Fast-Rise Brake Lamp as a Collision-Prevention Device

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16. Abstract

Conventional tungsten-filament brake lamps have a relatively slow rise time. It takes approximately 250 msec for them to reach 90% of the asymptotic luminous intensity. This slowness of response can cause important delays of warning information to following drivers. We have designed a simple and relatively inexpensive circuit that produces a faster warning signal using a conventional lamp. As we have reported previously, this device reduces reaction times to the onset of brake lamps by about 115 msec. The present study evaluated the benefits of a 115 msec reduction in driver brake reaction time. Two approaches were used. In the first approach we calculated the reductions in effective stopping distance assuming a range of initial speeds. The results indicate, for example, that if the initial speed is 100 km/h, the reduction in the effective stopping distance is 3.2 m. In the second approach we calculated the reductions in the proportions of very long reaction times, assuming a normal distribution of reaction times that is shifted by 115 msec. For the distribution without the device we assumed a mean of 1.25 sec and a standard deviation of 0.46 sec. The results indicate, for example, that decreasing the mean by 115 msec yields a 55% reduction in the frequency of reaction times that are longer than 2.5 sec.

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INTRODUCTION

Brake lamps serve as warnings for what is perhaps the most frequently encountered roadway hazard: a decelerating vehicle ahead. The time that a driver has to recognize and react to those warnings is often limited. In spite of the importance and urgency of brake signals, the equipment used to provide them can be described as relatively sluggish. The line marked *standard* in Figure 1 shows the amount of visible light emitted by a typical tungsten-filament brake lamp as a function of time after standard voltage is applied to it. No measurable light is emitted for about 50 msec, and about 250 msec is required for the filament to reach 90% of its steady state output. This slow rise time of conventional brake lamp can cause potentially important delays of warning information to following drivers.

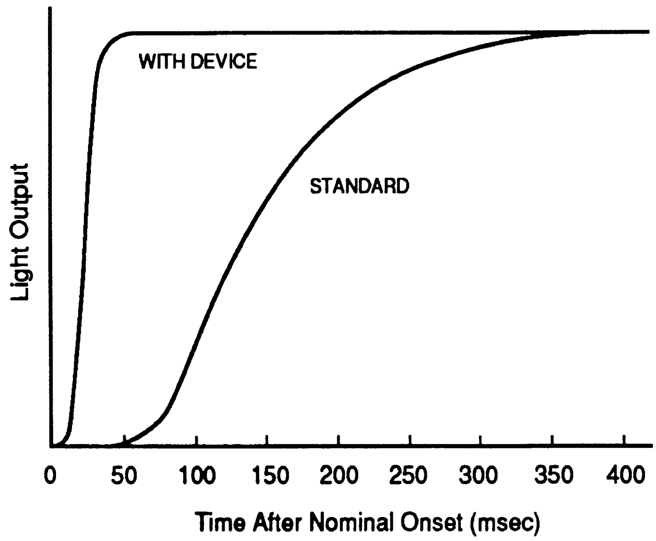

Figure 1. Rise times of light from tungsten-filament brake lamps under two conditions (adapted from Flannagan and Sivak, 1989).

One possible approach to improving this situation is the use of LED displays that have virtually instantaneous rise time. LEDs, however, are much more expensive than conventional tungsten-filament bulbs and require extensive redesign of lamp housings. An alternative approach (Flannagan and Sivak, 1988) utilizes conventional tungsten-filament bulbs, coupled with continuous preheating of the filament at approximately 2 V (below visible) and a brief overvoltage at the time of the application of the brakes. The effect of this device on the rise time of a standard brake filament is shown by the line marked *with device* in Figure 1. The rise time is much shorter than for standard operation. Light output reaches 90% of its steady state in about 50 msec rather than 250 msec.

Because the two rise-time curves in Figure 1 are not parallel, it is not clear, a priori, what is the expected saving in reaction times to brake signals equipped with this device. Consequently, we have evaluated the benefits of this device in a laboratory study that measured subjects' reaction times to the onset of brake lamps in a simulated car-following situation (Flannagan and Sivak, 1989). The results of this study indicate that reaction time to brake signals is, under conditions similar to actual driving, 115 msec shorter when the device is switched in. The present paper evaluates the implications of a 115 msec reduction in driver reaction time.

METHOD

To evaluate the potential safety implications of a fast-rise brake lamp, we performed two analyses. In the first analysis we calculated the distance traversed during 115 msec given a range of initial speeds from 40 to 160 km/h. These distances can be regarded as estimates of reductions in effective stopping distance. In the second analysis we estimated the reductions in the proportions of long reaction times when the mean reaction time is reduced by 115 msec. The underlying assumption for this analysis was that rear-end collisions are primarily the result of relatively long reaction times. From this point of view, a reduction in the proportion of very long reaction times is a reasonable measure of the utility of a collision-prevention device. The calculations were performed for a range of long reaction times (from 1.25 sec to 2.5 sec) assuming a normal distribution of reaction times.

RESULTS

Reductions in the effective stopping distance

Table 1 lists the reductions in the effective stopping distance assuming initiation of a braking response 115 msec sooner. These reductions were derived by calculating the distances traversed during 115 msec, given a range of initial speeds from 40 to 160 km/h. For example, at an initial speed of 100 km/h, a reduction of 115 msec in brake reaction time would yield a saving of 3.2 m in the effective stopping distance from the onset of the brake lamp.

