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16. Abstract

This study provides information about average annual use of the following automotive lighting equipment by U.S. drivers: low- and high-beam headlamps, turn signals, back-up, license plate, parking, sidemarker, stop, and tail lamps. The data were collected as part of a naturalistic field study of crash warning systems. Eighty-seven randomly selected drivers from southeastern Michigan were provided with instrumented research vehicles (11 identical 2003 Nissan Altimas) for periods averaging 26 days and instructed to drive the research vehicle in place of their personal vehicle.

The results are presented for each lamp type in terms of the average annual hours of use and minutes used per 100 km driven. These findings are discussed in relation to the rated life of various bulbs and the median life of vehicles in the U.S.

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INTRODUCTION

In use since the early 1900s, automotive lighting equipment provides illumination of road signs, obstacles, other vehicles, and pedestrians (For a comprehensive history of headlighting, see Moore (1998)). Additionally, signaling and marking lights display information about the vehicle's presence, position, size, direction of travel, and the driver's intentions and actions regarding direction and speed of travel.

While naturalistic use of high-beam headlamps has been studied (Mefford, Flannagan, and Bogard, 2006), real-world use of other types of automotive lighting has not been examined comprehensively. The present study investigated real-world use of automotive lighting equipment using secondary analysis of data from a field operational test of crash warning systems. Drivers were instructed to use instrumented experimental vehicles in place of their personal vehicles for extended time periods. The data collected provide information about naturalistic use of headlamps, turn signals, back up, license plate, parking, sidemarker, stop, and tail lamps.

METHOD

Data analyzed in this study were originally collected in a field operational test (FOT) that evaluated crash-warning systems. This FOT featured 11 instrumented vehicles and 87 participants.

Participants

With the assistance of the Michigan Secretary of State office, 6,000 licensed drivers were selected at random for possible participation in the FOT. The random sample contained only drivers who belonged to one of the following age groups: 20-30, 40-50, or 60-70 years old. From this random pool of 6,000 drivers, smaller random samples were selected to receive informational postcards. A toll-free number was provided for interested persons to learn more about the study and determine if they qualified. A minimum annual mileage threshold was required. This minimum value was determined using mean values from the 2001 National Personal Transportation Survey (NPTS). The NPTS reports average annual mileage by driver gender and age group. Additionally, drivers were excluded from participating in the study if they reported a significant violation (e.g., driving under the influence of alcohol, driving with a suspended license), or if they had had a crash that resulted in death or serious injury within the previous three years. The resulting sample of participants consisted of age groups of the following sizes: 20-30, n = 32 (14 females and 18 males); 40-50, n = 28 (13 females and 15 males); and 60-70, n = 27 (13 females and 14 males).

Instrumented Vehicles

Eleven identical 2003 Nissan Altimas with standard headlamps were used in this FOT. The high-beam headlamps were activated via a stalk-mounted control. Each instrumented vehicle was equipped with two crash warning systems (a lane departure warning system and a curve speed warning system), a face-camera, a forward-looking camera, and a data acquisition system that collected and stored over 500 data channels. Headlamp state (off, low, or high), brake pedal position, turn signal use, and gear shift position were several of the collected channels (see LeBlanc, et al., 2006 for a complete description of the research vehicles).

One consideration that must be made, particularly as is might affect data regarding the use of back up lamps, is that the data acquisition system on the research vehicles took approximately 60 s to complete its initiation once the ignition of the vehicle was turned to the on position (an event most often associated with starting the car). Although the "lost" data only accounted for approximately 2% of the overall time the vehicles were operated, given the short durations of backing events—and their likelihood of occurring relatively soon after an ignition cycle—the values provided for back up lamp usage are likely to be underestimated. Therefore, it is likely that substantially more backing events occurred than were recorded, and thus the back up lamps were illuminated for significantly longer periods. However, that these events were relatively short in duration (less than 60 s).

The research vehicles had as original equipment a setting for the vehicle lighting that would automatically turn the following lights on at low levels of ambient illumination: headlamps, license plate, parking, side-marker, and tail lamps. The data cannot be used to differentiate when the lamps were turned on via the automatic setting versus manually turned on by the driver. However, the duration and distance of travel accrued by the drivers as a function of day and night were recorded and are reported here. Day and night were defined by sun position (above or below 6° below the horizon), which can serve as a surrogate for actual ambient illumination.

Procedure

After a two-hour training session, participants were allowed to drive the research vehicle as their personal vehicle on average for 26 days. Of the 87 drivers who participated, 75 drivers had a vehicle for 26 days, while the remaining drivers had a vehicle from 13 to 27 days.

