Knowledge of Closing Rate Versus Knowledge of Oncoming-Car Speed as Determiners of Driver Passing Behavior

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Previous work by the authors has established that (a) drivers are unable to make useful discriminations of either oncoming-car speed or closing rate in passing situations on two-lane highways, and (b) providing drivers with knowledge of oncoming-car speed enhances their ability to make valid passing judgments. The purpose of the present research is to compare the utility of providing drivers with knowledge of lead-car/oncoming-car closing rate or of oncoming-car speed in making passing judgments. In controlled experiments on a closed roadway, subjects were required to make passing judgments under three different knowledge conditions: knowledge of oncoming-car speed, knowledge of closing rate, and no knowledge. The major findings were that (a) subjects displayed no ability to discriminate oncoming-car speed; (b) subjects were able to take their own speed into account in deciding when to pass; (c) subjects were able to make effective and accurate use of both closing-rate information and oncoming-car speed information in deciding when to pass; and (d) there were no significant differences between the closing-rate knowledge and oncoming-car speed knowledge conditions. It is recommended that the feasibility of providing drivers with knowledge of the speeds of other vehicles on the highway be explored with respect to its effect on safety.

•PREVIOUS studies of automobile overtaking and passing on two-lane highways have established that drivers cannot judge accurately either oncoming-car speed or closing rate. The purpose of this research was to determine the effect of providing drivers with knowledge of either closing rate or oncoming-car speed in accelerative passing situations on drivers' decisions as to whether or not to pass.

In an accelerative pass, the overtaking driver starts from a close following position, with little or no speed advantage, and accelerates to complete the maneuver. Where the passing opportunity is limited by an oncoming car, the would-be passer must consider his own speed, the speed of the oncoming car, and his distance from the oncoming car to make valid passing decisions, that is, to pass only when it is safe, and never to pass when it is unsafe.

Oncoming-car gap acceptance behavior by drivers has been studied by several authors (1, 2, 7). These papers have been reviewed in detail elsewhere (3); the results indicate that drivers are relatively good judges of distance in passing situations, but poor judges of either closing rate or oncoming-car speed. Similarly, the results of observational studies of passing behavior on two-lane public highways (5) indicate that

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the passing decision appears to be completely unrelated to oncoming-car speed. Michaels (6) provides a basis for understanding this insensitivity to oncoming-car speed; his data suggest that, at the distance at which most passes take place, the speed cue associated with the rate of change of the visual angle subtended by the oncoming car is below threshold.

Since a driver has first-hand phenomenal and metric knowledge of his own speed and can judge distance with reasonable accuracy, much of the variability in passing judgment apparently is associated with insensitivity to oncoming-car speed. It thus appeared reasonable to assume that if drivers were relieved of the necessity of judging oncoming-car speed, passing-judgment accuracy would improve. Results of a series of studies conducted by the present authors to evaluate this hypothesis clearly showed that providing subject drivers with verbal knowledge of oncoming-car speed significantly improved their passing judgment.

To use verbal knowledge of oncoming-car speed effectively, a driver must also consider the speed of the car he is following, since the oncoming-car—lead car closing rate determines whether or not a pass is safe at a given distance. Thus, however he uses the information, a driver given knowledge of oncoming-car speed must consider two numbers. For this reason, it was felt that the verbal knowledge of closing rate would simplify the judgment process and would improve the accuracy of the passing judgment more than verbal knowledge of oncoming-car speed. The major objective of the present study was to compare the relative utility of oncoming-car speed information and closing-rate information. A secondary purpose was to determine the ability of drivers to consider their own speed in deciding whether or not to pass.

METHOD

Ten subjects were used, all Philadelphia public-school teachers with a minimum of 8 years driving experience. The experiments were conducted on a completed but unopened section of I-95 in Philadelphia. The test section provided over a mile of sight distance, of which 3500 ft was straight and level. The tests were conducted on one side of the expressway, which contained four 12-ft lanes.

Three cars were used in the test. A Rambler sedan and an Ambassador station wagon, loaned to the project by American Motors, were used as the oncoming car and lead car; a 1965 Ford sedan, with power steering, automatic transmission, and a 356-cu in. V-8 engine, was used as the overtaking car.

