THE UNIVERSITY OF NORTH CAROLINA

HIGHWAY SAFETY RESEARCH CENTER

A STUDY OF THE IMMEDIATE EFFECTS OF ENFORCEMENT ON VEHICULAR SPEEDS

FORREST M. COUNCIL

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A B S T R A C T

This study examined the effects on vehicular speeds of two types of enforcement symbols in or adjacent to the traffic stream on rural roadways. The enforcement units of the North Carolina Highway Patrol were: (1) a single stationary patrol vehicle parked adjacent to the roadway in a position visible to oncoming traffic; and, (2) a single patrol vehicle moving in the stream of traffic. The effect of the two symbols was indicated by changes in traffic of mean speeds, speed variances, the percentage of vehicles traveling at speeds above the posted speed limit, and the percentage of vehicles traveling at speeds above the posted speed limit plus a 5 mph tolerance. Data were collected approximatley 1-¼ miles upstream from the patrol unit and 1-¼ miles downstream from the unit. Changes in the above-stated indicators resulted in the final conclusions.

Analysis indicated reduction in mean speed, variance and in the percentage of vehicles traveling above the posted speed limit and the speed limit plus tolerance when the stationary unit was employed on all test tracks under all test conditions. Analysis showed no significant change or a significant increase in the corresponding measurements between the upstream and downstream points when the moving patrol unit was introduced into the traffic stream.

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A Study of the Immediate Effects
of Enforcement on Vehicular Speeds

INTRODUCTION[1]

Many studies concerning highway safety have reported a relationship between vehicular speed and accident occurrence and intensity. The use of a specific traffic characteristic such as vehicular speed as an indicator of driver conduct is questioned by some researchers due to the variety of behavioral responses open to the driver and the variability of spot speeds (See Michaels, page 5). However, the lack of other indicators which might better be employed and the relative ease with which related speed data may be obtained lead to the use of this characteristic in much of the research.

Various enforcement techniques are used in an attempt to control traffic and to aid in promoting safe vehicular travel. State highway patrols, existing in some form in every state, are the on-the-road means by which laws are enforced and by which those who violate these laws, and thus exhibit behavior which deviates from that of the remainder of the driving population, are apprehended and removed from the roadway. But more important than this actual apprehension of violators is the role of the enforcement agency as a deterrent whose presence, either actual or assumed, aids in prohibiting the deviate behavior. Baker (2) hypothesizes that the knowledge that an enforcement unit is or may be nearby encourages less radical behavior because of fear of the physical or economic penalty which may be imposed.

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[1] A more complete description of this research is available in the author's M. S. thesis.

Therefore, it is important to ascertain, first, if the "deterrent" effect actually exists; second, if so, to what extent it reveals itself through various indicators such as vehicular speed; and third, if there are variations in the deterrent effect as a function of type of enforcement.

REVIEW OF LITERATURE

Baker (1945) has discussed some of the original research done at the Traffic Institute of Northwestern University. He reports that police activity is believed to act in three ways as a deterrent to people who drive faster than the law permits.

1. The visible presence of a patrol unit presents the immediate possibility of enforcement against violators at that time and place.
2. The general belief that speed laws are enforced on a highway will deter drivers from exceeding the speed limits, even if no patrol car is known to be in the area.
3. A general belief that traffic laws are enforced in a community or other areas will stimulate compliance with the speed laws in that community.

In conducting a pilot study concerning statements one and three above, the researchers chose to use what they called the Average Excess Speed (AES) which is the sum of all the amounts by which each vehicle exceeds the speed limit divided by the total number of vehicles. The radar meter and other devices similar in design to the "whammy"[2] were used as measuring instruments. Measurements were made of the effects on the AES of a patrol

[2] The whammy is a speed detection device consisting of two hollow tubes laid across the roadway at a measured distance apart and a stop-watch type speed indicator which is activated by electrical signals. These signals are initiated by changes in the air pressure in the tubes occurring when the wheels of a vehicle pass over them.

car parked beside a roadway as compared with a patrol car moving in the flow of traffic. In the stationary patrol car stage of the experiment, speeds were recorded at distances of 300 feet behind and in front of the enforcement vehicle, but the researchers concluded that the data showed no significant effect. Next, as the moving patrol car traveled past a checkpoint at predetermined speeds (i.e., at the posted speed limit and at 5 mph below the posted speed limit), target vehicles following or preceding the patrol car were clocked. For each of these vehicles, a spot speed (the speed at a given instant), and the time lag between the target vehicle and the patrol car were recorded for later analysis. The research concluded that the span of effect was less than 1000 feet ahead and only a few hundred feet behind the moving patrol unit. The vehicles did form a queue behind the enforcement vehicle. The final statement of the report was to the effect that the volume of data was insufficient to be conclusive.

Further research was conducted at the same institution in 1955-57 and reported by Robert P. Shumate (11) under the title Effects of Increased Patrol on Accidents, Diversion, and Speed. The fourfold purpose of the study was:

1. Verification of the hypothesis that reductions in accident frequency follow increases in amount of enforcement.
2. Preliminary exploration of quantitative relationships between enforcement and accidents.
3. The effect of increased number of patrol units on use by traffic of less desirable but parallel routes.
4. The effect of increased number of patrol units on vehicular speeds by:
    a. reduction in mean speeds.
    b. reduction in percentage over the speed limit.
    c. reduction in variance in speeds.

The researchers selected four test routes characterized by high accident rates. Each route had a parallel "control" route of the same length and design standards. Speed limits on all routes were 65 mph. The control routes were far enough removed from the test routes to prevent any carry-over effect of the enforcement. Each of the test routes was placed under patrol for three months (at different times of the calendar year). Accident data studied were based on mandatory accident reports sent to the highway department on accidents with personal injury and/or over $100.00 property damage. Speed data came from samples taken by the highway department as part of their annual survey of vehicle speeds, and were obtained during daytime hours when traffic was moving freely. Speed data were from 1955, the last year preceding an increase in enforcement, and 1957, the first whole year with the enforcement present. Approximately 3000 vehicular speeds for each year were obtained for both the test routes and control routes. Upon analyzing the data, the researchers found that:

1. The proportion of passenger vehicles exceeding the legal speed limit is reduced after the assignment of enforcement units to a stretch of highway.
2. Average vehicle speeds are not significantly affected as a result of increasing patrol on a route.
3. There is some indication that vehicle speeds tend to group more closely around the average when additional patrol units are placed on a given section of the highway.

No effect on accidents was noted. The researchers suggest that these results indicate that effects of enforcement on traffic behavior are at the very least indirect. Enforcement had a relatively small effect on all variables measured, possibly because of the crudeness of measures employed and the unreliability of measurements inherent in any field study of this magnitude.

The research was later evaluated by Richard M. Michaels (9) in conjunction with the Division of Traffic Operations of the Bureau of Public Roads under the title The Effects of Enforcement on Traffic Behavior. The reasons given for again evaluating the earlier research were:

1. The questionable statistical assumptions employed originally on accident data.
2. The design of the experiment -- This was thought to be one of the best designed studies conducted in the enforcement area.

Using the analysis of variance technique on the means and the percentage of drivers exceeding the speed limit, Michaels concluded that the decreases shown here also could not be attributed to enforcement. The reduction in the variance of speeds obtained, in the original study, were analyzed using the F-test and were demonstrated to be statistically significant. Shumate stated that this indicated that enforcement causes people to cluster more nearly about the mean speed -- and to do so in relation to the amount of enforcement present. Another report, The Federal Role in Highway Safety, (4) printed in 1959, has shown that the accident involvement rate was higher with drivers who operated in the extremes of the speed distribution. Michaels felt that these results were exaggerated due to the variability of spot speeds. Shumate assumed these speeds to be characteristic of all highways and all traffic over time. Because other research has shown Shumate's assumption to be untrue, the results of the F-tests are compromised. Michaels stated that to speak of speed behavior hardly scratches the surface of driver reactions. He noted the following restrictions on the data used:

1. Limited efficiency of many of the measures used in traffic behavior studies. This is especially true

when generalizing about driver behavior.

