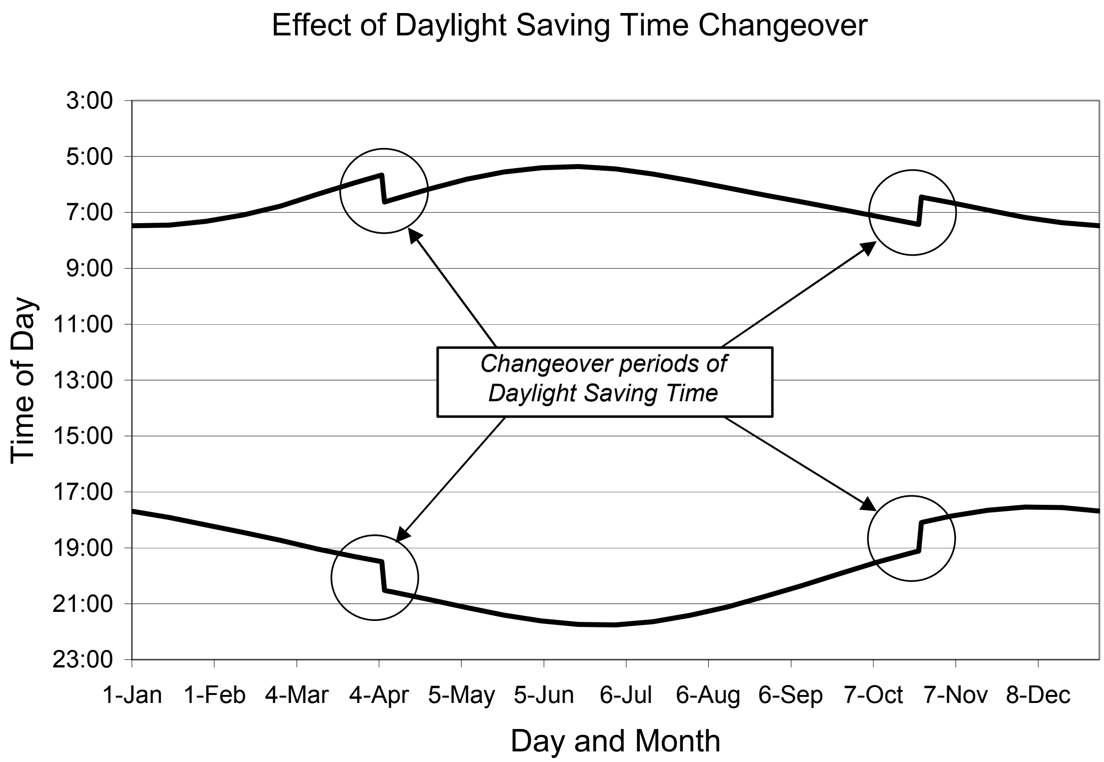

Figure 1. Daylight saving time changeover characteristics for spring and fall. The solid line is the clock time of the start (top) and end (bottom) of civil twilight throughout the year for the Ann Arbor/Detroit area (1997).

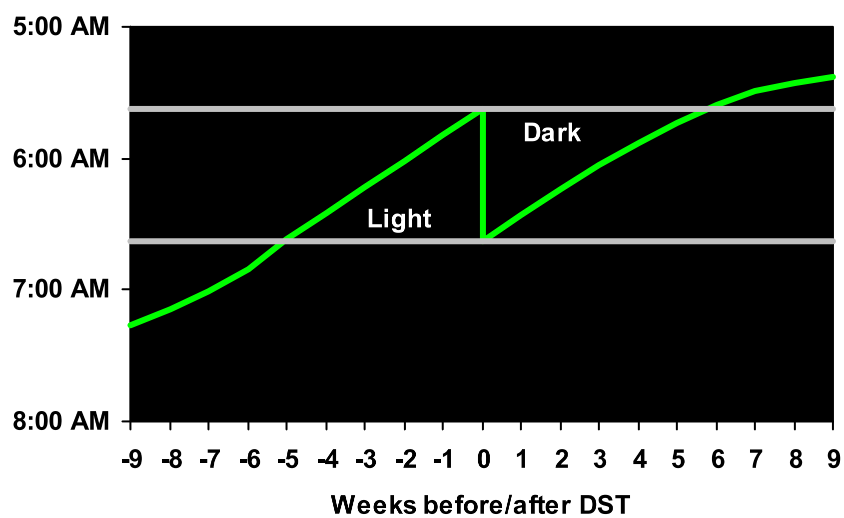

Figure 2. Spring morning transition to daylight savings time. The line traces the end of civil twilight throughout the weeks before and after the transition.

The magnitude of the risk was estimated by examining the ratio of crashes occurring during the dark period to those occurring during the light period. A simple null hypothesis would suggest that a crash is equally likely to occur in either the dark or light period, and should produce a dark-light ratio of 1. A ratio greater than 1 indicates an increased risk in darkness; a ratio less than 1 indicates reduced risk in darkness.