Because of the limits of the map database that was employed by the curve speed warning system, drivers were asked to restrict their travel to Michigan, northwestern Ohio, northern Indiana, and parts of Illinois and Wisconsin. Participants were otherwise free to drive wherever and whenever they wanted. GPS and other data were collected continuously.

At the completion of each driver's participation, all of the data were downloaded from a hard drive on the research vehicle and transferred to servers. The data collected in the FOT were stored in Microsoft SQL Server databases. Queries were run to aggregate the data by lighting equipment type, driver age, and driver gender. Use was documented for low- and high-beam headlamps and back up, license plate, parking, sidemarker, stop, and tail lamps as well as turn signals. Based on each driver's period of participation (27 days or fewer), the data were extrapolated for annual use in terms of hours of lamp activation. Additionally, use is reported in terms of minutes per 100 km driven to investigate the effect of driver age on lamp use.

RESULTS

Hours and distance of total driving exposure

Table 1 presents the average annual distance driven by day versus night. Day and night are determined by solar zenith angle. Solar zenith angles greater than or equal to 96° (6° below the horizon) were considered night. Daytime and nighttime distances accrued for each month of the FOT are displayed in Figure 1.

Table 1
Average annual daytime and nighttime distance driven.

Time of Day	Average Annual Distance (km)
Day	19,673
Night	5,981

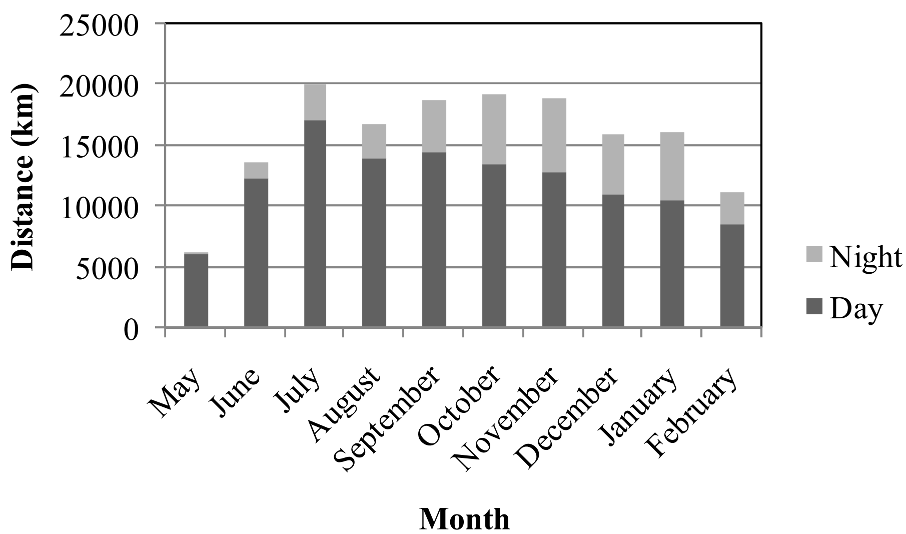

Figure 1. Monthly daytime and nighttime distances accrued by all drivers.

Figure 2 illustrates the distribution of backing maneuvers for which the data acquisition system was fully operational before the backing maneuver was initiated. Note that the duration of backing maneuvers is relatively short, with an average of 19.2 s (SD = 22.9 s). Virtually no backing maneuvers (less than 1%) were observed in which the duration exceeded 120 s.