2. The freedom of responses available to drivers is so great that variability in driver behavior is excessive. Consequently, measurements taken from the roadside on a mass of motorists are often so unrelible that definite inferences are not possible.
3. Time varying characteristics of the highway system prevent the establishment of any real experimental control in the field situation.

The Highway Patrol of the State of California (5) has presented research concerning the Immediate Effects of Visible Patrol on Vehicular Speeds. In the initial part of the report, the authors stated that (5, p. 2) "As excessive speed is known to be a primary factor in the cause and severity of accidents, it is important to know the effect of patrol units on traffic speeds". The researchers conducted their work on a 5½ mile section of the Oso Creek and Santa Ana Freeway. Three hidden radar units were set up beside the roadway approximately 2½ miles apart and three types of test runs were conducted. In the first type (which is intended as the control segment), no patrol car was used. In the second type, eight patrol units were introduced into the flow of traffic and traveled at ten mph under the speed limit for four miles up to the first radar unit. They then withdrew and proceeded back to the initial point. Speed data were obtained on vehicles traveling in the same direction (southbound) as the patrol cars. In the third segment of the testing, the eight patrol units were parked on the center dividing strip of the highway two miles apart for 16 miles preceding the first point, and speed data were again obtained on the southbound vehicles. The three tests were conducted on successive Friday nights in April at the same locations and approximatley the same times. The three definitions of speed used in the analysis were critical speed -- the

85th percentile speed, absolute speed -- the number and percentage over the speed limit, and the number and percentage over the speed limit plus a three mph tolerance. Using the Chi-square technique at .01 or .05 levels of significance for the data analysis, the findings were:

1. Critical speeds were not reduced significantly regardless of the location of patrol units.

2. At unit #1, both number of speeds over the absolute and the number of speeds over the absolute plus tolerance were significantly reduced both when the patrol units were moving in the traffic and when they were parked.

3. At unit #2, the number above the absolute decreased significantly under the parked patrol unit condition but not under the moving patrol unit condition. The number over the absolute plus tolerance decreased significantly for both situations.

4. At unit #3, no significant effects were found under any test condition.

The authors concluded (but not necessarily from the results obtained) that there was a greater reduction in speeds where patrol units were parked, permitting more motorists to see the units.

Perhaps the most intensive and best conducted research done to date was The Effects of Enforcement on Driving Behavior by R. Dean Smith (12) for the International Association of Chiefs of Police. The problem facing enforcement agencies today is one of maximizing the effect of law enforcement on hazardous behavior with available personnel while minimizing the costs. The solution can perhaps be broken into two parts -- (1) Find what effect certain enforcement techniques have on driving behavior, and (2) with this knowledge apply the techniques and study the effect of the techniques on accident distribution. The total study involved four states, eleven separate highway segments, and approximately 5000 individual experimental observations.

This report concerned only one of the eleven states. The purpose of this study was to measure the immediate effect, if any, of certain enforcement symbols on driving behavior on two-lane, rural roadways. The term "symbol" denotes the equipment (patrol unit) usage ranging from none (control) to marked and unmarked cars, parked on either side of the roadway or traveling with the flow of traffic in either direction. There were nine different symbols used in the study. Speed was used as a measure of driving behavior. Because travel time was thought to be less affected by random variables than spot speeds, these times were used. On the test track used, four instruments, each including a camera for identification and recording, a clock and a radar unit, were hidden along side the roadway in "dummy" mail boxes. Each was activated when the target vehicle passed over a small pneumatic tube. The instruments were positioned exactly one mile apart ($\pm$ 10 ft.). All data were collected on a successive Monday and Friday at each of three sites during a three-week period. Each test day all nine treatments were used in random order in an attempt to overcome any variable factor and to distribute any potential systematic error through the entire investigation. The time for each treatment was variable depending on the time required to let ten free-flowing passenger cars (i.e., vehicles with headways of 15 seconds or more) to pass the mid-point. The treatment was stationed at the mid-point of the track and data were taken from both directions. Each target vehicle thus traveled through one mile of no treatment and a second mile where the treatment was located, and three speeds were recorded for each target vehicle. The results of the research revealed that the mean travel time was reduced most significantly by the treatment of the patrol unit moving into the predominant flow of

traffic on a given signal behind a moving vehicle. Analysis showed that there was a significant difference from treatment to treatment. An attempt was made to determine the immediate effect of enforcement on the speeds of vehicles traveling above the speed limit. Here, for a specific treatment, the number of vehicles which were traveling at speeds over the speed limit in the first mile but who slowed to speeds under the speed limit in the second or treatment mile was recorded. Also recorded was the number of vehicles which were traveling at speeds under the speed limit in the first mile who increased their speeds to ones above the speed limit in the treatment mile. These numbers were compared to determine whether or not they varied significantly. Here the results varied with the treatment and site. At the end of each test day another test was run in an attempt to determine the degeneration of the immediate effect of enforcement on spot speeds. The patrol unit was parked beside the roadway preceding the initial point at one end of the test track for 15 minutes and spot speeds were recorded at all cameras. Then the patrol unit was removed and data was recorded for a 15 minute control period. The procedure was then repeated at the opposite end of the test track. A plot of the averages at each point for the test data versus the control data at each site revealed that the spot speeds were consistently lower for the test runs and remained lower for three miles. The conclusion was drawn that the effect degenerates, but not totally in three miles. The researchers then reemphasized the point that the data and conclusions drawn pertained to only the particular type of road and traffic characteristics studied and were not to be extrapolated to other types. Here, the great need for more research in the area was

cited. The findings of the experiment were as follows:

1. The presence of an enforcement symbol has a significant effect upon the speed at which vehicle operators travel between points within a test site.

2. The conspicuously marked patrol vehicle, moving with the predominant traffic flow within a test site, has a greater immediate effect on speed between observation points within a test site than any other symbol tested.

3. Regardless of the symbol introduced into the highway segment studied, the greatest immediate effect is observed when the symbol is positioned at or operated from the side of the roadway carrying the predominant traffic volume.

4. The immediate effect of the marked enforcement symbol is maintained for a distance greater than three miles.

5. Both the marked and unmarked symbol had a significant effect on reducing the number of vehicles over the speed limit after exposure at one site. At other sites no significant reduction was observed for the unmarked symbol.

In summary, a review of the research concerning the effects of enforcement on speed shows the following general findings:

1. The presence of a patrol unit has a significant effect on vehicular speeds within a test site.

2. The most effect is caused by a conspicuously marked patrol car.

3. The range of effect of a patrol unit parked beside the roadway is at least three miles.

4. The proportion of passenger vehicles exceeding the legal speed limit is reduced after assignment of additional enforcement units to a stretch of highway.

However, because some of the statistical analyses employed in certain studies may be questioned, these conclusions should be considered tentative at this time. Available data do not provide information concerning the following:

1. The effect of enforcement in certain actual patrol situations, e.g., the effect of a single moving patrol unit on oncoming traffic in terms of speed and number of vehicles exceeding the speed limit.

