Daytime running lights: A closer look at their justification for Australia

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ABSTRACT

Daytime running lights (DRL) have been advocated as a road safety measure for implementation in Australia. Two recent studies have calculated that a substantial number of crashes could be prevented each year, and that the cost of their widespread adoption would be outweighed by their benefits. However, both the number of crashes and the rate of crash prevention can be questioned, resulting in the need to reconsider the cost-benefit analysis. Treating Victoria as a case study, here a road crash database is analysed for crashes that might be averted or reduced in severity through implementation of DRL. Further, meteorology data is used to eliminate crashes that occur during hours of darkness and twilight, times during which drivers are likely to have turned their lights on anyway. The possibility that DRL may reduce or actually improve motorcycle safety is also briefly discussed.

INTRODUCTION

Dedicated daytime running lights (DRL) are a set of bright, additional forward-facing vehicle lights that operate independently of the vehicle's other external lighting, and are lit only during daylight hours. As a road safety countermeasure they are intended to increase a vehicle's conspicuity. This in turn should reduce the number of crashes and/or reduce the severity of crashes by enabling drivers (and riders and pedestrians and bicyclists) to see an oncoming vehicle sooner (or at all) and begin to react earlier to attempt to avoid a crash, or begin braking sooner and thus reduce the crash's severity. In a more generic sense the acronym DRL can also include the operation of normal headlights as a reduced intensity high beam or the use of low beam headlights, or operation of parking or front turning lights.

A significant number of studies conducted in Europe, North America and Australia have examined the potential and actual effect of DRL in preventing crashes. Several recent comprehensive reviews have described and/or evaluated this past research (see Paine, 2003, Cairney & Styles, 2003, and Knight, Sexton, Bartlett, Barlow, Latham & McCrae, 2006). This paper does not intend to duplicate the review function, or replicate a discussion of the technical aspects or merits of the various means of having DRL – consult any of the reviews for such treatments.

According to three previous reviews, DRL studies all predict, or find, a positive benefit of DRL, though there are widely varying views of the size of that benefit – the number or proportion of crashes that might be prevented. The size of the effect is important for the range of cost-benefit analyses that have been proffered to justify various models of DRL adoption. Those models range from a proposed mandate that all vehicles be fitted with dedicated DRL through to encouragement of a voluntary use of low-beam headlights during daylight hours. Brighter DRL should result in the greatest number of crashes prevented. This would be best achieved with a set of dedicated additional lights with a light sensor that automatically switches them on in daylight (when the engine is running or the vehicle is moving) and off in favour of normal headlights when it becomes dark enough. Suggestions have also been made that such a sensor could automatically adjust the brightness of the DRL as a function of the brightness of daylight, particularly if modern LED models are employed. Both dedicated DRL and simply operating normal headlights will result in increased fuel consumption to more regularly charge the vehicle's battery. However, headlight use also means that tail lights are in operation, and accordingly that option is more fuel intensive. With a greater number of lights operating, there will also be a larger cost for more regular bulb replacement.

Concern has also been expressed about a fleet of mixed use – some vehicles with DRL and some without. A voluntary scheme or mandating that all new vehicles be fitted with DRL and waiting for the feature to spread through the fleet will result such a mix of use, which is a concern to the Federation of European Motorcyclists Associations (FEMA, 2006). FEMA and other motorcycling groups also worry that the safety benefit enjoyed by motorcyclists who operate their headlight during the day will be lost with mixed or 100% DRL use amongst car drivers. That argument is on-going and will not be explored here, though Paine (2009) urges a system of bright yellow DRL for motorcycles (with bright, always-on turn signals that flash to indicate a turn) and bright white DRL for other vehicles, using dedicated DRL in both cases to reduce costs of bulb replacement and additional fuel use. Paine's suggestion might satisfy both those concerned about a potential detriment to motorcycle safety from wider DRL use, and those lobbying for DRL adoption by all vehicles (and Paine would seem to be in both camps).

An accurate estimate of the number of crashes prevented by DRL is important for an accurate cost-benefit analysis calculation. The various options for adoption can then be properly costed. In their critical review, Knight et al (2006) note that depending on the choice of crash prevention factor and model for adoption, cost-benefit analyses can range from a net financial cost to a net financial gain. Most other calculations, including those reported by Paine (2003) and Cairney and Styles (2003) report only that the benefits outweigh the costs. The current paper does not seek to duplicate Knight et al's critical approach, but instead addresses another area that does not seem to have been considered by any of the previous publications or addressed by any of the three reviews – the choice of crashes to include when determining the potential benefit of DRL use in preventing crashes.

