Pergamon

Accid. Anal. and Prev., Vol. 26, No. 6, pp. 751–765, 1994

0001-4575/94 $6.00 + .00

0001-4575(94)00034-4

AN EXPERIMENTAL STUDY TO EVALUATE THE EFFECTIVENESS OF DIFFERENT METHODS AND INTENSITIES OF LAW ENFORCEMENT ON DRIVING SPEED ON MOTORWAYS

DICK DE WAARD and TON ROOIJERS

Traffic Research Centre, University of Groningen, P.O. Box 69, 9750 AB Haren, The Netherlands;
E-mail: D.de.Waard.@TRC.RUG.NL

(*Accepted* 15 *March* 1994)

Abstract—Two field experiments were conducted to establish the most effective method of enforcement in reducing driving speed and to establish the most efficient strategy in terms of police force personnel required. In the first experiment, the effect of three variables on driving speed on motorways was studied. The first variable, intensity of enforcement, was manipulated by creating three different objective levels of apprehension for detected speeding drivers. The second variable was method of enforcement. On-view stopping and ticketing of offenders was compared to mailing of fines on the basis of the car's licence plate number. The third variable manipulated was the time delay in the mailing of fines. Time delay between detection of the offence and feedback to the driver was shortened in one condition. In a second experiment, police enforcement effort was optimized by relating intensity level of enforcement to the proportion of speeding vehicles. In the first experiment, police enforcement was applied for four weeks; in the second experiment, enforcement activities were continued for 12 consecutive weeks. In both cases the main dependent variable was driving speed. Before, during, and after the application of enforcement, speed was registered using induction loops. In addition, driver opinion about speeding and speed enforcement was studied using postal questionnaire surveys. The results show the largest and longest lasting reduction in driving speed in the highest intensity level-condition, giving support for a relation between objective chance of apprehension and speed choice. On-view stopping of offenders was shown to be a more effective method to reduce driving speed than mailing of fines. Some of these results are discussed in the light of game theory. The questionnaire surveys indicated that most drivers did not notice the recurrence in enforcement activities due to infrequent passing of the sections of motorways studied. The preventive effect of police enforcement appeared to be far more substantial than its repressive effect. Enforcement primarily deters the current nonoffender from speeding.

INTRODUCTION

Accident statistics suggest that four-lane motorways are relatively safe. In 1992 only 3% of all accidents in the Netherlands occurred on motorways with a speed limit of 120 km/h (CBS 1993), while these roads carried up to 45% of nonurban vehicle kilometres (Blokpoel 1989). A similar situation exists in the United States where in 1991 2% of all accidents occurred on roads with a speed limit of 60–65 mph (NHTSA 1991). Although, compared to other roads, few accidents happen on motorways, the largest proportion (55%) of the crashes that do happen is severe or have fatal injuries as result (NHTSA 1991). High driving speed is the main cause for this severity. Several studies (Salusjärvi 1981, 1988; Nilsson 1981, 1988; Johnson et al. 1981; Christensen 1981) have demonstrated that reductions in average or median driving speed of 2 to 5 km/h can result in a reduction of up to 30% in injury and fatal accidents, while the increase in interstate speed limit in the United States was accompanied by an increase in fatality and injury rate (e.g. Wagenaar et al. 1990). In addition to average driving speed the distribution of driving speeds is of major importance (e.g. Hale 1990); large differences in driving speed increase the amount of encounters between vehicles and thus the probability of a conflict or accident occurring. Considering these facts and also taking into account the negative effect high driving speeds have on the environment there is good reason to reduce speeding on motorways.

In the Netherlands, speed-limit compliance on motorways is relatively low. At most locations, a

speed limit of 120 km/h is in effect, and at these locations more than 15% of the private vehicles and motorcycles drive above the limit (DVK 1992). At locations where a limit of 100 km/h is in effect, more than 50% of the drivers violate this limit. The problem of violation of speed limits is not confined to the Netherlands. In Great Britain, for example, in 1992 more than half of the cars travelling on nonurban motorways exceeded the 70 mph speed limit (IIHS 1993).