2. The true effect of additional enforcement on a given stretch of highway.

3. The effect of enforcement on different types of highway and different traffic characteristics.

4. How enforcement affects behavior responses such as tracking, alertness, passing maneuvors, and spacing.

5. The effect of enforcement on accidents.

METHOD

The purpose of this study was to determine the effects of two enforcement techniques on vehicular speed. The two techniques employed were:

1. A stationary speed watch in which a patrol unit is located beside the roadway and the operator checks the speed or vehicles as they pass.

2. A moving speed watch in which vehicles are clocked by the patrolling unit while it is moving in the stream of traffic.

In this study, analyses were based only on speeds of vehicles approaching from a single direction in the stationary watch condition and speeds of vehicles meeting the enforcement unit in the moving watch condition.

Target Vehicles

Speed data were based on free-flowing automobiles only. The term "free-flowing" refers to vehicles which in the observor's judgment had freedom to attain the speeds the drivers desired to attain. No vehicles whose speed was slowed by a commercial vehicle or other slow

moving automobile was clocked. In instances of queues, the lead vehicle was the target vehicle whose speed was clocked.

Because there is some evidence that the speed of trucks is to some extent controlled by the topography of the roadway, no speed data were collected on trucks. Thus any vehicle with more than two axles or more than two wheels on any one axle was eliminated from the study.

Research Units

Data collected consisted of vehicular speeds measured at three points in the research frame (see Figure 1). The first point, hereafter called Point A, was the location of an unmarked car approximately 1-¼ miles upstream from the marked enforcement unit. Point B, the second point in the research frame, was the location of the enforcement unit or symbol, a North Carolina State Highway Patrol Unit clearly identified as such. Point C, the location of a second unmarked car, was located approximately 1-¼ miles downstream.

In each of the three cars or units, there were a driver and an observor. The driver drove the vehicle at a predetermined speed and operated the speed recording device.[3] The observor counted the vehicles met in the oncoming stream of traffic. When a vehicle was clocked, the observor recorded the speed and a short description of the vehicle, including make, year, color, and its number in relation to the total vehicular count. This information was dictated onto a tape for later

[3] The device used in all units was the VASCAR, the Visual Average Speed Computer and Recorder, a mechanical computer of vehicular speed using time and distance traveled by the target vehicle. For operational and testing information, refer to (13).

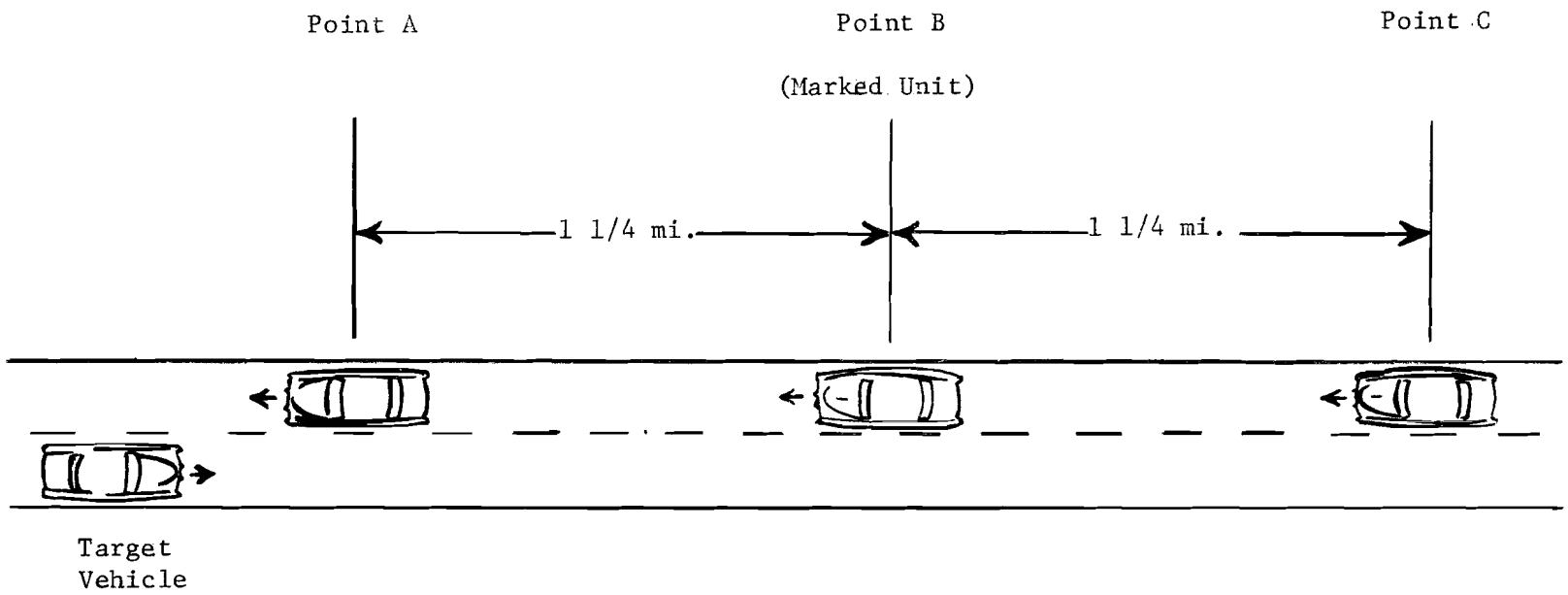

Figure 1. Research frame for moving segments of the testing

transcription. The observor also operated a radio at predetermined headway check points to ascertain that proper distances were being maintained between the three experimental units. The vehicles at Points A and C, an unmarked Ford and an unmarked Plymouth, were employed in an effort to minimize the effects of these vehicles on the speed of traffic and thus to help insure that any noticeable effect was attributable to the enforcement symbol.

Test Track

The test track chosen for the research was a four-sided rectangle of roadway located in central North Carolina. Its sides measure 10, 12, 17, and 18 miles in length, and the total track measures 57 miles. A major consideration in the choice of track was the nature of the roadways themselves. The use of roadways with the same or similar characteristics was desired in order to reduce various systematic errors in the data. All four segments of the track are rural two-lane roadways and all possess similar topographic features. None is a special purpose type facility such as a recreational route. The speed limit on two segments is 55 mph and on the other two segments is 60 mph.

Preliminary studies indicated that the volume characteristics of the four chosen test segments were similar in nature, an important requirement in terms of eliminating systematic errors. Volume counts during the actual test runs were conducted for determination of the level of service[4] for each of the segments. The final calculations indicated that all of the segments were operating under conditions of high speeds and low volumes.[5]

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[4] Level of service denotes the operating conditions of a given roadway.

[5] All segments were operating at level of service A or B.

Testing Procedure

Moving Runs. As indicated earlier, the testing procedure included two techniques, the moving speed watch and the stationary speed watch. The moving runs were begun at 9:00 A.M. each testing day. Four revolutions of the four-sided test track were completed each day. Two revolutions were experimental runs and the other two were control runs.

In the experimental runs all three units (the two unmarked vehicles and the marked State Highway Patrol car) met at the starting point of the first segment (Segment 1). After equipment checks were completed, unit A, the lead car, would depart and accelerate to the predetermined running speed (5 mph below the posted speed limit). The observor in this car would radio the other two units when he passed a preset check point. Upon receiving this radio signal, unit B would leave the starting point and travel in the same direction as the lead car. Unit B would repeat the signaling procedure upon reaching the check point to enable Car C to depart and join the research frame. In this manner headway distances of between 1.25 and 1.50 miles were established between the successive test units. Each unit began to collect data as soon as it had accelerated to the proper running speed. At the end of each segment all units stopped at the starting point of the next segment of the track and repeated the same starting procedure as before.

In the control runs the same procedure was used as in the experimental runs with the exception that there was no enforcement unit present (Unit B). Thus Car A and Car C traveled through the run approximately 2-½ to 3 miles apart. Measurements were obtained by both units in order to control

for whatever effect the first unmarked unit might have upon traffic speed. Headways were established and maintained by use of a clocking procedure and checkpoints as previously described.