At the start of each trial, the oncoming and lead cars were positioned at opposite ends of the test section; the overtaking car was positioned immediately behind the lead car (see Fig. 1). On the start signal, the oncoming and lead cars accelerated to their assigned speeds and approached each other in the two adjacent center lanes. The subject was instructed to follow the lead car closely, to estimate the time gap between his own car and the oncoming car, and to pass the lead car when the time gap closed to 12 sec. After each trial, the subject was told what the time gap actually was at the start of the pass. This technique is clearly quite sensitive to a subject's ability to judge and utilize distance, oncoming-car speed, and his own car speed. Note that, since the subject vehicle follows the lead vehicle closely before passing, passing-car speed and lead-car speed are equivalent. If subjects judged these variables perfectly, they would pass at 12 secs on every trial; therefore, ability to maintain the time gap at close to 12 sec during several trials is taken as a measure of passing-judgment accuracy.

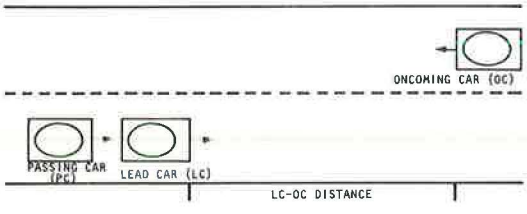

Figure 1. Experimental site.

ONCOMING CAR SPEED (MPH)	NO KNOWLEDGE				ONCOMING-CAR-SPEED KNOWLEDGE				CLOSING-RATE KNOWLEDGE			
	LEAD-CAR SPEED (MPH)											
	25	35	45	55	25	35	45	55	25	35	45	55
30												
40												
50												
60												

Figure 2. Experimental design.

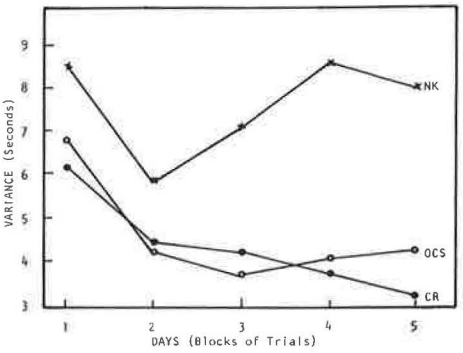

Figure 3. Variance of time-gap estimates within blocks of trials as a function of days for different knowledge conditions.

EXPERIMENTAL DESIGN

The experimental design is shown in Figure 2. Each subject performed three blocks of trials per day for 5 days. A block consisted of 16 trials, each with a different combination of lead-car and oncoming-car speeds. Lead-car speed was 30, 40, 50, or 60 mph; oncoming-car speed was 25, 35, 45, or 55 mph. Each subject had one no-knowledge (NK) block, one closing-rate knowledge (CR) block, and one oncoming-car speed knowledge (OCS) block each day. In the NK block, the subject had only his own judgment of oncoming-car speed; with CR knowledge, before each trial in a block began, the subject was told what the CR would be for that trial; and, with OCS knowledge, the subject was told before each trial in the block began what the OCS would be for that trial. The 16 speed conditions in each block were presented in a different random order each day, and the order of presentation of the knowledge-condition blocks was counterbalanced between subjects and days.

RESULTS

As shown in Figure 3, the variance of the time gap judged by the subjects to be 12 sec is less for both knowledge conditions than for the no-knowledge conditions. The difference between the two knowledge conditions are not significant; the difference between each knowledge condition and the no-knowledge condition is significant on days 3 through 5. The no-knowledge variances exhibit no systematic trend across the 5 days of practice and tend to remain high. The variances associated with knowledge conditions, however, decrease significantly with time, indicating a practice effect. The knowledge condition did not affect the average time gap at which subjects passed across all speed combinations; this gap ranged from 14.3 to 14.5 sec for the three conditions.

The effects on passing time of lead-car speed and of oncoming-car speed, with and without knowledge, are shown in Figure 4. The points on the graph show the average passing car—oncoming car time gap judged to be 12 sec for each of the three knowledge conditions and for each lead-car speed. The sloping line on each graph indicates the distance equivalent to 12 sec at each oncoming-car speed; thus, if all subjects had passed at exactly 12 sec, the line would pass through all the points.