Most of the studies previously reported analyse crash rates (or odds ratios) for DRL-equipped versus non-DRL vehicles. This has been accomplished in a range of designs, including the following: a before versus after comparison following a mandated jurisdiction-wide switch to compulsory DRL use; particular fleets switched to DRL (or operated with dipped headlights during daylight hours) and were compared with before outcomes and/or that for comparable control fleets; particular vehicle types were released with DRL and their crash records were compared to those of the same model sold the year before DRL became available; specific towns or regions strongly encouraged DRL use compared with similar locations without the initiative; and variations on these broad methods, including case-control approaches. Another approach of particular relevance here is interrogating a mass-crash database, isolating the crash types that might be reduced through DRL use, and applying some factor to calculate the potential number of crashes that might have been prevented had DRL been in widespread (or complete) use.

Paine (2003) and Cairney and Styles (2003) both analysed Australian crash databases (for New South Wales and Victoria respectively), focusing on daytime multi-vehicle crashes. Both removed rear-end crashes as these can not be prevented with DRL. In such analyses pedestrian-involved crashes seem to be either all included or all excluded, despite the fact that some of them could not be affected by DRL use, such as when a pedestrian is walking in the same direction as the vehicle before the collision – the pedestrian must be able to see the vehicle's DRL for DRL to be protective. Additionally, the crashes detailed by mass-crash databases are recorded by individual police officers. They note the time of the crash and, at least in Victoria, indicate whether the crash occurred during the day or dawn/dusk or at night. There is likely to be variability in the determination of day versus dawn/dusk versus night, and thus a potential impact on the number of crashes counted as "daytime" for the purposes of DRL calculations. To investigate the potential impact of both factors, the current analyses more carefully chooses potential DRL crash types and uses the sunset and sunrise times published by Geoscience Australia to define day versus night.

METHOD

Victoria's crash statistics for the years 2005 to 2007 inclusive were used. Based on a form completed by the police officer who attends the crash, this data includes variables that indicate the time of the crash, the crash type or configuration, and the quality of light (night, day, dusk, etc). There is likely to be a lack of consistency in the definition of day versus night applied by attending officers just before and during twilight hours, but not so with the actual time. Arbitrarily using a cut-off such as 6am and 6pm or assuming that the difference between the officer's definitions will randomise out as a factor might be acceptable if vehicle use was not seasonal. To remove potential bias a more systematic method of determining daylight hours is required, particularly since DRL are only useful as a countermeasure during daylight hours – once drivers deem there is insufficient light they will turn on their headlights (and dedicated DRL are too bright when it is dark).

The Australian Government's Geoscience Australia website (http://www.ga.gov.au/) provides a function for calculating the sunrise and sunset hours for locations across Australia. In this instance the longitude and lattitude for Melbourne has been used. The sunrise and sunset times for each day of the year was applied to the crash database as a means of determining whether the crash occurred during the day (between sunrise and sunset) or the night (between sunset and sunrise). Appropriate adjustments were made to account for daylight savings time. In 2007 the range of times for sunrise varied by two hours and forty-five minutes, and by two hours and thirty-nine minutes for sunset.

In Victoria's crash database the DCA code variable describes the type or configuration of crash – the interaction between road users. From the 80 potential DCA crash types 29 were selected as crashes that could be affected by the use of daytime running lights. For example, single-vehicle crashes (e.g. run-off-road) are not likely to be mitigated with DRL, nor are struck-object or struck-animal collisons, or crashes between vehicles travelling in the same direction. Crashes involving multiple vehicles or a vehicle and a pedestrian may be reduced with DRL (NHTSA, 2000, cited in Cairney & Styles, 2003 found a substantial reduction of vehicle-pedestrian crashes with the use of DRL) if one of the crash parties sees the other crash party sooner (or at all) and begins to react earlier than they might otherwise have acted. In the case of multiple vehicle crashes DRL allows either driver to react sooner, while for vehicle-pedestrian crashes the pedestrian may be more likely to see the vehicle and not step out in front of it.