In both the experimental and control conditions all vehicles clocked were meeting the research units and were therefore traveling in a counter-clockwise direction around the test track.

Stationary Runs. In the stationary runs, as in the moving runs, speed measurements were obtained at three distinct points, hereafter referred to as Points A, B, and C. Successive points were located approximately 1.25 to 1.50 miles apart to correspond to the headways in the moving runs. The unmarked units were located at Points A and C and in most cases were parked at roadside rest areas, hidden from view by the available trees and shrubbery, or disguished as vehicles in distress (having a flat tire, engine trouble, etc.). As in the moving runs, one man in each car operated the speed recording unit while the other man operated the radio and tape recorder. In addition, volume counts were made for traffic traveling in both directions. At point B the marked Highway Patrol vehicle was parked beside the roadway, clearly visible from both directions. As in the moving runs, only vehicles traveling in a counter-clockwise direction (in relation to the entire test track) were clocked.

In the control portions of the stationary runs the basic procedure was the same as in the experimental portions except that the enforcement unit was removed. The remaining units, Car A and Car C, were stationed at the same sites on each of the test segments as in the experimental portions and each recorded data similar to that of the experimental

portions. Both units were employed in the control condition in order to detect any speed deviations between points A and C caused by topographical features, as well as any changes in speed caused by the presence of unit A in the research frame.

The Test Schedule

Figure 2 depicts the test schedule used. Although the enforcement unit was available for only half a day at a time, it was possible to counterbalance the conditions in such a way as to control for variations in time of day. In Figure 2 the symbols "MR," "MC," "SR," and "SC," denote respectively a moving experimental run with the enforcement unit present, a moving control run with no enforcement unit, a stationary experimental run with enforcement unit, and a stationary control run with no enforcement unit. Those research blocks in the figure that are outlined with broken lines depict the test runs during which the enforcement unit was present.

RESULTS

This study was designed to determine, first, whether there is a significant short term or immediate effect of enforcement on vehicular speeds on two-lane rural roadways, and, second, whether there is a significant difference between the effects of a moving enforcement symbol and a stationary enforcement symbol on vehicular speeds.

All analyses were limited to pairs of "matched" speeds. These "matched" speeds were obtained in the following manner. As noted earlier, a description was obtained of each target vehicle clocked by a research unit. Descriptions were later compared to match those for the same vehicles. In this manner data were isolated for those vehicles

Time	Monday (6/10)	Tuesday (6/11)	Wednesday (6/12)	Thursday (6/13)
9:00-10:30	MR-1	MR-1	MR-1	MR-1
10:30-12:00	MR-2	MR-2	MR-2	MR-2
1:00-2:30	MC-1	MC-1	MC-1	MC-1
2:30-4:00	MC-2	MC-2	MC-2	MC-2
	(6/17)	(6/18)	(6/19)	(6/20)
9:00-10:30	MC-1	MC-1	MC-1	MC-1
10:30-12:00	MC-2	MC-2	MC-2	MC-2
1:00-2:30	MR-1	MR-1	MR-1	MR-1
2:30-4:00	MR-2	MR-2	MR-2	MR-2
	(6/24)	(6/25)	(6/26)	(6/27)
9:00-10:30	SR-(15-501)	SR-(15-501)	SR-(64)	SR-(55)
10:30-12:00	SR-(54)	SR-(64)	SR-(55)	SR-(54)
1:00-2:30	SC-(15-501)	SC-(64)	SC-(64)	SC-(54)
2:30-4:00	SC-(54)	SC-(15-501)	SC-(55)	SC-(55)
	(7/1)	(7/2)	(7/10)	(7/11)
9:00-10:30	SC-(15-501)	SC-(15-501)	SC-(64)	SC-(55)
10:30-12:00	SC-(54)	SC-(64)	SC-(55)	SC-(54)
1:00-2:30	SR-(15-501)	SR-(64)	SR-(64)	SR-(54)
2:30-4:00	SR-(54)	SR-(15-501)	SR-(55)	SR-(55)

MR- Moving Experimental Run (with enforcement unit). SR-(55) -Stationary Experimental Run on NC-55.
MC- Moving Control Run (without enforcement unit). SC-(64) -Stationary Control Run on US-64.

Figure 2. Final test run schedule

which were clocked at all three points in the research frame. Thus the three speeds for a particular vehicle which had been clocked by all three research units (cars A, B, and C) would be used, while the speeds of a vehicle clocked by unit A but not by unit C would not be included in the data to be analyzed. The former speeds are considered "matched", while the latter are not. This use of "matched" speeds was employed for all moving, stationary, experimental, and control phases of the study. The resulting numbers of vehicles for each condition are shown in Table 1. In explanation, cell (213) containing the number 59 represents cell $A_2B_1C_3$ and includes all stationary (A_2) experimental (B_1) speeds from segment 3 of the test track (C_3). The 59 refers to the number of "matched" speeds which fall into this category. Thus there were 59 vehicles which were clocked at points A, B, and C on segment 3 of the test track during the stationary experimental condition.

Table 1. Data cell sample sizes

Track	MOVING (A_1)		STATIONARY (A_2)	
	Experimental (B_1)	Control (B_2)	Experimental (B_1)	Control (B_2)
C_1	(111) 42	(121) 28	(211)47	(221) 76
C_2	(112) 44	(122) 30	(212) 46	(222) 63
C_3	(113) 68	(123) 67	(213) 59	(223) 72
C_4	(114) 39	(124) 52	(214) 39	(224) 64

Statistical analyses involved, first, an analysis based on the mean speeds at each point in the different test situations, and, second, an analysis based on speeds classified as either legal or illegal.

Analyses Based on Mean Speeds

Table 2 shows the mean speeds at all three points in the experimental conditions, while Table 3 shows the magnitude of speed changes between the points. Examination of these tables indicates that in the moving runs the target vehicles approaching the enforcement unit increased their speed on some segments of the test track, while decreasing on others. With the exception of one track segment, there tended to be an increase in speed after passing the enforcement vehicle.

For the stationary conditions there were more consistent trends. Between points A and B (as the target vehicles approached the parked enforcement unit) there was a consistent decrease in speed. However, after passing the enforcement unit the target vehicles increased their speed again.

Table 2. Means of "matched" speeds obtained during experimental segments of testing at all points

	MOVING			STATIONARY		
Track	Point A	Point B	Point C	Point A	Point B	Point C
1	50.27	51.50	51.98	54.68	48.29	53.45
2	60.95	60.68	59.73	59.54	53.28	57.87
3	59.87	60.72	60.83	58.20	52.25	57.56
4	52.69	51.63	54.31	56.23	50.31	54.41

Table 3. Differences between point means presented in Table 2

	MOVING		STATIONARY	
Track	B-A	C-B	B-A	C-B
1	+1.23	+0.48	-6.39	+5.16
2	-0.27	-0.95	-6.26	+4.59
3	+0.85	+0.11	-5.95	+5.31
4	-1.06	+2.68	-5.92	+4.10

Note: A minus sign indicates a decrease in speed between the two points indicated, while a plus sign indicates an increase in speed.

Because in the control conditions there were no speed measures obtained at point B, the rest of the analyses of mean speeds are based on speeds obtained at points A and C. In this way direct comparisons can be made between the experimental and control conditions.