In the first analysis, rear-end, front-end, and side-impact crash data involving 2 vehicles were compiled across the DST transitions. A further analysis was then conducted to examine the characteristics of rear-end collision risk as a function of vehicle role (striking, struck) and vehicle type (light vehicle, truck).

Results

Figure 3 illustrates the raw crash counts for each collision type across the 1-hour evening time interval that changes from light to dark during the fall transition to standard time. The data are accumulated over 15 years (1987 to 2001) and show crash rates 5 weeks before and 5 weeks after the transition. Rear-end collisions change from an average count of about 13 crashes in the light to an average of 37 in the dark, suggesting a dark-to-light crash ratio of about 3 to 1. For the remaining analyses, ratios are computed by pooling crash counts for spring and fall during the 5-week dark and 5-week light intervals before and after the transitions. Table 1 provides a breakdown of crash counts in dark and light for each crash type.

Overall, fatal rear-end collisions were less frequent than either side-impact collisions or front-end collisions, although they appeared to be more than twice as frequent in darkness as in daylight, suggesting that ambient light level may indeed play some role in affecting the likelihood of rear-end collisions.

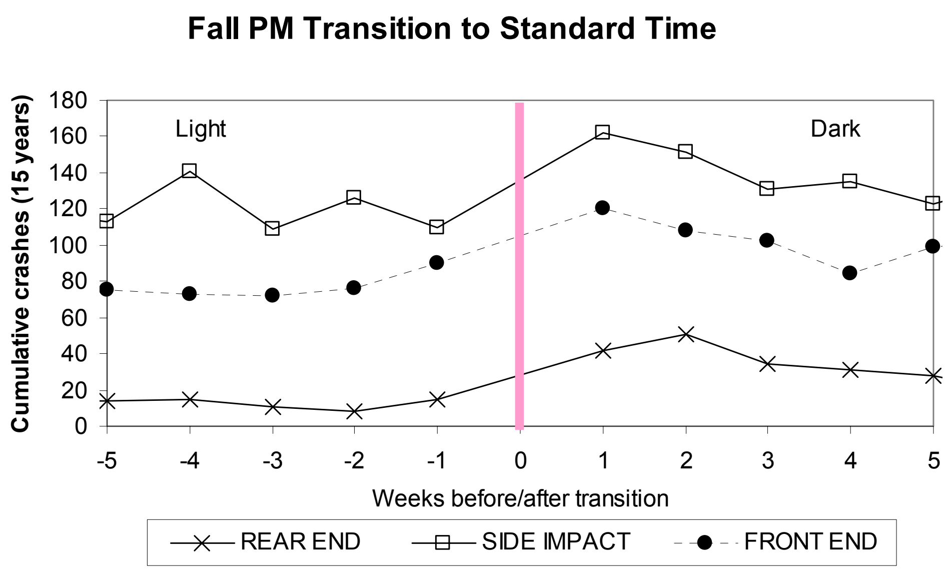

Figure 3. Crash counts in the weeks prior to and following the fall evening return to standard time. The left half of the figure shows crashes occurring during a 1-hour time interval that is in daylight prior to the transition to standard time; the right half shows crashes in darkness.

Table 1

Accumulated crashes (and percentages) in the dark and light intervals 5 weeks before and after the evening DST transition combined for both spring and fall.

Crash Type	Ambient Light		Dark/Light Ratio
	Dark	Light	
Rear-End	289 (70%)	123 (30%)	2.4
Side-Impact	1099 (52%)	1008 (48%)	1.1
Front-End	785 (55%)	649 (45%)	1.2

In the next analysis, we examined the relationship between vehicle type (light vehicle or truck) and the role (striking or struck) played by each vehicle in the crash. Vehicle-type categories were defined using the same scheme applied in previous rear-end collision analyses (Wiacek & Najm, 1999): the category "light vehicles" included automobiles, light trucks, SUVs, and vans; the category "trucks" included medium and heavy trucks. Because of the small number of fatal bus and motorcycles crashes, they were not included in this analysis.

The breakdown of fatal crashes is shown in Figure 3. While fatal rear-end collisions involving striking light vehicles are 3 times more likely in the dark, there appears to be little difference in the striking-truck frequency during the dark and light periods. Especially noteworthy is that medium and heavy trucks appear to be over 8 times as likely to be rear-ended in darkness as in daylight. This suggests that trucks are either more often unnoticed or somehow misperceived by drivers in darkness, leading to fatal collisions. That trucks are overrepresented as struck vehicles in nighttime crashes has been reported before (Green, Kubaki, Olson, & Sivak, 1979) and this has prompted regulatory action in the last 10 years to make trucks more conspicuous, with some effect (Morgan, 2001).