The deviation of knowledge-condition points from the line indicates how well the subjects could use the knowledge of oncoming-car speed or closing rate. The no-knowledge subjects show no systematic response to oncoming-car speed and tend to pass a constant distance within each lead-car speed category. With either oncoming-car speed knowledge or closing-rate knowledge, the subjects passed at greater distances as oncoming-car speed increased. However, the slope of the increase is less than the slope of the 12-sec line, indicating that even under the knowledge condition subjects tended to pass slightly early at low oncoming-car speeds and slightly late at high oncoming-car speeds. Nevertheless, performance under either knowledge condition is considerably better than under the no-knowledge condition. Note that at a lead-car speed of 55 mph the average

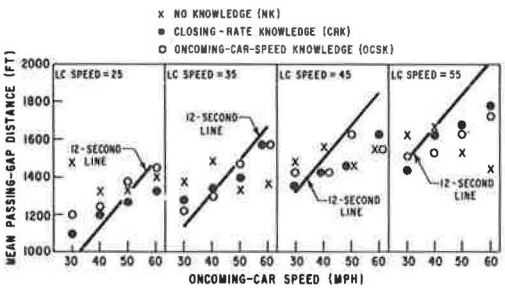

Figure 4. Mean passing distance as a function of OCS for different lead-car speeds.

no-knowledge passing distance when oncoming-car speed was 60 mph was actually less than the average passing distance when oncoming-car speed was 30 mph.

Under all conditions, as lead-car speed increased, subjects passed at greater distances. However, as lead-car speed increased, the points fall further below the 12-sec line, indicating that at high lead-car speeds subjects tended to pass slightly late, that is, to overestimate the time gap between the lead and oncoming cars.

In Figure 5, the average passing distance is plotted as a function of closing rate for each of the three knowledge conditions. Because of the oncoming and lead-car speed combinations used, all the closing rates except 55 and 115 mph appear more than once. Both knowledge conditions show an increase in passing distance with closing rate, with less of a slope than than of the 12-sec line. Because subjects, even with no knowledge, tended to respond appropriately to lead-car speed, the NK points follow a slight slope; however, the NK points are considerably more scattered than the K points.

Figure 6 shows the least-squares fit line of passing distance as a function of closing rate for the three knowledge conditions; the 12-sec line is also shown for comparison. The correlations between closing rate and distance for the NK, OCS, and CR conditions were 0.18, 0.60, and 0.62. The no-knowledge condition slope is nearly horizontal, while the slopes of the two knowledge conditions are less steep than that of the 12-sec line. Thus, subjects passed slightly early at low closing rates, and slightly late at high closing rates; that is, at low closing rates they underestimated the time gap between lead and oncoming cars, and at high closing rates they overestimated the time gap.

To estimate the time gap realistically when provided only with oncoming-car speed, subjects had to consider their own speed. When given closing-rate information, subjects should have ignored their own speeds because, under either knowledge condition at a given closing rate, passing distance equivalent to 12 sec is independent of lead-car speed. However, as shown in Figure 7a, subjects with oncoming-car speed knowledge passed at greater distances as lead-car speed increased, within each closing rate. As shown in Figure 7b, subjects with closing-rate information also tended to pass at greater distances with increasing lead-car speed, although not so markedly as did subjects with oncoming-car speed knowledge. Thus, subjects did not base their estimates of the time gap solely on closing rate and distance, regardless of the information they had been provided; however, subjects with closing-rate information apparently were less liable to misuse lead-car speed information.

Oncoming-car information is best used by summing it with the passing-car speedometer reading and basing the time-gap estimate on the resulting closing rate and on distance; however, interviews with subjects following the last experimental ses-

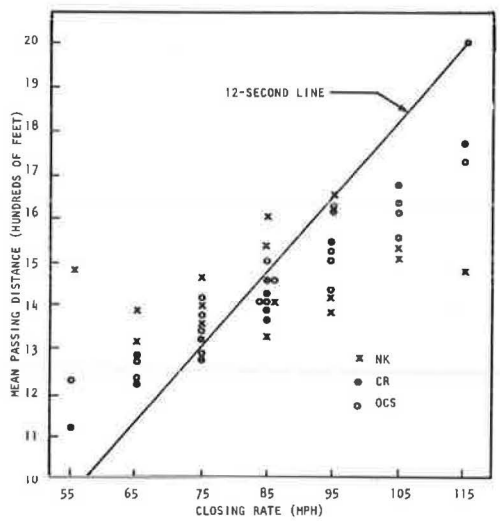

Figure 5. Mean passing distance as a function of closing rate for three knowledge conditions.