Table 4 shows the mean speeds for each point on each track segment for each research condition. As can be seen, there are some slight differences in absolute speeds on the different segments of the test track even when speed limits are the same. For example, segments 1 and 4, each of which has a posted speed limit of 55 mph, exhibit mean speeds that differ by approximately 2 mph, indicating a difference in actual travel speeds for the two roadways. Segments 2 and 3, with a posted speed limit of 60 mph, exhibit somewhat similar, although smaller, differences.

Table 5 shows the differences in the mean speeds between points

A and C for each of the test conditions. It can be seen by examination of the first column that in three out of the four segments of the test track in the moving experimental condition the target vehicles showed an increase in mean speed between points A and C. This means that the target vehicles increased their speeds to higher levels than they had been at point A after meeting and passing the patrol vehicle. This kind of maneuver would be considered by most law enforcement personnel to be rather undesirable. In the corresponding control phase (column 2 of Table 5) the differences in speeds between points A and C were smaller and varied in direction. The overall difference for the control condition was only .06 mph, indicating that the control conditions were effective in failing to influence the speed of vehicles.

The right half of Table 5 shows the results for the stationary conditions. In the experimental runs (with the enforcement unit parked by the road) there is a decrease in speed between points A and C for all four track segments. This means that while the target vehicles did tend to increase their speeds after passing the stationary patrol unit, they did not return to as high a speed as they had been traveling at point A. While there was also a decrease in speed under the control conditions (no enforcement unit present), the magnitude of the decrease was not so great.

Table 4. Means of "matched" speeds obtained in all phases of testing

Segment	MOVING				STATIONARY			
	Experimental		Control		Experimental		Control	
	Point A	Point C	Point A	Point C	Point A	Point C	Point A	Point C
1	50.27	51.98	50.50	50.68	54.68	53.45	54.11	53.96
2	60.95	59.73	60.30	59.83	59.54	57.87	60.68	60.30
3	59.87	60.83	57.78	57.97	58.20	57.56	60.61	59.47
4	52.69	54.31	52.98	52.69	56.23	54.41	54.89	53.33
Overall	56.58	57.33	55.64	55.58	57.26	55.98	57.50	56.71

Table 5. Differences between point means presented in Table 4

Track Segment	MOVING		STATIONARY	
	Experimental	Control	Experimental	Control
1	+1.71	+0.18	-1.23	-0.15
2	-1.22	-0.47	-1.67	-0.38
3	+0.96	+0.19	-0.64	-1.14
4	+1.62	-0.29	-1.82	-1.56
Overall	+0.75	-0.06	-1.28	-0.79

Note: A minus sign indicates a decrease in speed between the two points indicated, while a plus sign indicates an increase in speed.

Thus, analyses of the mean speeds indicate that the moving enforcement unit is associated with <u>increases</u> in the speed of target vehicles once they have passed the unit. On the other hand, an enforcement unit parked by the roadway leads to a <u>decrease</u> in the speed of the target vehicles, even after they have passed the unit.

Variation in Mean Speeds

Because greater variation in speed is likely to be associated with higher accident rates (Bureau of Public Roads, 1959), it is of interest to examine this feature of the data. Tables 6 and 7 present the variances and standard deviations of the speeds recorded in the various test conditions. These figures represent the spread or the scatter of the data, that is, they indicate the degree to which the data group or cluster around the mean. The data indicate that there was a considerable range in speeds. For example, approximately 98% of the observed speeds in the moving experimental condition at point A on segment 1 of the test track fell between 32.06 mph and 68.48 mph, a fairly wide span. For other conditions the spans are even larger.

Table 6. Variances of speed data in all cells

Track	MOVING				STATIONARY			
	Experimental		Control		Experimental		Control	
	Point A	Point C	Point A	Point C	Point A	Point C	Point A	Point C
1	36.84	43.58	30.63	44.08	33.74	24.08	47.30	41.48
2	69.49	56.30	54.72	57.18	32.88	22.16	36.96	62.15
3	58.98	42.77	63.66	44.33	44.51	34.49	41.31	46.28
4	73.27	65.11	77.71	29.39	31.13	19.99	26.73	30.13

Table 7. Standard deviations of speed data in all cells

Track	MOVING				STATIONARY			
	Experimental		Control		Experimental		Control	
	Point A	Point C	Point A	Point C	Point A	Point C	Point A	Point C
1	6.0696	6.6015	5.5344	6.6393	5.8086	4.9071	6.8775	6.4405
2	8.3361	7.5033	7.3770	7.5617	5.7341	4.7074	6.0795	7.8835
3	7.6788	6.5399	7.9787	6.6581	6.6716	5.8728	6.4273	6.8029
4	8.5598	8.0691	8.8153	5.4213	5.5794	4.4710	5.1701	5.4891

In comparing the variances in speed over the four tracks at point A and at point C, it was found that they were not equal (Barlett's test, in Snedecor and Cochran's Statistical Methods, page 296, see Appendix B). While such inequality of variance may raise some questions regarding comparisons of speeds between points A and C, nevertheless this finding suggests that the presence of the enforcement symbol may not only serve to decrease the faster traveling vehicles but may also encourage vehicles traveling at very low speeds to increase their speeds to a more desirable level. In theory, if all vehicles traveled at an identical speed, the number of certain types of accidents would decrease. Therefore, if the presence of an enforcement vehicle causes the speeds of all vehicles to cluster more closely around the mean speed, then the standard deviations in the experimental conditions should be smaller than those in the corresponding control conditions at point C. From Table 7 it can be seen that this trend does appear in the stationary conditions.

These control and experimental variances were statistically compared using the F-test for equality of two variances (See the Appendix B, page for the test statistic and the corresponding results.) At point A of the

stationary runs, the control data variance was apparently larger than the experimental data variance. ($.05 < p < .10$) This suggests that there was some difference between control and experimental runs at this point and can be indicative of some source of error. At point C in the stationary runs, the control data variance was much larger than the experimental data variance. This difference was highly significant ($p < .001$). This difference indicates that in the stationary runs, the presence of the enforcement symbol did cause the speeds to group more closely about the mean speed.

In the moving runs, the same statistical test indicated a different trend. At point A, the control and experimental data variances were not statistically different, as would be expected. At point C, the point following the enforcement unit, the control data variance and the experimental data variance were slightly different (p approximately .10). Of interest here is the direction of the difference. The experimental data variance was greater than the variance of the control data. This indicates that the effect of the moving enforcement symbol was a divergence or spread of the speeds from around the mean speed, an undesirable trend if the above stated theory is valid. Once again the stationary patrol car appears to have a greater effect in the desired direction than does the moving patrol car.

Analyses Based on "Grouped" Speeds

The second major analytical methodology employed in this research is one involving a grouping technique. Vehicles were classified according to whether they were traveling above or below the posted speed limit. The presence of the enforcement symbol was analyzed according

to its effect upon the percentage of illegal drivers, i.e., those drivers traveling above the posted speed limit.

If it is postulated that the posted speed limit on a highway may be established as a break point between relatively safe travel and unsafe travel, then a decrease in the number of drivers over the speed limit could correspondingly lead to a decrease in the accident rate and an increase in the safety of the roadway. The posted speed limit in North Carolina is determined by a combination of factors, including various roadway characteristics and the actual speed at which users travel. While it is difficult to assume that there is one definite speed which marks the absolute limit of safe travel under all conditions, an arbitrary break point must be chosen for research purposes. Because of public awareness that the posted speed limit represents a guide for maximum safe travel speed and that legal action is initiated against those who are apprehended at speeds above this limit, it was felt that the presence or absence of enforcement symbols would likely be reflected by the proportion of vehicles traveling below or above this speed limit. It was also felt that, because enforcement is aimed primarily at the law breaker, changes in the legal-illegal speed variable would better reflect the importance of enforcement than would changes in the mean speeds.

