Evaluation of an Accelerator Position Signal

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The vehicle rear lighting and signaling system plays a valuable role in promoting safe car following and in reducing the frequency of rear-end collisions. However, although the information currently presented on the rear of vehicles is valuable, it probably does not constitute the most useful information possible. In this respect, a number of studies have been conducted to evaluate additional forms of signals, such as coasting signals, to aid following drivers (1, 2).

One series of studies (3) found that an accelerator position signal (APS) system allowed drivers to detect coasting of a lead vehicle (which would be shown by the lighting of a yellow lamp) sooner than when such a signal was not given. Whenever the yellow signal appeared on the lead vehicle, it was coasting at the normal coasting deceleration for that vehicle, which means that the coasting signal never gave erroneous information.

The potential false alarms that can be given by a coasting signal were investigated by Mortimer (4). In that study, a motor-pool vehicle was driven for 3946 km (2452 miles) by various drivers and surreptitiously instrumented to measure the duration of coasting, the initial and final speed of each coasting maneuver, and whether the accelerator or brake was the control next used by the driver. The primary findings were that about 80 percent of the coasting durations were 2 s or less, about half were followed by braking, and fewer than 7 percent were less than 0.5 s and followed by braking. These data indicated that coasting durations are generally short and therefore involve a minor reduction in vehicle speed [in 90 percent of coasting events the vehicle slowed less than 6.4 km/h (4 mph)]. In addition, one cannot use the coasting signal to reliably infer that braking of the lead vehicle, especially moderate or severe braking, will follow. It was concluded that a coasting signal should not be given each time the accelerator is released except when the coasting duration exceeds about 5 s, a period during which a significant reduction in vehicle velocity could be expected to occur and that was usually followed by braking.

A further study of APS was recently completed. The rear lighting systems evaluated were the conventional system, consisting of one red lamp on each side of the vehicle that carried out presence (tail), stop, and turn functions, and the conventional system supplemented by an APS, represented by a vertical array of three centrally mounted lamps that indicated from top to bottom braking (red), coasting (yellow), and accelerator depressed (green blue).

These lighting systems were compared in tests consisting of (a) a driving simulator test in which drivers followed a lead vehicle that exhibited "normal" velocities and accelerations; (b) a driving simulator test in which the lead vehicle was revealed to the following car driver while exhibiting some unusual maneuvers, such as high decelerations or high closing velocities, as well as during normal accelerations, decelerations, and coasting or while maintaining a fixed speed; and (c) a road test in which the car-following behavior of naive drivers was surreptitiously recorded as they followed a test car on a two-lane road. A fourth evaluation was made in a structured road test in which subjects followed an APS-equipped car to determine whether they could intuitively comprehend the intended meaning of the APS's, to obtain their evaluations of its perceived effectiveness in a number of driving schedules that varied in the consistency of braking following coasting, and to obtain measurements of their relative frequency of accelerator releases and brake applications with respect to those of an experimenter driving the APS-equipped car.

In the interests of brevity, only the major findings of these studies will be presented here. The reader is referred to Mortimer and Sturgis (5) for a detailed account of the design, methodology, and analysis.

FINDINGS AND DISCUSSION OF RESULTS

Driving Simulator Studies

The results of the initial driving simulator study indicated no differences in drivers' ability to detect and identify stop and turn signals between the conventional system and

Publication of this paper sponsored by Committee on Motorist Information Systems.

that system augmented by the APS. It might have been expected that, if the yellow signal had the ability to alert drivers to impending braking, response times to stop signals would have been reduced. However, this was not found and confirms the contention of Nickerson and others (1) that such a meaning cannot be reliably inferred unless braking follows coasting on most occasions. APS might also have been expected to produce improved car-following performance, but none of the recorded measures (headway standard deviation, relative velocity standard deviation) indicated that this occurred.

The second simulator study, which was conducted to evaluate the rear lighting systems in situations that had a high predisposition for a rear-end crash to occur, showed one statistically significant difference between systems, but in a condition in which lead car speed remained constant and the green lamp of the APS was lighted throughout. Since this condition represented a positive initial relative velocity, there is no implication of a safety benefit for the APS.