Table 1. Reductions in stopping distances due to application of brakes 115 msec sooner.

Initial speed (km/h)	Reduction in stopping distance (m)
40	1.3
60	1.9
80	2.6
100	3.2
120	3.8
140	4.5
160	5.1

Reductions in the proportions of long reaction times

A somewhat more complex way to evaluate the obtained reaction-time savings is to estimate the reduction in the frequency of critically long reaction times. Let us assume that driver reaction times are normally distributed. The existing field data from unalerted drivers (reviewed by Sivak, 1987) indicate that a reasonable mean reaction time for in-traffic responses to brake signals from standard brake lamps is 1.25 sec, with a standard deviation of about 0.46 seconds. Consequently, the likely distribution of in-traffic reaction times to brake lamps that are energized 115 msec sooner would have a mean of 1.135 sec, with an unchanged standard deviation—0.46 sec. Assuming a normal distribution of driver reaction times, we calculated the percentage of reaction times that would be longer than certain critical values under either of the two distributions (i.e., with the mean of 1.25 sec and 1.135 sec, respectively). These calculations require the derivation of the z-scores of the critical values under the corresponding normal distributions, and calculation of the proportions of a normal distribution exceeding those z-scores. Finally, percentage reductions in the frequency of reaction times that are longer than the critical values were calculated. Table 2 presents the results for a selected set of critical reaction times, ranging from 1.25 sec to 2.5 sec.

Table 2. Reductions in the frequency of reaction times greater than selected critical values.

Critical reaction time (sec)	*z*-score of the critical reaction time A		% of reaction times greater than the critical value A		% reduction in the frequency of reaction times greater than the critical value A, computed as $100\,(D - E)/D$
	If the mean is 1.25 sec	If the mean is 1.135 sec	If the mean is 1.25 sec	If the mean is 1.135 sec	
A	B	C	D	E	F
1.25	0.00	0.25	50.00	40.13	20
1.50	0.54	0.79	29.46	21.48	27
1.75	1.09	1.34	13.79	9.01	35
2.00	1.63	1.88	5.16	3.01	42
2.25	2.17	2.42	1.50	0.78	48
2.50	2.72	2.97	0.33	0.15	55

The information in Table 2 indicates that a reduction of 115 msec in mean driver reaction time can lead to substantial reductions in the percentage of long reaction times. Furthermore, there is an increase in the percentage reduction in the frequency of long reaction times as the critical value is increased. For example, by reducing the mean reaction time by 115 msec, the frequency of reaction times that are longer than 1.25 sec is reduced by 20%, while the corresponding reduction of reaction times that are longer than 2.5 sec is 55%.

DISCUSSION

This paper presented two approaches—one standard and one novel—for evaluating the collision-prevention benefits of a 115-msec reduction in driver reaction time to the onset of brake signals. In the first, standard approach we calculated the reductions in the effective stopping distance assuming a range of initial speeds. This is a simple, straightforward analysis that does not require any assumptions about the underlying distribution of driver reaction times.

In the second, novel approach we calculated the reductions in the proportions of very long reaction times. In this approach, the normality assumption of driver reaction times is crucial. Specifically, it is an important question whether the upper tail of the actual distribution of driver reaction times conforms to the normal distribution. Unfortunately, while the tails of distributions are most important for prediction of rare events such as traffic accidents, they are also most difficult to pin down empirically. Furthermore, this approach assumes that the entire distribution is rigidly shifted by 115 msec. Despite these critical assumptions, the form of this analysis illustrates a potentially important way in which to evaluate the significance of changes in mean value.

The present calculations of reductions in the proportions of long reaction times assume that the process resulting in long reaction times is qualitatively the same as the process resulting in short reaction times. An alternative possibility is that long reaction times are consequences of qualitatively different processes (e.g., temporary distractions). In such a case a fast-rise stimulus may still be beneficial because of greater attention-getting properties. In support of that possibility, our evaluation of the effect of fast-rise stimuli indicated that reaction-time savings increased as potentially distracting demands on the subject increased (Flannagan and Sivak, 1989).

The ultimate question—What is the likely reduction in the frequency of rear-end collisions as a consequence of using a fast-rise brake lamp?—is difficult to answer without making critical assumptions about distributions of relative closing speeds in collisions and deceleration rates. Enke (1979) provides a nomogram (Enke's Figure 9) that relates reductions in driver reaction times to estimated reductions in the frequency of rear-end collisions. Enke's calculations were based on distributions of relative closing speeds in rear-end collisions that were collected in Germany by Danner and Krais (1976), and on the assumption of the deceleration rate being 5 m/sec^2. Using Enke's Figure 9, the initiation of the deceleration 115 msec sooner would lead to a reduction of about 15% in the frequency of rear-end collisions (comparable to the actual reductions due to the use of high-mounted brake lamps [Kahane, 1989]), and in a reduction of the severity of the remaining collisions.

In conclusion, the present analyses provide estimates of reductions in both the effective stopping distance and proportions of long driver reaction times, as a consequence of a 115 msec reduction in the mean reaction time to fast-rise brake lamps. While these two sets of estimates cannot easily be used to predict likely reductions in rear-end collisions, they provide some insights concerning the effects of such a reduction in the mean reaction time on likely components in the process leading to collisions.

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