Table 8 presents the percentage and frequencies of legal (L) and illegal ($\bar{L}$) vehicles for the various test conditions. The table in Appendix A includes a complete breakdown of the data by segment of the test track). Table 9 presents the same data classified as to experimental versus control conditions, while Table 10 presents the data broken down according to moving versus stationary runs.

Table 8. Frequency and Percentage of legal (L) and illegal ($\bar{L}$) target vehicles

	EXPERIMENTAL				CONTROL			
	A \ C →	L	$\bar{L}$	Total	A \ C →	L	$\bar{L}$	Total
MOVING	L	73 (37.8)	42 (21.8)	115 (59.6)	L	87 (49.2)	25 (14.1)	112 (63.3)
	$\bar{L}$	33 (17.1)	45 (23.3)	78 (40.4)	$\bar{L}$	35 (19.8)	30 (16.9)	65 (36.7)
	Total	106 (54.9)	87 (45.1)	193 (100.0)	Total	122 (68.9)	55 (31.1)	177 (100.0)
		L	$\bar{L}$	Total		L	$\bar{L}$	Total
STATIONARY	L	85 (44.5)	19 (9.9)	104 (54.5)	L	116 (42.2)	30 (10.9)	146 (53.1)
	$\bar{L}$	44 (23.0)	43 (22.5)	87 (45.5)	$\bar{L}$	45 (16.4)	84 (30.5)	129 (46.9)
	Total	129 (67.5)	62 (32.5)	191 (100.0)	Total	161 (58.5)	114 (41.5)	275 (100.0)

Table 9. Frequency and Percentage of legal and illegal target vehicles in the moving and in the stationary segments of the testing

MOVING				STATIONARY			
A \ C →	L	$\bar{L}$	Total	A \ C →	L	$\bar{L}$	Total
L	160 (43.2)	67 (18.1)	227 (61.4)	L	201 (43.1)	49 (10.5)	250 (53.6)
$\bar{L}$	68 (18.4)	75 (20.3)	143 (38.6)	$\bar{L}$	89 (19.1)	127 (27.3)	216 (46.4)
Total	228 (61.6)	142 (38.4)	370 (100.0)	Total	290 (62.2)	176 (37.8)	466 (100.0)

Table 10. Frequency and Percentage of legal and illegal target vehicles in the experimental and in the control segments of the testing

EXPERIMENTAL				CONTROL			
A↓ \ C→	L	$\bar{L}$	Total	A↓ \ C→	L	$\bar{L}$	Total
L	158 (41.1)	61 (15.9)	219 (57.0)	L	203 (44.9)	55 (12.2)	258 (57.1)
$\bar{L}$	77 (20.1)	88 (22.9)	165 (43.0)	$\bar{L}$	80 (17.7)	114 (25.2)	194 (42.9)
Total	235 (61.2)	149 (38.8)	384 (100.0)	Total	283 (62.6)	169 (37.4)	452 (100.0)

These data were analyzed in terms of the following hypotheses.

1. The Marginals of Point A Do Not Differ on M/S. The null hypothesis to be tested is, in simplest terms, a statement of the fact that the totals of legal and illegal drivers at point A are not significantly different in the moving and stationary segments of the testing. In testing this hypothesis, as well as those to follow, three divisions were used. First the hypothesis was tested when summing over all other effects (i.e., within E/C). This is a test of the marginals of A in Table 9. Additional tests were then conducted concerning the null hypothesis within only the experimental segments and within only the control segments to detect any inconsistencies which might have been present. The statistical test employed was a Chi-square test of significance as explained by Bhapkar and Koch (3). (See Appendix B for results).

In the first hypothesis, the results are rather unclear as to a significant difference in the marginals within E/C. On the basis of a

"p" = 0.05, no difference is shown. Within the experimental segments of the testing (see Table 8 left side) there is no significant difference in the marginals indicating that the stationary and moving tests are good representatives of each other at this point. In the control segments of the testing, however, there are significant differences in the marginals of point A. This indicates that point A of the stationary testing is not a good representation of the entire test track, a statement supported by earlier analysis.

It is difficult to determine the reasons for this difference in results. But of further interest is study of Table 11, which presents only the percentages for point A classified as either moving or stationary. The differences in this table again reveal the conclusion that the stationary points could not be assumed to be representative of the entire track, a conclusion also supported by results of the initial mean analysis.

Table 11. Percentages of legal and illegal vehicles at point A with differentiation by moving -- stationary variable

	Moving	Stationary
Legal	61.4	53.6
Illegal	38.6	46.4

In order to better examine the trends in this legal versus illegal speed analysis, a second breakpoint was established. In this analysis the limit of legal travel was set at the posted speed limit plus a 5 mph tolerance. This was done in an attempt to overcome any error in

the speed detection device (which is less than 2 mph) which might have caused misclassification of a vehicle, and to try to insure that the bulk of vehicles traveling at illegal speeds were not those driving at 1 or 2 mph above the posted speed limit, a common occurrence. Table 12 presents the frequency and percentage of legal and illegal vehicles as determined by the speed limit plus tolerance breakpoint. Analysis was conducted in the same manner as in the initial legal-illegal tabulation as determined with the posted speed limit.

Table 12. Frequency and Percentage of legal (L) and illegal ($\bar{L}$) target vehicles (as determined by speed limit plus tolerance)

	EXPERIMENTAL				CONTROL			
	A ↓ / C →	L	$\bar{L}$	Total	A ↓ / C →	L	$\bar{L}$	Total
MOVING	L	137 (71.0)	19 (9.8)	156 (80.8)	L	139 (78.5)	13 (7.4)	152 (85.9)
	$\bar{L}$	25 (13.0)	12 (6.2)	37 (19.2)	$\bar{L}$	21 (11.9)	4 (2.2)	25 (14.1)
	Total	162 (84.0)	31 (16.0)	193 (100.0)	Total	160 (90.4)	17 (9.6)	177 (100.0)
		L	$\bar{L}$	Total		L	$\bar{L}$	Total
STATIONARY	L	154 (80.6)	9 (4.7)	163 (85.3)	L	211 (76.7)	19 (6.9)	230 (83.6)
	$\bar{L}$	23 (12.1)	5 (2.6)	28 (14.7)	$\bar{L}$	22 (8.0)	23 (8.4)	95 (16.4)
	Total	177 (92.7)	14 (7.3)	191 (100.0)	Total	233 (84.7)	42 (15.3)	275 (100.0)

In this first hyphothesis, the results of the speed limit plus tolerance data analysis (hereafter called "tolerance data") were similar to the results of the first analysis. There were no significant differences in the marginals within E/C, experimental, or control. The lack of significances in the experimental and control segments indicate that the stationary point A was a good representation of the moving point A when the speed limit plus tolerance breakpoint is used.

2. Marginals of Point A Do Not Differ on E/C. This hypothesis is a statement of the fact that the percentage of legal and illegal vehicles at point A is unaffected by whether the test run is experimental, with the enforcement symbol present, or control. The test results of all three breakdowns indicate that this hypothesis is acceptable. There is no significant difference in the marginals of point A between the experimental and control segments, a fact which would suggest that the research procedure was good in that there was no effect caused by point A. The three resulting "p" values are found from studying Table 10 for overall differences, the top half of Table 8 for differences within the moving segments, and the lower half of the same table for differences within the stationary segments of the research.

In analysis of the tolerance data, the same results are indicated. There is no significant difference in the marginals of point A between the experimental and control segments within M/S, moving, or stationary.