One of the ways to reduce speeding is police enforcement. Obtrusive law enforcement can have two effects (see e.g. Rothengatter 1982). First, there is a preventive effect: passing drivers notice enforcement activities and most will be deterred from speeding. Second, there is a repressive effect for detected offenders; they either receive a warning or a speeding ticket. The police can choose to optimize one of these two effects. Use of a marked police car will enhance deterrence, but will reduce detection. Use of unobtrusive speed-radar measurements will increase detection but will be less often noticed. Shinar and McKnight (1985) concluded that, in order to be effective, enforcement has to increase perceived risk of detection by maintaining a certain level of objective probability of detection. This conclusion is in accord with that of Rothengatter (1988), who demonstrated that intensifying apparent enforcement without increasing the objective level of apprehension—achieved by moving surveillance with obtrusive police vehicles—does not influence actual speed choice. An increase in objective level of probability of apprehension by added radar check posts, however, did reduce the number of speeding drivers. Speed choice is influenced by an increase in enforcement level while attitude towards speeding remained unaffected. Perceived level of risk is affected only in cases in which the objective level of apprehension is increased. Rothengatter states that enforcement can probably be best seen as an external variable that affects behaviour without affecting intention to display that behaviour.

A recent overview of studies regarding the relation between intensity of enforcement level and violation rate is presented by Bjørnskau and Elvik (1992), who describe studies in which speed-enforcement activities were increased up to eight times the initial level. The studies usually show that violation rates decline when enforcement is increased. In some studies, only excessive speeds are found to be reduced; in other studies, overall violation rate declines between 7% and 35%. An increase in enforcement activities usually implies an increase in manpower or time devoted to enforcement. Although these factors are not unrelated to detection probability—the "chance of getting caught"—a systematical dose-effect study manipulating detection probability has not yet been accomplished. Moreover, very few experimental studies have been carried out on motorways. In the current study, objective probability of apprehension is manipulated on three levels by stopping every 100th, 25th, or 6th offender. The other detected offenders could pass without being penalized.

The level of enforcement intensity is likely to interact with the enforcement method. Different methods of enforcement have been compared in the past (see e.g. Shinar and Stiebel 1986; Rothengatter et al. 1985) and usually these studies show that the presence of marked police cars or on-view stopping of offenders have the largest effect on driving speed. We have not found, however, a systematic comparison of methods in which the actual probability of apprehension for offenders for both methods was equal, for which reason the variable "Method" was included into the design of the current study. On-view stopping of every sixth offender was compared to photographing every sixth violator and subsequently sending a fine to the driver's home address identified on the basis of the car's licence plate number.

While on-view stopping of offenders could deter other drivers from speeding due to its obtrusiveness, this is less likely when offenders are being photographed. This method is expected to have a repressive effect mainly on speeding drivers, even though only a few of the other drivers may notice the speed radar or camera flash. Another difference is that most speeding drivers will not be sure whether their offence is detected, since no feedback is given; while stopped offenders will receive immediate feedback. In order to reduce the time delay between photographing and informing the driver about the registration of the offence, another condition is included in the design. In one condition, a feedback letter was sent to the detected offender as soon as possible. Sending warning letters has been shown to reduce speeding (Rothengatter 1982), in particular if the letter is personalized and refers to the actual time and place of the offence. However, in the studies described, drivers were not fined; only warning or advisory letters were sent. Feedback in the current study is different. In this case, it implies a reduction in the time gap between detection of the offence and informing the driver about a penalty.

In a second experiment, enforcement efficiency was optimized by relating the intensity level of enforcement to the proportion of offenders. Enforcement activities were continued for a period of three months. Results from the first experiment were used

to offset parameters in this study. During both experiments postal questionnaire surveys were carried out to study drivers' opinions about speeding and speed enforcement.

METHOD

Manipulation of enforcement-related variables

Moving surveillance apart, three different methods of police enforcement of speeding are common in the Netherlands. The first method is on-view stopping of offenders. A speed radar together with a camera are positioned inconspicuously alongside the road. The radar is connected to an unmarked police passenger car, which is not visible from the road. A police officer in the car has access to the speed measurements and has a view of the road. The officer also has radio contact with marked police vehicles, parked inconspicuously, for instance on a lay-by, further alongside the road. After being warned, the drivers of the marked police vehicles stop offenders on-view alongside the road, usually on the emergency shoulder. Offenders who cannot be stopped are fined on the basis of the vehicle's licence plate number.