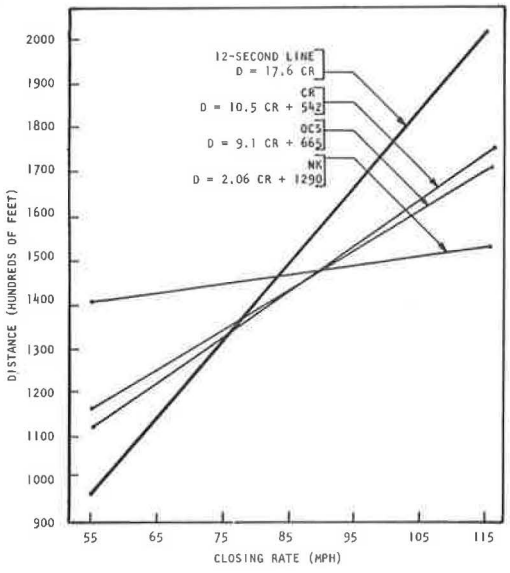

Figure 6. Least-squares fit of passing distances as a function of closing rate for three knowledge conditions.

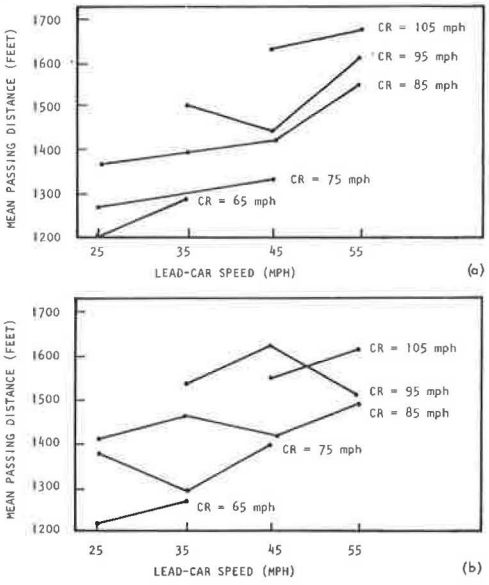

Figure 7. Passing distance as a function of lead-car speed for different closing rates with (a) oncoming-car speed knowledge and (b) closing-rate knowledge.

sion revealed that they did not use this procedure. In fact, 6 of the 10 subjects indicated that, when given closing-rate information, they subtracted their own speed from the closing rate to obtain oncoming-car speed. Thus, if subjects had been given more detailed instructions concerning how to use the information provided, they probably would have performed better.

CONCLUSIONS

On the straight roadway of the test site, subjects could not judge oncoming-car speeds. When subjects were provided with knowledge of either closing rate or of oncoming-car speed, they judged the time gap between their own car and an oncoming vehicle better than when they were not given this information; however, they used this information imperfectly and passed slightly early at low closing rates and slightly late at high closing rates. Similarly, subjects under all conditions could take their own speed into account appropriately, but tended to pass slightly early at low lead-car speeds and slightly late at high lead-car speeds. With either type of knowledge, when closing rate was constant, subjects responded inappropriately to lead-car speed by passing at greater distances as lead-car speed increased. In general, subjects used verbal information about closing rate or oncoming-car speed as well as they did that of lead-car speed about which they had phenomenal as well as speedometer information. Performance under the two knowledge conditions did not differ, either practically or statistically. Variance of the passing-time gap with either knowledge condition was about half of that resulting from the no-knowledge condition.

The application of these data is straightforward. Although the passing behavior of drivers on public highways varies considerably, the threshold passing distance adopted by drivers tends to remain constant regardless of oncoming-car speed; this distance is appropriate only for oncoming-car speeds close to or slightly above speed limits. Therefore, drivers miss passing opportunities when oncoming traffic is slow and frequently accept hazardous passing opportunities when the oncoming vehicle is traveling 10 or 15 mph above the speed limit. If drivers knew either the oncoming-car speed or the

closing rate, more of them probably would pass when they should and fewer would pass when they should not.

Providing closing-rate information is technically complex; however, oncoming-car speed information appears to be equally effective and is much easier to provide. Much research currently is being performed toward developing vehicle lighting systems that convey more information than is provided on present vehicles; such a system could include information about vehicle speed. By incorporating such systems on all motor vehicles, safety and throughput on two-lane highways could be significantly improved.

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