

Alternatives to Enforcement in Modifying the Speeding Behavior of Drivers

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Two experiments were conducted to examine alternatives to enforcement as a means of reducing speeding behavior. The first employed transverse lines painted on the roadway at progressively diminishing distances apart to produce an alerting response and an illusion of vehicle acceleration. Data were collected on 247,036 vehicles during a period of several weeks. The number of drivers that were exceeding the recommended speed by more than 30 km/hr was reduced by 25 percent, but this effect on speed began to disappear after 3 weeks. The second experiment provided drivers with feedback (using a traffic sign) about the percentage of drivers who were not speeding on the previous day. Data gathered on approximately 690,000 vehicles during 3.5 months indicated that excessive speeding could be reduced by 40 percent. This speed reduction was maintained for weeks after the sign was removed. The implications of these findings for alerting drivers and reducing speeding behavior are discussed.

It is undeniable that the traffic safety problem is very diverse and immense in scope. The high annual cost in human life and property damage also gives it priority. Although roads, vehicles, and traffic control devices are constantly being improved and made safer, there has been little advancement in the safety features of the human operator.

The traditional method of driver control is the imposition of safety rules and the use of police enforcement to obtain compliance. The presence of enforcement usually results in an immediate reduction in offenses (1-3). There is also a reduction in compliance after the police have left (known as the residual impact), depending on the duration and regularity of enforcement and the frequency with which the same traffic uses the same roadway at the same time each day (4, 5).

The major drawback to enforcement as a means of controlling behavior is that it does not appear to be effective over the long term. Police personnel are in short supply and very expensive, making enforcement programs haphazard and short term. Because detection rates are low, compliance is also low as enforcement does not affect the intentions of the violator.

In-depth collision analyses (6) have indicated that a significant proportion of traffic collisions is due to failure of drivers to pay proper attention. Although violations such as speeding are very often committed intentionally, it may well be that excessive speeding (e.g., 25 to 35 km/hr over the limit) is a result of driver inattention. Drivers may miss seeing traffic signs that indicate speed limit changes or may not be paying sufficient attention to their own vehicle speed. Increased enforcement will not necessarily increase driver attention.

By decreasing the overall demand of enforcement programs,

police personnel can be directed specifically to those locations where there is the greatest need with the enforcement consistency required to make a long-term impact. It is necessary, therefore, to develop programs that encourage drivers to comply with traffic regulations regardless of police presence. The following experiments were performed to investigate two possible approaches.

EXPERIMENT 1: DIMINISHING LINES

Experiment 1 evaluates the impact of a strong visual stimulus on speeding. It is posited that the stimulus will increase driver attentiveness and thereby reduce speeding. The stimulus used was a series of reflective white lines, similar to those used by Helliard-Symons (7), painted transversely across an exit ramp of a freeway in the city of Calgary. It has been demonstrated that the use of these lines has been quite effective in reducing speed and collisions (7, 8).

Method

Subjects

Speed measurements were collected over a 5.5-week period for a total of 752 hr of data. The speeds were collected from motorists traveling the 900-m southbound exit ramp from the Deerfoot Trail freeway to the 16th Avenue split diamond interchange. A total of 247,036 vehicle speeds were recorded. Given the nature of the roadway, a considerable number of vehicles were repeat users of the ramp; however, there was also a large number of infrequent or novice users at any given time. Exact proportions were not recorded. The drivers involved were unaware that they were participating in a speed study and that their speeds were being recorded.

Apparatus

Speed and volume were measured by using a Stevens PPR II Print-Punch Traffic Classifier manufactured by Leupold and Stevens Inc. This instrument is a microprocessor-controlled, electromechanical recorder that converts output pneumatic pulses from rubber hoses to a printed record. Two 1/4-in. hoses were laid perpendicular to the traffic flow 4.9 m apart. Impulses were stored in memory and then printed as a summary for a specific time interval in standard ASCII punched format on a 2.5-cm heat-sensitive paper tape. For this study the time interval was 1 hr, meaning that all vehicle speeds were averaged over a 1-hr period.