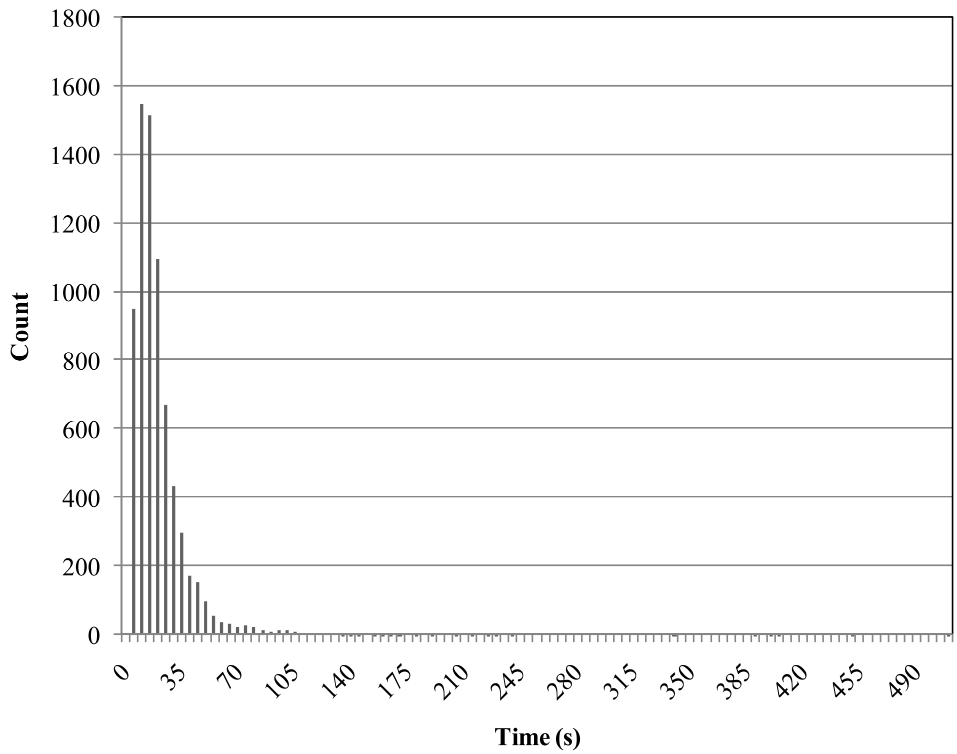

Figure 2. Distribution of backing maneuvers in which the data acquisition system was fully operational before the backing maneuver was initiated.

Hours of lamp use

Table 2 presents annual average use for each type of lighting equipment. Table 3 and 4 present the same data stratified by age group and gender, respectively.

Table 2
Average annual use of lighting equipment.

Function	Average Annual Use (hrs)
Back up	3.8
High-beam headlamp	9.8
Low-beam headlamp	97.3
License plate	107.1
Parking	107.1
Sidemarker	107.1
Stop	80.7
Tail	107.1
Turn signal, left	24.9
Turn signal, right	19.5

Table 3
Average annual use of lighting equipment by driver age group.

	Average Annual Use (hrs)		
Function	Young	Middle-Aged	Old
Back up	4.9	2.9	3.4
High-beam headlamp	7.3	12.5	10.8
Low-beam headlamp	159.3	71.3	47.0
License plate	166.6	83.8	57.8
Parking	166.6	83.8	57.8
Sidemarker	166.6	83.8	57.8
Stop	88.3	77.5	75.0
Tail	166.6	83.8	57.8
Turn signal, left	29.9	22.5	21.5
Turn signal, right	23.4	18.6	15.7

Table 4
Average annual use of lighting equipment by driver gender.

Function	Average Annual Use (hrs)	
	Female	Male
Back up	4.2	3.4
High-beam headlamp	11.8	8.5
Low-beam headlamp	79.0	112.8
License plate	90.8	121.3
Parking	90.8	121.3
Sidemarker	90.8	121.3
Stop	82.2	79.0
Tail	90.8	121.3
Turn signal, left	24.2	25.5
Turn signal, right	19.1	19.8

Based upon a recent study, the median age of cars on U.S. roads in 2007 was 9.2 years (Motor Authority, 2008). Table 5 displays the rated life for automotive lighting bulbs found in a 2003 Nissan Altima (GE Lighting, 2008), the research vehicle employed in this study. Table 5 also lists the cumulative hours of use over the median life of a vehicle with these bulb types.

Table 5
Rated life for automotive lighting bulbs for a 2003 Nissan Altima, the research vehicle employed in this study.

Function	Bulb	Rated Life (hrs)	Average Use Over Median Life of a Vehicle* (hrs)
Back up	921	1,000	35
High-beam headlamp	9005	800	90
Low-beam headlamp	H1-55W	225	895
License plate	168	1,500	985
Parking	1157**	5,000	985
Sidemarker	168	1,500	985
Stop	3157LL**	2,000	742
Tail	3157LL**	10,000	985
Turn signal, front right	1157**	1,200	179
Turn signal, front left	1157**	1,200	229
Turn signal, rear right	3156LL	2,000	179
Turn signal, rear left	3156LL	2,000	229

* Use over 9.2 years
** Dual filament bulb. The rated life reported corresponds to the listed function.

Minutes per 100 km

Tables 6 through 8 provide use rates in terms of minutes per 100 km of total distance driven (i.e., not distinguishing day and night).

Table 6
Use in terms of minutes/100 km.

Function	Use (min/100 km)
Back up	0.9
High-beam headlamp	9.8
Low-beam headlamp	97.6
License plate	107.4
Parking	107.4
Sidemarker	107.4
Stop	18.9
Tail	107.4
Turn signal, left	5.8
Turn signal, right	4.6

Table 7
Use by driver age groups in terms of minutes/100 km.

	Use (min/100 km)		
Function	Young	Middle-Aged	Old
Back up	1.0	0.6	1.0
High-beam headlamp	4.6	14.8	24.2
Low-beam headlamp	100.0	84.2	105.3
License plate	104.6	99.0	129.5
Parking	104.6	99.0	129.5
Sidemarker	104.6	99.0	129.5
Stop	18.5	16.7	22.7
Tail	104.6	99.0	129.5
Turn signal, left	6.3	4.8	6.5
Turn signal, right	4.9	4.0	4.7

Table 8
Use by driver gender in terms of minutes/100 km.