The second method of speed-law enforcement is comparable to the first in the sense that a speed radar with a camera is positioned on the edge of the road. Again the radar is connected to an unmarked police car. All detected offenders are photographed, none is stopped. This is, compared to other countries, a well-accepted and often-used method in the Netherlands. On the photographs, location, driving speed, and time are also registered. According to Dutch law, this is sufficient evidence to prosecute, there is no need to be able to identify the driver from the photograph as is the case in France, for example (Van Opheusden 1990). About two weeks after detection of the offence, the driver will receive a ticket at home. The method is easy to apply, even at locations where it is difficult to stop an offender. Moreover, at every location where this method of police enforcement is applied, no more than one car and one or two police officers are needed to perform speed checks.

Even less police manpower resources are needed for the third method, automatic speed enforcement. A container with a speed radar and a camera is positioned at a fixed point alongside the road. Speeding drivers are photographed in a manner similar to that of the second method, and fines are mailed to the owner on the basis of the vehicle's licence plate number. No police officers are present during detection and registration.

In the current experiment, three enforcement-related variables have been manipulated. The first variable, *intensity* of enforcement, has been operationalised as the actual risk of apprehension for a speeding offender. The police used the first described method, on-view stopping of offenders. Contrary to the normal procedure, only those offenders who were stopped were charged with the offence, and the other detected offenders were not penalized. Three conditions were part of the experiment, and different levels of enforcement were created by stopping every 100th, every 25th, or every 6th offender. The selection of offenders that were stopped depended only upon sequence of arrival at the radar location; the extent to which the limit was exceeded did not play a role in any of the conditions.

The second factor varied was the *method* of enforcement. Two conditions were part of the experiment: on-view stopping of offenders and mailing of fines. In both conditions, every sixth offender was fined.

The third factor that was manipulated was *time delay* in the case of mailed fines. Two conditions were a part of this study, and, again, in both conditions every sixth offender was fined. In one condition, offenders received, as soon as possible, a personal feedback-letter stating that their speeding offence had been registered, which speed was measured, where and when detection had taken place, and that a fine would be forwarded. The original effort was aimed at informing the offender by letter within 24 hours. Further transaction of the offence was standard. In the other condition, no letters were sent and the complete procedure was as usual.

All manipulations were carried out by the police at different sections of motorways during one month. Five conditions correspond to five motorway sections. These sections and a sixth control section, where no enforcement activities were carried out, were similar regarding speed limit (120 km/h) and number of lanes (2 × 2 lanes plus emergency lane). Furthermore, the possibility that a driver would pass more than one experimental section during a trip had been minimized. Speed-enforcement activities were in effect during four weeks, four working days a week between 10 A.M. and 3 P.M. at all experimental locations. Table 1 summarizes the six conditions.

At all locations, the average speed was measured by induction loops of the local road authority. Data were available per hour. In addition to these loops that measure only average speed and standard deviation (*SD*) of speed, classification induction loops were installed. These loops classify individual vehicle speeds into speed classes with a bandwidth of 10 km/h. During a two-week period before enforcement was started—the pre-enforcement

Table 1. Conditions in Experiment 1. Each condition denotes a different motorway section. "Ratio" indicates which offender was fined

Condition	Study	Ratio	Method	Legal transaction
Stop 100	Intensity	1:100	On-view stopping	Standard
Stop 25	Intensity	1:25	On-view stopping	Standard
Stop 6	Intensity + Method	1:6	On-view stopping	Standard
Plate 6	Method + Delay	1:6	Licence plate	Standard
Feedback 6	Delay	1:6	Licence plate + letter	Feedback
Control	Intensity + Method + Delay	—	No enforcement	—

phase—speed was measured by both types of induction loop. Both during and after the enforcement phase driving speed was measured for four successive weeks.

The average distance between the inconspicuous radar detection site and the induction loops was 5.2 km. In the appropriate conditions, police officers would await the violator who had to be stopped somewhere between the radar site and the detection loops. The act of stopping itself was performed on the emergency lane, and violators were ticketed conspicuously for all traffic participants. This was always at a point before the induction loops.