Not all types of pedestrian-vehicle crashes have been included. For example, in the case of a pedestrian walking beside the road in the same direction as the vehicle DRL is not likely to be protective for either party. Likewise, not all multi-vehicle crashes are included. For example, rear-end crashes are not likely to be reduced by DRL. Indeed it might be argued that rear-end crashes might be slightly increased if the lead vehicle has lights (and therefore tail lights) on and the following vehicle's driver is less likely to notice the onset of brake lights. Indeed some studies cited in Knight et al's (2006) review suggest that this type of crash may increase with DRL.

CRASHES POTENTIALLY AFFECTED BY DRL USE

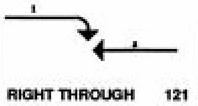
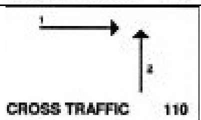
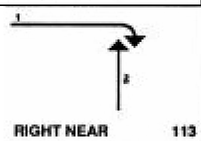
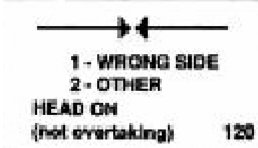
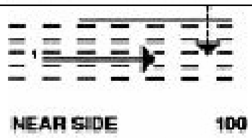
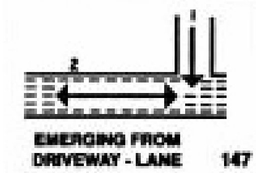
Across the period 2005-2007 inclusive there were 43,577 crashes in Victoria, or an average of 14,526 per year (38%, 31% and 31% of these crashes of the total occurred in 2005, 2006, and 2007 respectively). These crashes involved 108,760 individuals (an average of 36,253 individuals per year). Around 2% of those crashes (912 crashes, an average of 304 per year) involved a fatality, 40% (17,239 crashes or 5,746 per year) was defined as serious, and the remaining 58% (25,426 crashes or 8,475 crashes per year) resulted in an injury that was less than serious. By definition all crashes had been reported to and were documented by a police officer.

Using the sunset and sunrise times to define night versus day, 71% of all crashes in this three-year period (30,827 crashes) occurred during the day – night-time crashes were removed. Only 24 crashes did not have a crash time in the database to determine whether they occurred during the day or night, and they were discarded. Forty per cent of all crashes (17,258 crashes) had a DCA code that met the definition of potentially being mitigated with the use of DRL. A final total of 12,744 crashes (or 29% of all crashes that occurred during those three years) occurred during daylight hours and had a DRL-applicable DCA code; from this point those crashes – referred to as DRL crashes – are the focus of further analyses.

Twenty-six DCA crash configurations were included in the definition of a possible DRL crash. Of those, six DCA crash types represented more than three-quarters of all DRL-crashes (see Table 1). Three of those crash types occurred at intersections (the most common three), one type is a head-on crash in which one vehicle was travelling on the wrong side of the road but was not overtaking, one involved a pedestrian stepping into the path of a vehicle, and the last occurred when a vehicle emerges from a driveway or lane and is involved in a collision with another vehicle passing through.

Table 1 also indicates that this set of six crash types result in the greatest proportion of crashes at each level of severity, but there is a lack of consistency. To illustrate, at 34% a head-on (not overtaking) crash (DCA 120) accounts for the greatest number of fatal DRL-crashes, but is the fourth and sixth most common serious and other-injury crash respectively. This set of six crash types accounts for between 77% and 86% of crashes at each crash severity level.

Table 1. Six most common DCA crash types, average number of crashes per year, percentage of all DRL crash types and crash severity ranking.

DCA code		Avg no. crashes	Avge % all DRL crashes	Severity ranking		
				Fatal	Serious	Other
121		930	22%	3 (11%)	1 (21%)	1 (23%)
110		758	18%	2 (11%)	2 (18%)	2 (18%)
113		597	14%	4 (10%)	3 (14%)	3 (14%)
120		363	9%	1 (34%)	4 (11%)	6 (6%)
100		338	8%	5 (10%)	5 (9%)	5 (17%)
147		274	6%	12 (1%)	7 (5%)	4 (8%)
Total		3259	77%	(77%)	(78%)	(86%)

The crash data allows for five separate vehicles (and a pedestrian) to be recorded for any particular crash. A total of 47,749 vehicles were involved in DRL crashes across the three-year period; most (88% or 41,809 vehicles) were cars. Motorcycles and bicycles represented 4% each and trucks and buses 3% and 1% respectively (with 1% "other"). A variety of variables are shown in Figure 1, and indicate that most DRL crashes occurred on a straight section of road, almost three-quarters at intersections, and almost 70% happened in low speed limit areas.