Road Tests

The unobtrusive measurements of naive drivers who approached the test car from the rear and subsequently followed it on a two-lane road indicated some differences in their responses depending on whether the test car was coasting or braking. The following vehicle braked more frequently when the lead vehicle was braking than when the lead vehicle was coasting, which showed that the procedure has some degree of sensitivity in terms of measurable responses of following car drivers. On the first exposure of the following vehicle to a coasting lead vehicle displaying the APS, there was noticeable coasting of the following vehicle as measured by the significantly greater headways maintained with the lead car compared to when the lead car was displaying the conventional lighting system. However, this response to a change from the green to the yellow lamp of the APS was not noted on a second exposure to coasting of the lead car.

Although there was an indication that the standard deviations of headway and relative velocity were less when these drivers were following the test car equipped with the APS than when they were following the car with the conventional system, none of the differences proved to be statistically significant. This confirms the findings of the driving simulator tests that found no differences in a number of car-following measures and agreed with earlier studies (3) that also reported no benefits attributable to an APS in car following. In this test there were no differences between systems in the response of following drivers to braking lead vehicles, which would be expected because the braking signal is given by both systems.

In the structured driving study, 75 percent of the drivers were able to correctly infer the meaning of the APS signals. The drivers considered the signals of the APS to be useful, as shown by questionnaire responses. However, of major interest was a comparison of the effectiveness ratings made after conditions that differed both in the relative frequency with which braking followed release of the accelerator and in the duration of coasting events. These differences should have been reflected in the ratings of the consistency of the yellow signal in providing coasting and impending braking information. However, the mean ratings assigned to questions given at the end of these conditions did not differ, indicating that subjects did not perceive the fairly large differences in the coasting durations and relative frequencies of braking that were used. This suggests that subjective evaluations of the relative effectiveness of signals of the APS lack sensitivity.

By comparison, the frequency of accelerator releases and brake applications of the following car driver with respect to those of the lead car driver did reflect significant differences between driving cycles as measured by accelerator release ratios. The data show that, as the relevance of the yellow signal increased, in terms of long coasting durations and the likelihood of coasting being followed by braking, there was a relative increase of accelerator releases by the following car driver, indicating that the APS system encourages an increase in release of the accelerator by following drivers.

An earlier study (6) reported that after some time drivers tended to ignore coasting signals because they realized that they were of little relevance on most occasions. This appears to be an effect similar to that found in the current test.

For both the APS and the conventional system, the relative frequency of braking by the subjects was about the same, showing that, when more highly relevant information is provided (information on braking rather than coasting), the drivers responded consistently. This result was also unaffected by the schedule of APS signal presentations.

CONCLUSIONS

Clearly, to introduce a new rear signal that will frequently light and at the same time often be of no relevance to a following driver is undesirable. Such a new signal could be distracting and possibly lead drivers to pay less attention to other more important driving tasks as well as interfere with detection of the other important rear lighting signals. It has already been demonstrated that the ability to detect coasting of vehicles can be accomplished by drivers fairly well by using "primary" cues such as the change in the headway gap or visual angle subtended by the vehicle (2). Because coasting is not followed by braking in a sufficiently large proportion of cases to allow a coasting signal to alert drivers to braking and, more important, to alert drivers to moderate or severe braking (2), the only potentially useful information provided by a coasting signal would be to alert drivers to long coasting durations in the event that they are not detected by other means. For this reason, Mortimer (2) suggested that a coasting signal only be presented when coasting durations exceed about 5 s because then the change in speed of the vehicle could be substantial and bring about high relative speeds and changes in headway.

The findings of the current study have indicated scarcely any benefits attributable to an APS, although they have indicated at least two important undesirable characteristics of it: (a) an increase in the frequency of accelerator releases by following car drivers and (b) a frequently appearing signal on the rear of a vehicle that on most occasions provides no useful information to the drivers of following vehicles.

ACKNOWLEDGMENTS

This study was conducted at the Highway Safety Research Institute, University of Michigan, and was sponsored by the National Highway Traffic Safety Administration, U.S. Department of Transportation, under contract DOT-HS-031-3-723. We wish to acknowledge the able assistance of J. C. Campbell, C. D. Moore, Jr., C. M. Jorgeson, and B. Abbott.

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