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Procedure

The site for the experiment was chosen for several reasons. First, the ramp had a posted advisory speed of 50 km/hr, which was considerably less than the speed limit of 100 km/hr on the freeway. Because this was an advised speed, there was no legal compulsion for drivers to slow down. The intersection was a split diamond with straight off ramps so that drivers could operate at any speed desired given free-flow conditions. Any reduction in speed should therefore reflect a change in driver decision making. Second, the ramp approached a signal-controlled intersection that had a high collision rate. Third, a speed problem on the ramp had been independently identified through collision investigation and direct observation. Finally, the ramp was a straight, long, single-lane road, which made it ideal for painting the lines and installing the data collection equipment.

On April 28, 1982, the classifier was installed 130 m upstream of the traffic control light and 770 m downstream of the beginning of the ramp. Data were collected until May 16 that formed the pretest baseline phase of the study. Vehicle speeds in each hour were averaged by the classifier to obtain a score for that hour. The number of vehicles during each hour ranged from 4 to 865, with an average of 328 vehicles. Although this technique does not differentiate between free-flow and platooned traffic, this was not considered a problem because the average platoon speed would approximate that of the platoon leader. Also, speeding was not a particular problem when traffic was platooned. There were 336 hr of data collection (106,444 vehicles or 318 per hour) in the pretest baseline phase.

The ramp was then closed for approximately 8 hr while 90 fluorescent white lines were painted transversely on the ramp over a 404-m distance (Figure 1). Each line was 60 cm wide and 4 m long (curb to curb). The distance between the lines gradually decreased from 7.7 m at the start to 2.75 m, accord-

ing to the specification outlined by Helliar-Symons (7). The lines started 100 m after the ramp began and finished 400 m from the traffic light. After the lines were installed, data collection continued until June 5. There were 416 hr of data collection (140,622 vehicles or 338 per hour) in this phase.

In both phases of the experiment, data collection was not continuous. The most common reason for lost data was either a break in one of the hoses or condensation following rain or snowfall. Several hours of data recorded during snow or rain storms were also omitted, because they were unrepresentative of the driving conditions. In Phase 1, 68 hr from a total of 404 (16.8 percent) was lost. In Phase 2, 60 hr from a total of 466 (12.6 percent) was not reported. Breaks (due to street cleaning) were more of a problem in Phase 1 than in Phase 2, where condensation appeared more prevalent. The hoses were checked every morning and if necessary replaced promptly so that only small blocks of time were lost. The damage was primarily confined to early morning hours or weekends. Overall the weather was relatively consistent throughout the study. Although there was slightly more snowfall during the pretest phase, the ramp itself did not ice up and there was no apparent weather-related effect on speed.

Results

Two dependent variables were measured in this study, mean speed and the percentage of vehicles travelling faster than 80 km/hr, which is 30 km/hr over the advised speed. The latter was of interest because this speed was considered a high risk for collisions and thus a desirable target for speed reduction. Using a one-tailed *t*-test and the Mann-Whitney *U*-test, significant decreases were found in both as a result of the diminishing lines ($t = -2.64$ for mean speed and -3.73 for percentage faster than 80 km/hr, $df = 285$, $p < 0.001$). There were also decreases



FIGURE 1 Transverse pavement markings used in Experiment 1.

TABLE 1 EFFECT OF DIMINISHING LINES ON SPEED
(Experiment 1)

	Mean Speed (km/hr)	Standard Deviation (km/hr)	Percent >80 km/hr	Standard Deviation (km/hr)
Before	63.46	2.96	5.45	3.78
After	61.44	2.81	4.06	3.07
Percent difference	-3.3		-25.5	
<i>t</i> -value	-2.64 ^a	-	-3.73 ^a	-

^a*p* < 0.001.

in the standard deviations within both measures. The results are detailed in Table 1. The effects decayed over time, as shown in Table 2.