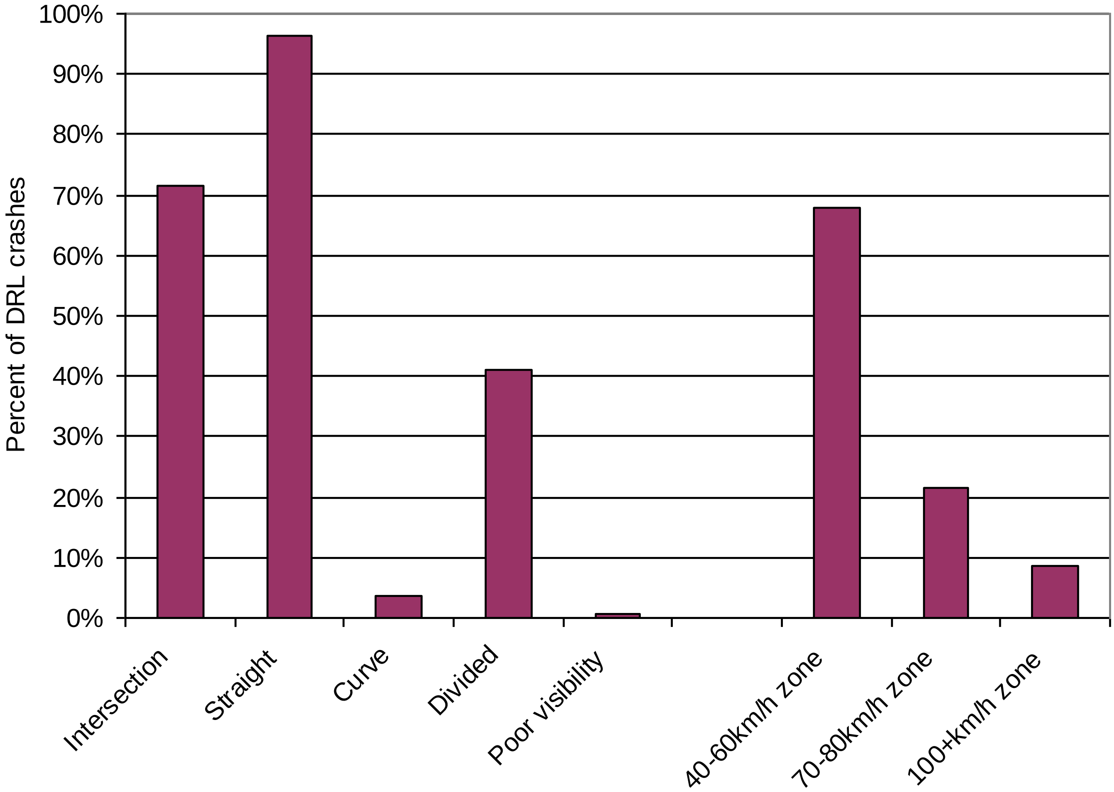


Figure 1. Percentage of DRL crashes as a function of various crash variables.

CRASHES PREVENTED WITH DRL USE

Koornstra, Bijleveld and Hagenzieker (1997) reviewed all available European DRL evaluations and developed a formula for determining the number of crashes that could be prevented with DRL use. That formula included a latitude factor and has since been used at other latitudes in Europe, in Canada and the US, and in Australia. The latitude component allows for light levels and duration of twilight. For example, Australia would have higher levels of ambient light and shortened twilight periods compared to many of the European countries within which DRL studies have been conducted (Cairney & Styles, 2003).

Coincidentally, two reports were published in Australia in 2003 that reviewed the DRL literature and calculated potential crash reductions had DRL been mandated. Both used Koornstra et al's (1997) formulae to determine a crash reduction factor. Paine's (2003) study was based on New South Wales crash data and used the latitude for Sydney to identify the Koornstra et al factors (though values quoted seem high). Cairney and Styles (2003) used Victorian crash data and Melbourne's latitude and will serve as a convenient comparison for more carefully considering the selection of crash types.

Cairney and Styles (2003) extracted conspicuity-related crashes from Victoria's crash database from a three year period. They defined such a crash as "…multiple-party excluding rear-end crashes occurring during daylight, dawn or dusk…" (p 47). It is likely that they have used all multi-vehicle crashes except rear-end, despite the fact that not all will be effected by DRL. It is also possible they have not included a subset of pedestrian-involved crashes (by definition a vehicle striking a pedestrian is a single-vehicle crash). And finally, they have relied upon the attending officer's determination for daylight, dawn and dusk, and dark.