3. Marginals of Point C Do Not Differ on E/C. The hypothesis, is in simple terms a statement concerning the presence or absence of a significant effect resulting from the presence of the enforcement symbol. Here, as before, the hypothesis is tested within three frames of reference

-- M/S (Table 10), moving (Table 8, upper half), and stationary (Table 8, lower half). Within all three frames of reference, the above stated hypothesis is rejected, suggesting the presence of an effect caused by the enforcement symbol. (M/S - $p < .005$, M - $p < .01$, S - $p < .05$)

Study of the "p" values or level of significance indicates an even larger effect caused by the moving enforcement symbol than by the stationary symbol, an indication which at first glance would appear inconsistent with results of the initial mean analysis. Study of the actual changes in percentages of legal and illegal vehicles at point C does reveal, however, that the effect of the moving enforcement symbol is an <u>increase</u> in the percentage of <u>illegal</u> vehicles between the two points, while in the stationary segments of the testing a corresponding <u>decrease</u> in illegal vehicles is noted.

The tolerance data analysis reflects similar results. Within M/S, there is no significant difference between the experimental and control data. However, this lack of difference is caused by the cancelling effect of the combination of the moving and stationary data. Within the stationary segments, there is a large difference with significantly <u>fewer</u> illegal drivers in the experimental group ($p < .01$). In the moving segments, however, the results parallel those of the speed limit analysis. There are <u>more</u> illegal vehicles at point C in the experimental runs than in the control segments, although to a lesser degree of significance ($p < .10$). These two effects cancel when combined to cause the lack of difference in the M/S breakdown.

Both analyses reinforce the earlier conclusion that the moving enforcement symbol leads to an increase in speeds through the test frame. They also support the conclusion that in the stationary segments of the research, there was a significant reduction effect.

4. Marginals of Point C Do Not Differ on M/S. This may be regarded as further testing of the second general hypothesis, that there is no difference between the effects of moving and stationary enforcement symbols. Within all three frames of reference, the above stated hypothesis can be rejected, indicating a difference in the marginals between the moving segments and the stationary segments. (Within E/C - $p < .005$, E - $p < .025$, C - $p < .05$) Analysis of the left half of Table 8, the experimental cells, results in a "p" value indicating a more significant difference between the moving and stationary segments than is found in the control cells of the two segments.

While this does indicate a difference between the moving and stationary parts, the more important indication of the direction of the effect can only be gained from close study of the percentages in Table 13. Here study of the experimental cells of the tables indicates the aforementioned increase in percentage of legal vehicles between points A and C in the stationary test segments and decrease in the percentage of legal vehicles in the moving test segments.

Again the speed limit plus tolerance data were analyzed in a similar manner. Again, in the experimental segments of the testing there is a greater significant difference between the percentage of illegal vehicles in the moving segments versus the stationary segments ($p < .01$). There are fewer illegal vehicles in the stationary segments of the testing. Within the control segments, the stationary percentage of illegal vehicles is higher than the moving illegal percentage to some degree ($p < .10$), a characteristic of the final point not being representative of the whole track. Combined, these two effects again cause a cancelling to occur resulting in a lack of significance within the E/C analysis.

The results of the four above stated hypotheses suggest trends which are presented in another manner in Table 13. Here the illegal vehicle percentages alone are presented in the form of percentages over the speed limit. The third column indicates the change in the percentages of illegal vehicles between the two points with a positive percentage indicating an increase in the percentage of illegal vehicles. Of interest is the almost identical decrease of illegal vehicles between points A and C in the two control segments of the testing. In both the moving control and the stationary control, there is a decrease of approximately 5.5%. Adding even further proof to the aforementioned conclusions is the appearance of a greater decrease in illegal vehicles during the stationary experimental testing than in the control segments coupled with the increase of illegal vehicles in the moving experimental testing.

Table 13. Percentages of target vehicles traveling at speeds over the posted speed limit in the various segments of the testing

TEST SEGMENT	Point A	Point C	Difference (C-A)*
MOVING - EXPERIMENTAL	40.4	45.1	+ 4.7
MOVING - CONTROL	36.7	31.1	- 5.6
STATIONARY - EXPERIMENTAL	45.5	32.5	-13.0
STATIONARY - CONTROL	46.9	41.5	- 5.4
EXPERIMENTAL	43.0	38.8	- 4.2
CONTROL	42.9	37.4	- 5.5
MOVING	38.6	38.4	- 0.2
STATIONARY	46.4	37.8	- 8.6
OVERALL TOTALS	42.9	38.0	

*NOTE: A minus (-) number in the difference column indicates a decrease in the percentage over the speed limit between point A and point C.

SUMMARY AND CONCLUSIONS

Every state employs an extensive system of law enforcement on the highway. The general assumption behind such effort is that the presence of enforcement not only leads to apprehension of the violator, but, perhaps more importantly, serves as a deterrent to violation of the traffic laws. It is important, therefore, to know to what extent enforcement does indeed serve as a deterrent to traffic violations. This study examined specifically the effects of enforcement on vehicular speeds on rural two-lane roadways.

In order to stimulate closely the procedure used by the North Carolina Highway Patrol, two enforcement techniques are employed, (1) a stationary speed watch, in which the patrol car was parked beside the road; and (2) a moving speed watch, in which the patrol car traveled in the stream of traffic. The speed of oncoming target vehicles was clocked at three points in the research frame. Each target vehicle was first clocked by an unmarked research unit approximately 1-¼ miles upstream from the enforcement symbol, a North Carolina State Highway Patrol vehicle. The target vehicle was clocked again at the enforcement symbol, and a third time by another unmarked vehicle at a point 1-¼ miles downstream from the enforcement symbol. Analyses were employed to determine differences in the speed of target vehicles before they reached the enforcement symbol and after they had passed it. The two general questions to be tested were:

1. Whether there is a significant effect of enforcement on vehicular speeds on two lane rural roadways.

2. Whether there is a significant difference between the effect of a moving enforcement symbol and a stationary enforcement symbol on vehicular speeds.

Analyses were based on differences in mean speeds obtained at the "before and after" points (points upstream and downstream from the enforcement symbol), and differences in the number of vehicles traveling at speeds above the posted speed limit at the same two locations.

The results indicated that vehicles which passed an enforcement symbol, either moving or stationary, were significantly affected by its presence. However, the effects were different for the moving enforcement symbol as opposed to the stationary one. In the stationary condition (the patrol car parked beside the road) the effect was a decrease in mean speeds and a decrease in violators (drivers traveling above the posted speed limit) between the "before and after" observation points. In other words, the average speed for the target vehicles was lower at the downstream observation point than the average speed of the same vehicles at the upstream observation point. There was also noted a corresponding decrease in the number of illegal (over the speed limit) target vehicles between the two points.

When a moving enforecment symbol was injected into the stream of traffic, the effect on oncoming vehicles was different from the effect of a parked patrol car. The moving patrol car resulted in either no change in speed between the two observation points or an increase in mean speed between the two points. There was a corresponding increase in the number of vehicles traveling at speeds above the posted speed limit at the downstream observation point as compared with the upstream point.

The results of this study are consistent in indicating that the stationary enforcement unit, as compared with the moving unit, is

more likely to be associated with a decrease in mean speed, as well as a decrease in the number of illegal drivers (drivers traveling above the posted speed limit). By contrast, vehicles meeting and passing a moving patrol car (traveling in the opposite direction) not only did not tend to decrease their speed, but in some instances tend to increase their speed. While many associated questions remain unanswered, such findings suggest that there may be a need for a re-evaluation of the most effective means of employing enforcement units. It should not be concluded, however, that all patrol vehicles should be parked beside the roadway at all times. This would be highly impractical. There are many times when a patrol unit must be on the road, and at these times moving patrol techniques are called for. However, if the newly gained capability of the moving clock is to be utilized toward the fullest deterrent effect, the public must be made more aware of this capability. This can be accomplished either by propaganda or by increased use of the clocking technique. The results also indicate that there may be need for changes in the moving patrol procedure. One possibility would be to have the patrol unit "backtrack" over a stretch of road more often to insure that deviate behavior does not increase when drivers feel that they have passed him and are out of his "apprehension halo".