Function	Use (min/100 km)	
	Female	Male
Back up	1.1	0.7
High-beam headlamp	14.5	7.4
Low-beam headlamp	97.3	97.7
License plate	111.8	105.1
Parking	111.8	105.1
Sidemarker	111.8	105.1
Stop	20.9	17.3
Tail	111.8	105.1
Turn signal, left	6.2	5.6
Turn signal, right	4.9	4.3

Concurrent use

Table 9 provides data about the concurrent use of turn signals and stop lamps. The data are presented as the percentage of time that either turn signal (left or right) is used during braking events.

Table 9
Percentage of time during braking that a turn signal is used.

Drivers	Concurrent Use (%)
All	24
Young	26
Middle-aged	23
Old	24
Female	25
Male	23

DISCUSSION

Although these data describe naturalistic use of automotive lighting equipment under reasonably general conditions, the generality of the results is limited in a number of ways. The reported average annual distance driven is higher than national averages. This may be the result of people driving more frequently and taking longer trips during their participation in the FOT. Because the data are stratified by age group and gender, the data presented here can be (and, indeed, should be) weighted based on a population of interest. Hours of night vary with east/west location within a time zone, resulting in higher usage rates in areas with greater amounts of darkness during the heaviest driving times, later in the day. The vast majority of the driving completed in the FOT was in southeastern Michigan, which is in the western part of the Eastern Time Zone. One could therefore predict higher lamp usage rates on the east coast of the U.S., for example, compared to Michigan. Finally, the FOT was conducted May 2004 through February 2005. During May, the FOT vehicles were phased in, that is, not all of vehicles were placed into the field at once. No data were collected in March or April, resulting in a bias of data collection toward months with greater darkness (Figure 1).

License plate, parking, sidemarker, and tail lamps are the most frequently used automotive lighting equipment, averaging just over 100 hours per year. The least used lamps are back up lamps, which are employed less than five hours per year. Although, as noted in the Method section, this value is probably underestimated. In order to determine the maximum possible back up lamp usage, despite the known absence of data during the first 60 s after the vehicle ignitions were turned on, a worst case scenario was constructed. The average annual number of trips per driver for these data is 2012 trips. Assuming that the first 60 s of every trip were spent backing up, an average driver would spend 33.5 hours per year using back up lamps. This translates to 309 hours over 9.2 years, which is still well below the estimated life of typical bulbs for this application.

Trends in lamp use across age groups are what would be expected; specifically, that average annual use (in terms of hours) decreased with increasing driver age. The exception to this trend is the use of high-beam headlamps. While rates of use for stop, turn signal, and back up lamps were similar for females and males, male drivers accrued

34% more hours of nighttime driving than female drivers, while using their high beams about half as often.

The data in Table 3 only provide a partial picture of the use of lamps at night. While it is true that older drivers use their high beams more frequently than younger drivers in terms of hours of use, the data in Table 7 demonstrate just how great the effect is when distance driven at night is factored in. Because older drivers drive far less distance at night, and at lower speeds, but use high-beam headlamps with greater frequency than their younger counterparts, their high-beam use is more than five times that of younger drivers. The effects of less nighttime distance and slower speeds for older drivers can also be seen in their higher use rates (in terms of minutes per 100 km) for the other lamps that are illuminated at night (low-beam headlamps, license plate, parking, sidemarker, and tail lamps).

Approximately 24% of the time that the brakes were engaged, a turn signal was also operating. This did not vary across age groups or by gender. Presumably, the concurrent use of a turn signal reduces the hours of use for certain stop lamps (i.e., those that are flashed off and on to supply the rear turn function). Assuming a 50% duty cycle for flashing the turn signals, and assuming, for simplicity, that the left and right turn signals were used equally often, that would reduce the estimated activation time for an individual stop lamp by about 6%. Of course, the number of activations and deactivations for those lamps would be increased by the flashing.

SUMMARY

This study obtained information about average annual use in the U.S. of the following automotive lighting equipment: low- and high-beam headlamps, turn signals, and back up, license plate, stop, parking, sidemarker, and tail lamps. The data were collected as part of a naturalistic field study of crash warning systems. Eighty-seven randomly selected drivers from southeastern Michigan were provided with instrumented research vehicles (11 identical 2003 Nissan Altimas) for periods averaging 26 days each and instructed to drive the vehicles as their personal vehicles.

The results are presented for each lamp type in terms of the average annual hours of use and minutes used per km driven. These findings are discussed in relation to the rated life of various bulbs and the average life of vehicles in the U.S.

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