We note that the data in Figure 3 show that the total for striking vehicles does not match the total for struck vehicles (354 versus 285). That is because struck vehicles of all types are included the tallies of the striking light vehicles and trucks, and striking vehicles of all types are included in the tallies of the struck light vehicles and trucks. For example, a light vehicle struck by a bus is counted among the struck vehicles, but the bus is not among the striking vehicles. If the analysis is restricted to include only 2-vehicle collisions in which both striking and struck vehicles are either a light vehicle or a truck, the results are similar when collapsed over each vehicle type (see Tables 2 and 3).

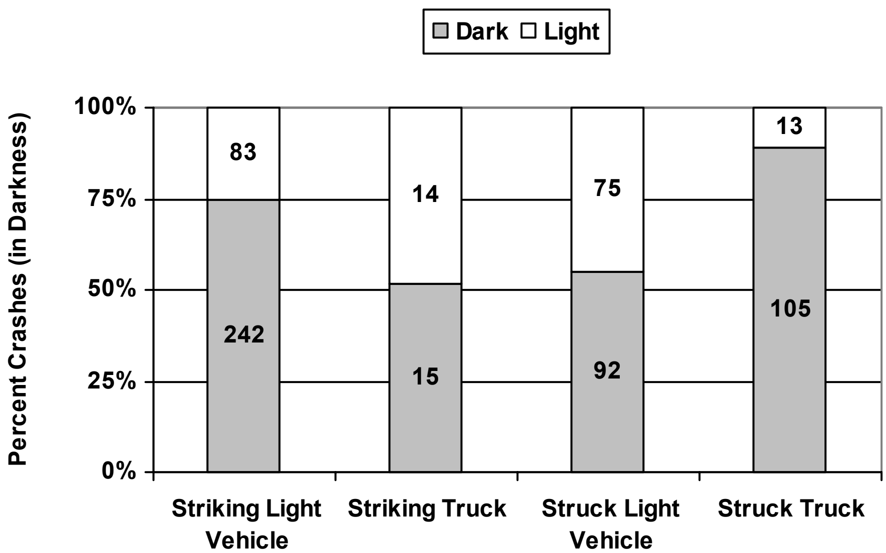

Figure 3. Fatal rear-end collisions during the spring and fall evening DST changeover period by vehicle type (light vehicle or truck) and role (striking or struck) in collision. The data were accumulated over 15 years (1987 to 2001) for 5-week periods before and after each changeover.

Table 2

Counts of fatal 2-vehicle rear-end collisions occurring in dark and light periods involving light vehicles and trucks.

Vehicle Types (Striking – Struck)	Ambient Light		Dark/Light Ratio
	Dark	Light	
Light Vehicle-Light Vehicle	74	45	1.6
Light Vehicle-Truck	95	10	9.5
Truck-Light Vehicle	7	9	0.8
Truck-Truck	4	2	2.0

Table 3

The data from Table 2 recompiled as in Figure 3. All crashes involving striking light vehicles and trucks are summed; similarly, all crashes involving struck light vehicles and trucks are summed.

Vehicle Types by Role		Ambient Light		Dark/Light Ratio
		Dark	Light	
Striking	**Light Vehicle**	169	55	3.1
	Truck	11	11	1.0
Struck	**Light Vehicle**	81	54	1.5
	Truck	99	12	8.3

Discussion and Conclusion

The risk of a fatal rear-end collision in darkness appears to be more than twice that in daylight. Although the added risk in darkness is substantial, it has perhaps been underappreciated until now because the volume of roadway encounters with stopped vehicles is far smaller in darkness than in daylight. We note that the identification of such an environmental influence on fatal rear-end crash risk does not diminish the importance of attentional mechanisms in rear-end collisions—in fact, allocation and reallocation of visual attention is likely influenced by target visibility. For example, detection of a looming object in the visual periphery is perhaps easier in daylight, permitting a better chance to avoid a rear-end collision. Alternatively, perhaps with reduced visibility of a forward vehicle, drivers are less likely to keep their attention on the road. In any case, the results suggest that some degree of fatal rear-end crash mitigation might be possible if target visibility is enhanced—especially, but not only, for large trucks.

As a final note, in December 1992, the Federal Motor Vehicle Safety Standard (FMVSS) No. 108, "Lamps, Reflective Device, and Associated Equipment," was amended to require all heavy trailers manufactured after December 1, 1993 to be marked with reflectors, reflective tape, and sheeting materials to enhance conspicuity. In March 1999, this requirement was extended to require the entire active trailer fleet to bear conspicuity markings by June 1, 2001. An interesting subject for future investigation would be to examine the dark/light ratios of struck trucks to determine if these legislative actions had measurable effects on the observed risks in darkness as quantified by the daylight savings time method for the period of 1987 to 2001.

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