The pretest and posttest data were also compared by day of the week and hour of the day to determine whether the effects were consistent. The results for each day of the week for which there was a complete 24 hr of data were averaged to obtain a daily score. An hourly score was obtained by averaging all like hours regardless of day of the week. This analysis indicated that the decrease in the dependent variables was remarkably consistent; there were decreases in almost every instance.

TABLE 2 COMPARISON OF POSTTEST
CONDITIONS

Week	Hours of Data	Mean Speed (km/hr)	Percent >80 km/hr
First	148	60.43	3.19
Second	130	61.89	4.55
Third	138	62.09	4.50
Total	416	61.44	4.06

Discussion

The results support the hypothesis that a strong visual stimulus can result in a reduction in speed. The lines create a startle effect and an illusion of acceleration, which causes drivers to pay more attention to their surroundings. Drivers responded by reducing their speed to comply more closely with the advised speed limit. The data also show that this reaction was consistent across each hour of the day and each day of the week.

It is also assumed that drivers who are the most inattentive would not decrease their speed until forced to by the traffic light. This group would most likely be exceeding 80 km/hr and an increase in attentiveness should be highly pronounced. The data support this conclusion, as shown by the 25.5 percent decrease in those exceeding 80 km/hr, which is a decrease of 764 fewer drivers a week, given an average daily volume of 8,000 vehicles.

The major failing of this manipulation is indicated in the decay of the speed reduction effect. The lines performed extremely well in the first week and then the effect dropped off. Continued monitoring of speed might have revealed a return to

the baseline rates or a plateau somewhere in the middle. As mentioned, monitoring was discontinued in June because of an anticipated change in the traffic mix during the summer months, when holidays and other factors bring an increase in out-of-town drivers. It is suggested that this decay occurred because drivers learned that the lines were there and anticipated them. This reduced the startle effect so that it could be ignored. There was also no compulsion for motorists to drive 50 km/hr, because the speed posted is advisory only.

Another confounding factor was the presence of the traffic lights at the top of the ramp. Many motorists would likely ignore the lines if slowing down would prevent them from reaching the intersection on a green light. Alternatively, the lights may have slowed down some drivers who otherwise would have continued their high speed. Although the traffic light does act as a speed controller, its performance was consistent across both conditions. The light was also 130 m from the traffic classifier, so it is unlikely that its impact had a significant influence on recorded speeds.

In conclusion, the results of this study support the use of these lines to decrease speeding, particularly excessive speeding. It could be validly questioned whether a mean speed reduction of 1.5 to 2 km/hr is of practical importance. This measure simply indicates the direction of the speed change. The actual impact of the lines is apparent in the considerable reductions in the number of drivers who were traveling well above the safe speed. Reduction of their speed reduced the overall speed variance, making the ramp that much safer. Further work will have to be done to validate this effect, particularly in areas where drivers are required to slow down, but frequently do not. It would also be useful to select an area that is not affected by other traffic control devices. An ideal location for further testing would be playground and school zones, where there is a high offense rate but also strong legal and social pressures to comply with the speed limits. The fact that drivers speed in such areas despite these pressures could indicate a high level of inattention.

EXPERIMENT 2: PUBLIC POSTING

The previous experiment demonstrated that increased attentiveness can result in a decrease in speeding. VanHouten et al. (9) employed a method of associating the threat of enforcement with an attentiveness-increasing stimulus (a sign indicating the percentage of drivers not speeding) and obtained very positive results. The present study was performed to replicate VanHouten's results by using more sophisticated data collection techniques and a larger sample size.

Method

Subjects

Speed data were collected over a 3.5-month period from motorists traveling southbound on a two-lane arterial road in the northwest part of Calgary. A total of 1,722 hours of speed data, representing the speeds of 690,614 vehicles, were collected. The drivers in the sample were unaware of participating in a speed study.