After they identified crashes from Victoria's crash database potentially impacted by DRL use, Cairney and Styles (2003) used the DRL crash reduction factors proposed by Koornstra et al (1997) to determine how many crashes might be prevented. Those factors, for Melbourne's latitude, are a reduction of 14.87% in fatal crashes, 12.53% in serious injury crashes, and 7.46% for other injury crashes. They then used the Australian Bureau of Transport Economics costs of a crash and applied an inflation adjustment to arrive at costs in 2003 of $1,673,000 for a fatal crash, $413,000 for a serious injury crash, and $14,000 for an other injury crash. In order to make comparisons between the outcomes of Cairney and Styles and the current calculations easier, those costs per crash have not been inflation-adjusted for the five years since their analysis. For the same reason – the opportunity to make direct comparison – the crash reduction factors they used are also re-employed.

Cairney and Styles (2003) determined that an annual average of 17 fatal, 187 serious and 243 other injury crashes would have been prevented in Victoria with DRL across the three-year period June 1999 to June 2002. Their method was replicated here for the three calendar years 2005-2007 to arrive at a saving of 12 fatal, 219 serious and 203 other injury crashes – see Table 2. Marked as "current approach", Table 2 also contains the results for more carefully choosing the crashes that could be impacted by DRL and applying Geoscience Australia times for sunrise and sunset.

Table 2. Number of DRL-relevant crashes and crashes prevented with DRL using Cairney & Styles' method and the current approach for calculating DRL crashes; and resultant difference in terms of number of prevented crashes, cost and percentage.

Severity	Cairney & Styles		Current approach		Difference		
	DRL crashes	Crashes prevented	DRL crashes	Crashes prevented	No. prevented	$	%
Fatal	81	12.0	78	11.5	0.5	$829,000	4.1%
Serious	1745	218.6	1676	210.0	8.6	$3,553,000	3.9%
Other	2717	202.7	2494	186.1	16.6	$233,000	8.2%
Total	4543	433.4	4248	407.6	25.7	$4,616,000	5.9%

As demonstrated in Table 2, the current approach for determining DRL crashes results in fewer prevented crashes at each level of severity compared with Cairney and Styles' (2003) method. In absolute and relative terms the differences are seemingly small, but when expressed in monetary terms those differences become more obviously substantial. For example, for fatal crashes the difference is an average of half a crash per year fewer using the current method, but that equates to 4.5% fewer crashes, representing just under a million dollars. The largest monetary difference (but smallest percentage difference) was for serious crashes, at $3.5 million less using the current approach. In total Cairney and Style's method results in an estimate of 6% more crashes in the period 2005-2007, worth more than 4.5 million dollars (in 2003 dollar terms).

A range of other estimates of crash reduction factors have been suggested. Two particular suggestions will be considered here because they are the outcomes of two different, recent DRL reviews. Paine (2003) recognised that the Koornstra et al (1997) reduction factors may be high and proposed a lower bound of 7% reduction in all multi-vehicle daytime crashes (adopted from a NHTSA project), though more recently Paine (2009) suggested that dedicated bright LED DRLs could reduce fatalities on Australian roads by 10%. A more considered critical review of DRL research presented in Knight et al (2006) weighted the previous research based on its rigour. They also concluded that Koornstra et al's factors were too high and instead proposed a 5.9% reduction across all severities. Applying that multiplier to the current data results in an average prevention of 212 crashes (5.9% of 4,248 DRL-relevant crashes), which is 52% of the 408 crashes calculated using the Koornstra et al factors (see Table 2). Figure 2 shows the four estimates of the total number of crashes prevented within the period 2005-2007 period. Note that both Paine's 7% and Knight et al's 5.9% reductions are based on the number of DRL-relevant crashes calculated using the current approach – a consideration of each crash type and the Bureau of Meteorology determination of sunset and sunrise.