Questionnaire

Licence plate numbers of vehicles were registered at all motorway sections during the enforcement phase. Licence plate numbers were compared to police data and were divided into three groups of approximately equal size: (i) drivers apprehended for speeding, (ii) offenders who had not been apprehended, and (iii) nonoffenders. Driving speed was derived from speed-radar measurements and was available for every individual. The observed speeds were linked to the questionnaire data, after which the link between licence plate and respondent was broken to guarantee anonymity of the respondents. In the questionnaire, several items asked about driving speed, preferred speed, and opinion about speed enforcement and risk of apprehension. Attitude toward speeding was determined on the basis of the sumscore of three 5-point scales. The respondents could indicate their attitude towards driving faster than 120 km/h in terms of good-bad, pleasant-unpleasant, and appealing-not appealing. The attitude could range from −6 (extremely negative attitude towards speeding; speeding is unpleasant, bad, and not appealing) to +6 (extremely positive attitude towards speeding). A total of 1,445 questionnaires was mailed.

The main hypothesis of the study was that a higher intensity level of enforcement has a greater speed-reducing effect. The study was also designed to establish an absolute level of enforcement required to obtain measurable effects on driving speed. A second hypothesis was that stopping of violators would deter more drivers from speeding than mailing of fines. When offenders are photographed, reducing the time delay was expected to have a greater effect on speed reduction compared with the standard time delay. If the level of enforcement intensity is great enough, a lower speed choice is expected to coincide with an increase in a driver's perceived probability of apprehension. The driver's attitude towards speeding is expected to remain unaffected by enforcement condition.

Both speed measurements and scores on questionnaire items were statistically tested using SPSS/PC (SPSS, Inc., Chicago, IL, U.S.A.).

RESULTS: EXPERIMENT 1

In the experiment, six locations corresponded with six conditions while three studies were part of the experiment. First, the intensity study compared three levels of intensity of enforcement, Stop 100, Stop 25, and Stop 6 (Table 1). Second, the method study compared two conditions, Stop 6 and Plate 6. Third, the time-delay study compared the conditions Plate 6 and Feedback 6. The sixth condition, Control, was used in all three studies as control location. No law enforcement activities were carried out here.

Although the film negative of the photographs of the speeding drivers was developed more quickly than usual in the feedback condition (Feedback 6), reading of the licence plate numbers and preparing and mailing of the letter took longer than expected. On average, offenders received a letter three to five days after the offence was registered. The actual ticket followed about 10 days later.

At all locations, driving speed was registered before, during, and after police enforcement. During the pre-enforcement phase it became apparent that the average driving speed differed from location to location. This is probably due to differences in traffic density. The motorway with the lowest traffic density was the condition in which every sixth offender was stopped (on average, 500 cars passed per hour)