These results may also be considered on another level. This study does not justify an overall conclusion that law enforcement is ineffective. The long term effects of a climate of law enforcement just were not subject to observation in this study.

On the other hand, the study failed to show any evidence that mere presence of a moving patrol vehicle has an immediate short term

effect. Since the idea of selective enforcement in part depends on an assumption of just such a short term effect, this practice might well deserve some close scrutiny.

Through much more needed research in all areas of the enforcement field, it might be possible to realize some amount of increased enforcement efficiency.

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Appendix

The number of legal, (L) and illegal, ($\bar{L}$) target vehicles in all test segments

TRACK	MOVING Experimental				MOVING Control				STATIONARY Experimental				STATIONARY Control			
	(111) C → / A ↓	L	$\bar{L}$	Total	(121)	L	$\bar{L}$	Total	(211)	L	$\bar{L}$	Total	(221)	L	$\bar{L}$	Total
1	L	22	9	31	L	16	5	21	L	23	4	27	L	35	15	50
	$\bar{L}$	6	5	11	$\bar{L}$	5	2	7	$\bar{L}$	12	8	20	$\bar{L}$	9	17	26
	Total	28	14	42	Total	21	7	28	Total	35	12	47	Total	44	32	76
	(112)	L	$\bar{L}$	Total	(122)	L	$\bar{L}$	Total	(212)	L	$\bar{L}$	Total	(222)	L	$\bar{L}$	Total
2	L	15	8	23	L	9	5	14	L	21	4	25	L	22	6	28
	$\bar{L}$	10	11	21	$\bar{L}$	6	10	16	$\bar{L}$	11	10	21	$\bar{L}$	14	21	35
	Total	25	19	44	Total	15	15	30	Total	32	14	46	Total	36	27	63
	(113)	L	$\bar{L}$	Total	(123)	L	$\bar{L}$	Total	(213)	L	$\bar{L}$	Total	(223)	L	$\bar{L}$	Total
3	L	21	17	38	L	37	10	47	L	26	8	34	L	32	5	37
	$\bar{L}$	12	18	30	$\bar{L}$	11	9	20	$\bar{L}$	13	12	25	$\bar{L}$	10	25	35
	Total	33	35	68	Total	48	19	67	Total	39	20	59	Total	42	30	72
	(114)	L	$\bar{L}$	Total	(124)	L	$\bar{L}$	Total	(214)	L	$\bar{L}$	Total	(224)	L	$\bar{L}$	Total
4	L	15	8	23	L	25	5	30	L	15	3	18	L	27	4	31
	$\bar{L}$	5	11	16	$\bar{L}$	13	9	22	$\bar{L}$	8	13	21	$\bar{L}$	12	21	33
	Total	20	19	39	Total	38	14	52	Total	23	16	39	Total	39	25	64

APPENDIX B

Statistical Tests

In order to test for the equality of k variances (k > 2), a test derived by Barlett is appropriate. The test statistic for Barlett's test is given by

$$X^2 = \frac{M}{C}$$

where

$$M = 2.3026[(\Sigma\Sigma n_{ij})\ln s^{-2} - \Sigma\Sigma(n_{ij}\ln s_{ij}^2)]$$

$$C = 1 + \frac{1}{3(k-1)}\left[\Sigma\Sigma\frac{1}{(n_{ij})} - \frac{1}{\Sigma\Sigma(n_{ij})}\right]$$

with

s_{ij}^2 = sample variance for the i^{th} track and the j^{th} column within Point A (or Point C) for Table 7

n_{ij} = corresponding number of observations for the preceding situation

k = number of sample variances (= 16)

ln ( ) = natural (or Naperian) logarithm of ( ) with 2.3026 = ln 10

$s^{-2} = \frac{\Sigma\Sigma(n_{ij}s_{ij}^2)}{\Sigma\Sigma(n_{ij})}$ = pooled estimate of variance

Under the null hypothesis of eauality of the k variances, X^2 is distributed approximately as a X^2 variate with k-1 degrees of freedom.

Relative to Table 7, we have the following results:

Point A: M = 2.3026[(836) (3.863) - 3185.87]

= 100.37

C = 1.0074

so that

$X^2 = 99.6$ $p < .005$

Point C: $M = 2.3026\,[(836)\ (3.720) - 3066.74\,]$

$= 99.43$

$C = 1.0074$

so that

$X^2 = 98.7 \qquad p < .005$

In order to test for the equality of two variances, the ordinary F-test (or variance ratio test) is appropriate. This is given by

$$F^* = s_1^2 / s_1^2$$

where s_1^2 is the larger sample variance. Under the null hypothesis of equality of the two variances, F* is distributed as Snedecor's F with $(N_1\text{-}1,\ N_2\text{-}1)$ degrees of freedom where N_k, k = 1,2, is the number of observations involved in s_k^2.

For the tests described in the text, the following results were obtained:

Comparison	$F^* = s_1^2/s_1^2$	p-value
Moving:		
Point A: Exp. vs. Control	$\frac{14,990.6/192}{12,749.2/176} = 1.08$	.25 (n.s.)
Point C: Exp. vs. Control	$\frac{12,098.8/192}{9,320.9/176} = 1.19$	approx. .10
Stationary:		
Point A: Exp. vs. Control	$\frac{13,050.6/274}{7,535.5/190} = 1.20$	.05 $p <$ .10
Point C: Exp. vs. Control	$\frac{14,765.9/274}{5,575.7/190} = 1.84$	$<$ .001

Appendix C. Test Results for Hypotheses Concerning Marginals of L and $\bar{L}$ for Speed Limit Breakpoint.

1. Marginals of Point A Do Not Differ on M/S

Within:	E/C	$\chi^2_2 = 5.59$	$.05 \leq p \leq .10$
	E	$\chi^2_1 = 1.033$	$p > 0.3$
	C	$\chi^2_1 = 4.561$	$.025 \leq p \leq .05$

2. Marginals of Point A Do Not Differ on E/C

Within:	M/S	$\chi^2_2 = 0.614$	$.29 \leq p \leq .55$
	M	$\chi^2_1 = 0.531$	$p > .5$
	S	$\chi^2_1 = 0.084$	$p > .9$

3. Marginals of Point C Do Not Differ on E/C

Within:	M/S	$\chi^2_2 = 11.54$	$.001 \leq p \leq .005$
	M	$\chi^2_1 = 7.657$	$.005 \leq p \leq .01$
	S	$\chi^2_1 = 3.879$	$.025 \leq p \leq .05$

4. Marginals of Point C Do Not Differ on M/S

Within:	E/C	$\chi^2_2 = 11.39$	$.001 \leq p \leq .005$
	E	$\chi^2_1 = 6.436$	$.01 \leq p \leq .025$
	C	$\chi^2_1 = 4.957$	$.025 \leq p \leq .05$

5. Points A and C are Independent Variables (Within M/S)

Within:	E/C	$\chi^2_4 = 96.348$	$p < .0005$
	E	$\chi^2_2 = 29.388$	$p < .0005$
	C	$\chi^2_2 = 66.960$	$p < .0005$

6. Points A and C are Independent Variables (Within E/C)

Within:	M/S	$\chi^2_4 = 96.348$	$p < .0005$
	M	$\chi^2_2 = 19.321$	$p < .0005$
	S	$\chi^2_2 = 77.027$	$p < .0005$