FIGURE 2 Speed feedback sign used in Experiment 2.

Apparatus

Speed and volume were recorded with the Stevens PPR II Print-Punch Traffic Classifier described in the first experiment. The recording interval was 1 hr. Each hour of data is an average of the speeds of all vehicles in that hour. The number of vehicles during any hour ranged from 6 to 982. The independent variable was a large metal sign measuring 1.3 by 2.3 m. The sign was green with white lettering that read Drivers Not Speeding Yesterday and Best Record. After each of these phrases was a space to insert a percentage. The sign was mounted 2 m above the ground on aluminum posts that were anchored in cement blocks (Figure 2).

Procedure

The sign was installed 30 m south of a sign indicating a speed reduction ahead from 70 to 50 km/hr. A sign for the 50-km/hr speed limit was located another 20 m further south. Approximately 150 m south of the message sign the road narrowed from two lanes southbound to one lane. Speed data were measured 500 m south of the message sign approximately halfway down a 200-m downgrade. This location was selected for several reasons. First, previous enforcement efforts had shown that this particular roadway had a high incidence of speeders and that speeding was a major contributing factor to collisions in the area. Second, the speed limit reduction from 70 to 50 km/hr was similar to that used by VanHouten et al. (9) and was replicated for comparison purposes. Third, the narrowing of traffic from two lanes to one in each direction made speed reduction even more important to safety. Finally, the area was totally devoid of any structures or artifacts that might obscure the sign from view or distract the drivers. The sign was clearly visible for almost 800 m.

In the pretest phase, data collection began June 12, 1982, and continued until October 2, 1982. A total of 417 hr of data were collected to determine the baseline behavior. On July 8, Phase 2, the first experimental phase, started, in which the sign was in place, but no percentages were indicated. In Phase 3 the sign contained percentages indicating speeding. This phase continued until August 17. Phases 2 and 3 covered a total of 712 hr. The final phase was a posttest measurement period during which the sign was removed. This continued for 593 hr until October 2. The hours of data collected and the number of vehicles in each phase are summarized in Table 3.

During Phase 2, the sign was present without any percentages displayed on it, to determine how much impact a large sign that mentioned speeding would have on drivers' speed. Then the percentages were changed regularly to reflect average vehicle speed based on a daily readout of the Leupold classifier data. The "yesterday" percentage on the sign increased or decreased depending on the speed reading and ranged from 79 to 94 percent. The "best record" percentage started at 79 percent and increased monotonically until it peaked at 94 percent. This number represented the best percentage that drivers had reached to that date.

TABLE 3 SUMMARY OF PUBLIC POSTING EXPERIMENT

Phase	Date	Hours of Data	No. of Vehicles
1 (pretest)	June 12–July 8	417	174,900
2 (sign alone)	July 8–21	149	59,150
3 (sign with percentages)	July 21–Aug. 17	563	214,120
4 (posttest)	Aug. 17–Oct. 2	593	242,444
Total	3.5 months	1,722	690,614

Results

The results support the use of this technique for reducing speed. The sign produced significant reductions across all three dependent variables: mean speed ($F = 24.5$, $df = 3/43$, $p < 0.001$), percentage of drivers traveling faster than 65 km/hr ($F = 53.4$, $df = 3/43$, $p < 0.001$), and percentage of drivers traveling faster than 80 km/hr ($F = 30.7$, $df = 3/43$, $p < 0.001$), as indicated by one-way analyses of variance. There were also reductions in the standard deviation within each measure. Although the posted speed limit was 50 km/hr, 65 km/hr was used as the cutoff between speeding and not speeding. This speed is specified by the Alberta Highway Traffic Act as the boundary between a \$20 and \$30 summons and is commonly used as a definition of speeding. The next cutoff, between a \$30 and a \$75 fine, is 80 km/hr, which is considered to be a high-risk speed for this location. The results of the data analysis are summarized in Table 4, which also shows the percentage of difference between this phase and the pretest. The percentage of drivers traveling faster than 50 km/hr is also shown; this was not used as a criterion in this study, although the difference was significant.