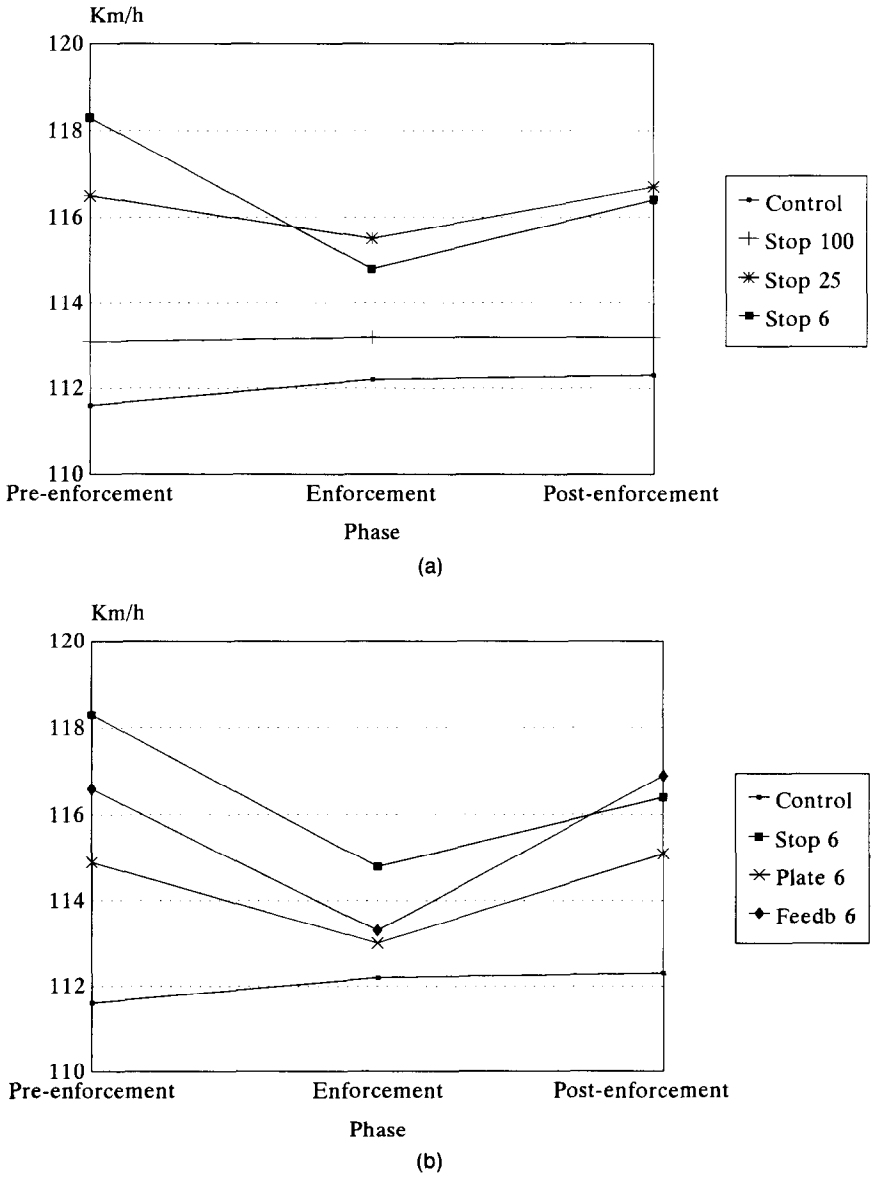


Fig. 1a, b. Average driving speed in km/h of cars up to 6 metres in length at six locations before, during, and after the application of police enforcement. Figure 1a depicts the intensity level study; Fig. 1b, the method and time-delay studies. The conditions are indicated by a combination of Stop (= stopping of speed violators alongside the road), Plate (= mailing of fines on the basis of the car's licence plate number), Feedb (= mailing of fines on the basis of the car's licence plate number preceded by a feedback letter), or Control (= control condition, no enforcement) and a figure (100 = every 100th, 25 = every 25th, 6 = every 6th offender was fined).

and the highest traffic flow was found at the control location (on average, 1,300 cars per hour). The average intensity level at the other locations was 800 cars per hour.

Effects on speed

In Fig. 1, the average driving speed is depicted before, during, and after the application of police enforcement. The data are based upon (enforcement) working days between 10 A.M. and 3 P.M. As motorway sections are not completely alike, driving speed will be compared to each location's pre-enforcement level. Only minor changes in traffic flow were measured on the locations between the three phases (before, during, and after police enforcement activities), so traffic flow cannot be responsible for changes in driving speed between phases. Speed effects have been tested statistically per driving lane and are summarised in Table 2.

Stopping of every 100th offender did not affect average driving speed, while stopping of every 25th offender reduced the average driving speed by 1

Table 2. Analysis of variance performed upon day's averages of the average and the *SD* of driving speed (in km/h) of cars up to 6 metres in length, per lane. Significance of effects is indicated by ○ ($\alpha < 0.10$) or * ($\alpha < 0.05$). Apart from the overall test (overall), a Student-Newman-Keuls (SNK) procedure was run comparing pre-enforcement (Pre), enforcement (Enf) and post-enforcement (Post) phase with each other. The conditions are indicated by a combination of Stop (= stopping of speed violators alongside the road), Plate (= mailing of fines on the basis of the car's licence plate number), Feedback (= mailing of fines on the basis of the car's licence plate number preceded by a feedback letter) or Control (= control condition, no enforcement) and a figure (100 = every 100th, 25 = every 25th, 6 = every 6th offender was fined)