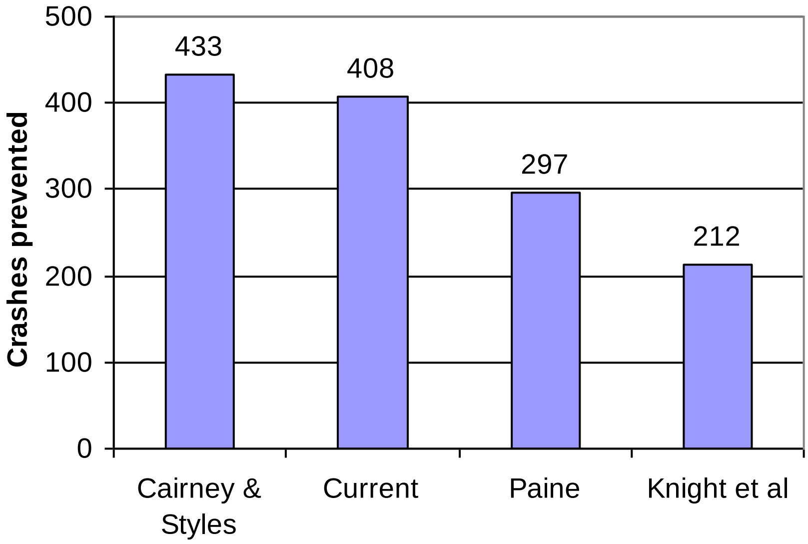


Figure 2. A comparison of the total number of crashes prevented with mandated DRL use by applying three different crash prevention factors.

In the current approach the sunset and sunrise times were used to define day and night. It is likely that many drivers have their headlights on for a period after sunrise and before sunset. If this is a widespread practice the crashes within those times should not contribute to the calculation of crashes saved. Observational data is required, but to illustrate the impact of this consideration, hours of darkness (i.e. non-daylight and therefore non-DRL hours) were increased by 30 minutes in the morning and 30 minutes in the evening. The outcome for each crash severity compared with Cairney and Styles' (2003) calculations are shown in Table 3. In total more than $11.5 million would be wiped from Cairney and Styles' calculated benefit before offsetting against costs. When determining the attractiveness of DRL use. Using Knight et al's (2006) 5.9% crash reduction factor as a lower limit, 200 crashes per year would be prevented, which is 46% of the number predicted by Cairney and Styles.

Table 3. Number of crashes prevented with DRL using Koornstra et al (1997) prevention factors: Cairney & Styles (2003) versus the current method with extra hour added to hours of darkness, and resultant difference in terms of number crashes, % of crashes & monetary value.

Severity	Crashes prevented		Difference		
	Cairney & Styles	Current	No.	$	%
Fatal	12.0	11.0	1.0	$1,741,426	8.6%
Serious	218.6	195.8	22.8	$9,418,300	10.4%
Other	202.7	175.9	26.8	$374,591	13.2%
Total	433.4	382.8	50.6	$11,534,317	11.7%

DISCUSSION

Based on an analysis of two different crash databases, both Paine (2003) and Cairney and Styles (2003) advocated adoption of daytime running lights in Australia, the former based on the number of crashes prevented, and the latter on a cost-benefit analysis taking into account crashes prevented, and costs associated such as the additional fuel consumed to operate the extra lights. However, the benefits proffered by both may be over-estimates. By taking a more considered definition of crash types and accounting for actual times of sunset and sunrise (rather than relying on the police crash report), the number of crashes potentially averted with DRL is less, as shown in the current analysis, particularly if drivers have their lights on after sunrise and before sunset.

Further, both Paine’s (2003) and Cairney and Styles’ (2003) estimates will be further inflated in light of Knight et al’s (2006) re-analysis and determination that the formulae developed by Koornstra et al (1997) led to crash prevention factors higher than justified. It is beyond the scope of this paper to present a new cost-benefit ratio, but perhaps one is needed, with consideration of Paine’s (2009) suggestion that motorcycle and car DRL configuration and colour be different.

The analyses conducted by Knight et al (2006), Cairney and styles (2003), Paine (2003), and the one presented here, all assume no deleterious effect of DRL use for motorcycle riders. Indeed some authors have pointed out that cars fitted with DRL will be seen better and sooner by riders than non-equipped cars and so widespread use should in fact make riding safer. Further, some studies have been conducted that examined whether motorcycles would be “lost” or misinterpreted when surrounded by cars with DRL and they concluded no negative effect. However, after also reviewing that research, Knight et al raised concerns about the methods used in that research and called for further investigation of the effect of high intensity DRL on motorcycle conspicuity. A significant study for NHTSA is currently underway (Jenness, personal communication) to address these and related issues. Knight et al were of the opinion that a suitable solution could be found, and such a solution may be Paine’s (2009) suggestion that motorcycles use always-on bright yellow LED front turn indicators while other vehicles are fitted with bright white dedicated LED DRL.

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