The data were also tested by using a Student Newman Keuls procedure to determine differences between phases. The pretest data were significantly greater than those for any of the other three phases across all measures. The only significant difference among Phases 2–4 was between Phases 2 and 3 in the percentage over 65 km/hr conditions. Neither of these was significantly different from Phase 4.

Discussion

The sign appears to have made a significant impact on drivers' speeds. During the pretest phase, 25.2 percent of the traffic was exceeding the speed limit by at least 16 km/hr. This represents an average of more than 2,400 vehicles every day. Of this group, 336 vehicles were traveling in excess of 80 km/hr. Yet this area was well enforced by police. During Phase 3, the percentage of speeders fell to 15 percent, a reduction of almost 980 vehicles daily, or 40 percent. The high-risk group also fell by 40 percent, a reduction of 134 vehicles daily.

Another interesting result was the duration of the effect. A substantial decrease across all dependent variables was still observed during October, 4 weeks after the sign had been removed. Although it is possible that some unaccounted-for

secondary variable was at work keeping the speeds down, it is also possible that the sign made a lasting behavioral change in the regular users of that route. It is also possible that the removal of the sign was in itself a sufficient change in the environment to increase attention levels and cause awareness of speeds and speed limit signs.

Obviously there are still questions to be answered regarding the use of this tool. On the basis of work by VanHouten and Nau (10), it seemed that there were certain factors that could influence the sign's effectiveness. It appeared to lose its impact if the "yesterday" percentage did not change at least a few times a week. There was also a drop if that percentage and the "best record" fell below 70 to 80 percent. It appears that the larger the percentage not speeding, the larger the impact of the sign. It may also be that if the compliance rate is very low initially, the speed limit may be improper for that area and the sign will not overcome the resistance. Further work with the sign will have to be completed before these variables can be properly evaluated.

As an aid to enforcement, however, this sign has shown potential for being very cost-effective. The sign cost approximately \$500 to make and required 1 hr in installation time. By setting up this device upstream of an area marked for special attention by radar patrols, enforcement personnel can be fairly confident that those drivers who do violate the speed limit are doing so intentionally. VanHouten and Nau (10) have already demonstrated that when the sign is coupled with enforcement, the impact is longer lasting. If the impact does decay at any time, the sign can simply be moved to a new location for a few months and perhaps be replaced by some other device. It is not necessary to tie up expensive data collection equipment to use this device. Once this study was completed, data for each hour were correlated with daily averages and it was determined which hours of the day were the most representative of the day as a total. This allowed an unmarked radar car to sample vehicle speeds during these times over 2 to 3 hr a week and to collect sufficient speed data to change the percentage figures on the sign with a high degree of validity.

CONCLUSIONS

Both of the foregoing approaches were effective in reducing speeding behavior through an environmental cue. The public posting was more effective and longer lasting. In retrospect this may have been because the diminishing lines were not used at

TABLE 4 RESULTS OF PUBLIC POSTING EXPERIMENT

Phase	Mean Speed (km/hr)	Percent Difference	Standard Deviation	>50 km/hr		>65 km/hr		>80 km/hr	
				Percent	Percent Difference	Percent	Percent Difference	Percent	Percent Difference
1	61.5	—	3.1	89.8	—	25.2	—	3.5	—
2	59.4	3.4	—	86.2	4.0	18.7	25.8	2.1	40.0
3	58.7	4.0	—	83.4	7.1	15.0	40.5	2.1	40.0
4	59.1	25.8	—	84.7	5.7	16.4	34.9	2.2	37.1
F-test	24.5 ^a	40.0	—	10.4 ^a	—	53.4 ^a	—	30.7 ^a	—

NOTE: F critical = 4.31, $\alpha = 0.01$, $df = 3/43$.