A. Average driving speed						Significance SNK-procedure		
Condition	Lane	Pre	Enf	Post	Overall	Pre-enf	Enf-post	Pre-post
Stop 100	Right	108.2	108.8	108.8	$F(2, 44) < 1.00$			
	Left	116.6	116.4	116.5	$F(2, 44) < 1.00$			
Stop 25	Right	112.5	111.9	112.9	$F(2, 53) = 1.00$			
	Left	121.1	119.9	121.4	$F(2, 53) = 2.50$°	○	*	
Stop 6	Right	114.9	112.2	113.6	$F(2, 42) = 7.52$*	*	*	○
	Left	125.3	120.1	121.8	$F(2, 42) = 23.53$*	*	*	*
Plate 6	Right	109.9	108.5	110.4	$F(2, 45) = 1.98$		○	
	Left	121.6	119.0	121.4	$F(2, 45) = 5.13$*	*	*	
Feedback 6	Right	110.6	107.9	111.9	$F(2, 46) = 12.69$*	*	*	
	Left	122.5	119.0	122.8	$F(2, 46) = 8.63$*	*	*	
Control	Right	106.6	107.1	107.3	$F(2, 58) < 1.00$			
	Left	117.4	118.2	118.2	$F(2, 58) < 1.00$			

B. *SD* driving speed						Significance SNK-procedure		
Condition	Lane	Pre	Enf	Post	Overall	Pre-enf	Enf-post	Pre-post
Stop 100	Right	24.1	20.3	21.8	$F(2, 44) = 3.67$*	*		
	Left	20.9	20.0	19.3	$F(2, 44) < 1.00$			
Stop 25	Right	28.3	22.1	26.3	$F(2, 53) = 14.04$*	*	*	○
	Left	25.1	20.4	26.3	$F(2, 53) = 5.04$*	*	*	
Stop 6	Right	42.7	27.8	36.2	$F(2, 42) = 37.07$*	*	*	*
	Left	41.4	23.5	30.6	$F(2, 42) = 33.10$*	*	*	*
Plate 6	Right	38.4	27.2	35.4	$F(2, 45) = 22.27$*	*	*	○
	Left	33.1	23.8	31.5	$F(2, 45) = 8.71$*	*	*	
Feedback 6	Right	31.7	29.2	29.1	$F(2, 46) = 1.55$			
	Left	32.4	31.5	33.7	$F(2, 46) < 1.00$			
Control	Right	32.2	35.1	34.9	$F(2, 58) = 4.24$*	*		*
	Left	14.9	16.8	16.5	$F(2, 58) = 1.00$			

km/h. When every sixth offender was stopped, the largest reduction in average driving speed (3.5 km/h) was measured. At this location, average driving speed remained almost 2 km/h lower during the postenforcement phase compared to the pre-enforcement phase. During enforcement, a reduction in driving speed of 2 to 3 km/h was found at the two locations where every sixth offender received a mailed fine, but this effect disappeared during the postenforcement period. A small nonsignificant increase in average driving speed during the enforcement phase was found at the control location where no enforcement activities were carried out.

Apart from average driving speed, the equipment connected to the detection loops also determined variation in driving speed. A similar image is apparent from these data, as shown in Fig. 2, where the change in standard deviation of driving speed compared to the pre-enforcement phase is depicted.

During the police enforcement phase, the *SD* of driving speed decreased at all locations except the location where offenders received a feedback letter and the control location. At the control location, the *SD* of the driving speed increased and remained higher during the postenforcement period compared to the preenforcement phase. Only in the condition where every 6th offender was stopped, the variability in driving speed remained lower during the postenforcement phase. At most other locations, the variability returned to its pre-enforcement level. In the condition where a feedback letter was sent to every 6th detected speeder, no effect on the *SD* of driving speed was found. The outcomes of the statistical tests are summarized in Table 2.

Within a distance of 400 metres from the existing loops of the local road authority the newly constructed classification induction loops have classified individual speeds. From these classifications the percentage of speed-limit offenders could be determined. Drivers were categorized offender if their measured speed was above 130 km/h.