^aSignificant $p < 0.001$.

an appropriate location. The diminishing lines appear very effective in stimulating driver awareness to the surroundings and creating an illusion of acceleration. There will be no long-term effect on speeding, however, unless there are valid and obvious reasons for the driver to slow in that particular area. The stronger implied surveillance and threat of enforcement may have contributed to the greater impact of the feedback sign, although more work will have to be done to factor out the respective impact of each.

Once the proper location has been determined for these techniques, they can be complementary to an enforcement program. Both are relatively permanent fixtures and remain active 24 hr a day, therefore being visible to all road users. They are also very effective in reducing inattention, thereby allowing the driver an opportunity to comply with the speed limit on his own accord. Drivers who ignore these devices and speed anyway usually do so intentionally and become suitable candidates for behavior modification through police enforcement. This allows police to concentrate their efforts on those locations and times when drivers are most likely to respond to their influence.

REFERENCES

1. P. J. Cooper. Effects of Increased Enforcement at Urban Intersections on Driver Behaviour and Safety. In J. Cooper *Effectiveness of Traffic Law Enforcement*, Delevin, Cather, and Co. of Canada, Toronto, 1974.
2. F. M. Council. *A Study of the Immediate Effects of Enforcement on Vehicular Speeds*. Highway Safety Research Center, University of North Carolina, Chapel Hill, 1970.
3. K. B. Joscelyn, T. H. Bryan, D. H. Golden-Baum. *A Study of the Effects of Law Enforcement on Traffic Flow Behavior*. National Highway Traffic Safety Administration, U.S. Department of Transportation, 1971.
4. W. L. Booth. *Police Management of Traffic Accident Prevention Programs*. Charles C Thomas, Springfield, Ill., 1980.
5. O. K. Dart and W. W. Hunter. Evaluation of the Halo Effect in Speed Detection and Enforcement. In *Transportation Research Record 609*, TRB, National Research Council, Washington, D.C., 1975, pp. 31–33.
6. J. Treat, N. Tumbas, S. McDonald, D. Shinar, R. Hume, R. Mayer, R. Stansifer, and N. Castellan. *Tri-Level Study of the Causes of Traffic Accidents*. Report DOT-HS-034-3-535-77 TAC. Indiana University, Indianapolis, 1977.
7. R. D. Helliard-Symons. Yellow Bar Experimental Carriageway Markings—Accident Study. TRRL Report 1010. U.K. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1975.
8. G. G. Denton. The Influence of Visual Pattern on Perceived Speed. TRRL Report 531. U.K. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1973.
9. R. VanHouten, P. Nau, and Z. Marini. An Analysis of Public Posting in Reducing Speeding Behaviour on an Urban Highway. *Journal of Applied Behavior Analysis*, Vol. 13, 1980, pp. 383–395.
10. R. VanHouten and P. Nau. *A Study To Assess the Effects of Feedback Signs on Driving Speed*. Technical Report. Transport Canada, Ottawa, Ontario, 1984.

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Excess Travel: Causes, Extent, and Consequences

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The amount of excess travel in the United States is estimated on the basis of past research and new empirical studies. Excess travel is defined as the arithmetic difference between total actual highway use, exclusive of destination-free "pleasure" driving, and the use that would have resulted if all such travel had been made by using the optimum route connecting each individual origin-destination pair. Excess travel is shown to be

caused by a number of different factors acting singly or in combination. These include route selection criteria and efficiencies in necessary route-planning information, in the highway information system, and in both route-planning and route-following skills. The synthesis of all available data indicates that excess travel contributes 4 percent of all vehicle miles of travel and 7 percent of all travel time for work-related trips. Corresponding figures for non-work-related trips are 20 and 40 percent, respectively. Applying these proportions to total U.S. travel results in a total of excess travel amounting to 83.5 billion mi and 914,000 person-years per year at a total estimated cost of more than \$45 billion.

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