Due to technical problems, not all data were

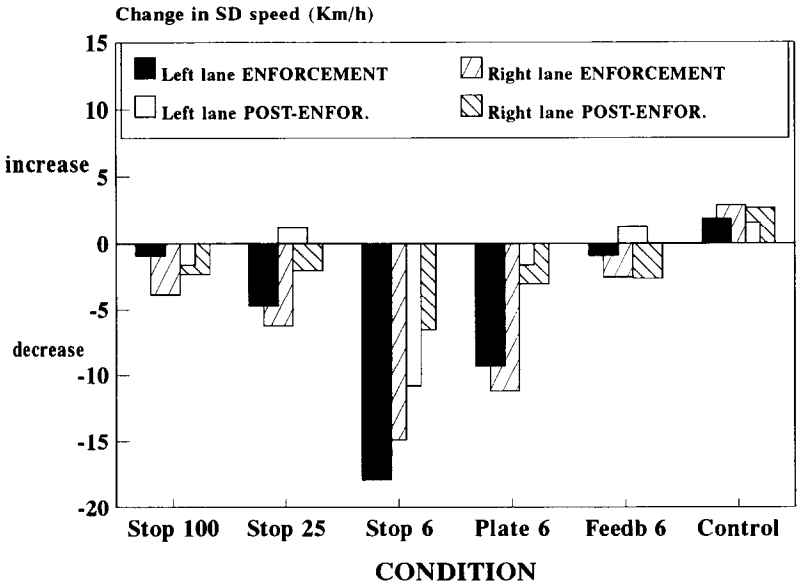


Fig. 2. Change in standard deviation (*SD*) of driving speed of cars up to 6 metres in length. The change in *SD* is compared with the pre-enforcement phase (set to zero) and is indicated for the enforcement phase and for the post-enforcement phase (POST-ENFOR.). All values are in km/h. The conditions are indicated by a combination of Stop (= stopping of speed violators alongside the road), Plate (= mailing of fines on the basis of the car's licence plate number), Feedb (= mailing of fines on the basis of the car's licence plate number preceded by a feedback letter) or control (= Control condition, no enforcement) and a figure (100 = every 100th, 25 = every 25th, 6 = every 6th offender was fined).

available. The available data indicate that the theoretical possibility that differences in mean speed, as measured by the other induction loops, represented a reduction in driving speed of nonoffenders only, can be ruled out. Table 3 summarizes the percentage offenders per lane.

Conclusions experiment 1: driving speed

The intensity study showed a clear relationship between intensity level of enforcement and the proportion of speeding drivers. The highest intensity level, stopping of every sixth offender, resulted in the largest and longest lasting reduction in driving speed. The lowest intensity level, stopping of every 100th offender, lacked effect on average speed and had only a small effect on the *SD* of driving speed that is restricted to the right lane only.

The method study demonstrated that during enforcement, effects on average driving speed of the methods on-view stopping versus photographing of offenders were similar. However, on-view stopping

Table 3. Percentage of cars up to 6 metres in length driving 130 km/h and over per lane. Significance of effects is indicated by $\bigcirc(\alpha < 0.10)$ or $*(\alpha < 0.05)$. Apart from the ANOVA run on day's averages (overall), a Student-Newman-Keuls procedure (SNK) was run comparing pre-enforcement (Pre), enforcement (Enf), and post-enforcement (Post) phases with each other. The conditions are indicated by a combination of Stop (= stopping of speed violators alongside the road), Plate (= mailing of fines on the basis of the car's licence plate number), feedback (= mailing of fines on the basis of the car's licence plate number preceded by a feedback letter) or Control (= control condition, no enforcement) and a figure (100 = every 100th, 25 = every 25th, 6 = every 6th offender was fined)

		Percentage cars driving faster than 130 km/h				Significance SNK-procedure		
Condition	Lane	Pre	Enf	Post	Overall	Pre-enf	Enf-post	Pre-post
Stop 100	Right	[a]	4.3[a]	3.6[a]	$F(1, 25) = 2.67$			
	Left	[a]	14.7[a]	13.5[a]	$F(1, 25) = 1.05$			
Stop 25	Right	9.0	8.1	12.2[a]	$F(2, 33) = 9.80$*		*	○
	Left	23.3	22.7	26.9[a]	$F(2, 33) = 3.33$*		*	
Stop 6	Right	19.9	14.0	17.8	$F(2, 39) = 14.21$*	*	*	○
	Left	[a]	24.4	30.6	$F(1, 26) = 17.28$*		*	
Plate 6	Right	9.4	5.6	7.8	$F(2, 39) = 6.59$*	*	*	
	Left	23.8	16.2	21.9	$F(2, 39) = 7.31$*	*	*	
Feedback 6	Right	8.1	5.4	9.4	$F(2, 39) = 21.85$*	*	*	○
	Left	23.9	17.6	24.3	$F(2, 39) = 8.05$*	*	*	
Control	Right	7.3	8.3	7.2	$F(2, 44) = 1.10$			
	Left	15.5	18.0	16.6	$F(2, 44) = 1.43$			

[a]Denotes missing or corrected values.

had an aftereffect on driving speed and had a larger effect on the *SD* of the driving speed both during and after enforcement activities.

Finally, the time delay study did not establish an additional effect of sending of the feedback letter. Although average speed decreased more during enforcement in the reduced delay condition, the reduction in the proportion of speeding cars (see Table 3) did not differ between conditions. Aftereffects were not measured in either condition.

Survey of drivers

Questionnaires were sent to three groups of car drivers, who had been classified on the basis of their radar-measured driving speed: (i) non-speed-limit offenders, (ii) drivers who exceeded the speed limit but were not fined, and (iii) drivers who broke the speed limit and received a speeding ticket.

No differences in response rate between locations were found, but the response rate of the group nonoffenders was higher (54%) than that of the fined offenders (44%). No differences were found between locations in respondent's reported speed choice. Both groups of offenders reported a higher driving speed, 129.7 km/h, and a higher kilometrage (39,100 km/year) compared to an average reported speed of 120.7 km/h and an average kilometrage of 29,700 km/year for nonoffenders [$F(2,710) = 54.74$, $p < .001$ and $F(2,705) = 19.78$, $p < .001$]. Ninety-one percent of the respondents in both groups of offenders were male opposed to 80% in the group nonoffenders [$\chi^2(2, N = 714) = 15.8, p < .001$]. Offenders were, on average, three years younger than nonoffenders, 41.2 versus 44.6 years of age [$F(2,711) = 7.3$, $p < .001$].

Twenty-two percent of the offenders would like to see a (large) increase in police enforcement activities, 48% of the nonoffenders were of this opinion [$\chi^2(4, N = 706) = 59.1, p < .001$]. One in every four offenders (25%) considered the speed limit of 120 km/h (very) positive, while this was the case for 53% of the nonoffenders [$\chi^2(4, N = 708) = 61.7, p < .001$]. Nonoffenders had a neutral attitude towards speeding (0.00), while both not-fined and fined offenders had a positive attitude towards speeding [+1.51 and +1.52, respectively, $F(2,714) = 32.77$, $p < 0.001$]. Attitudes of fined offenders and not-fined offenders did not differ between locations [$F(4, 176) = 1.02$, *NS* and $F(5,222) = 1.72$, *NS*].

Registration of licence plate numbers was carried out during the same hours that enforcement activities were carried out. An important finding was that 40% of the respondents at all locations indicated that they passed this section of motorway less than once a month. Twelve percent indicated a frequency of once a month. Consequently, at best half of the respondents could have noticed the recurrent increase in enforcement activities. With this in mind, it is not a surprise that no differences were found between conditions in perceived probability of apprehension when driving at a speed of 140 km/h. If the group of respondents is limited to repeat traffic, i.e. drivers who used the section of motorway at least once a month, a pattern emerged that corresponded to the actual manipulation of the probability of apprehension. Since most respondents used the middle of the six-point scale, the subjective risk of apprehension was recoded to a two-point scale (risk of apprehension is either "large" or "small"). The percentage of respondents in the group repeat traffic that estimated the risk of apprehension "large" were for each location: control, 16%; stopping of every 100th offender, 18%; stopping of every 25th offender, 26%; stopping of every 6th offender, 32%; mailing of fines, 26%, and mailing of fines plus a feedback letter, 27%. These differences are not statistically significant ($\chi^2(5, N = 437) = 6.0$, *NS*). Correlations calculated between observed speed, reported speed, and subjective probability of apprehension (six-point scale) showed a positive relationship between observed and reported speed ($r = +.41$, $p < .01$), a slightly positive relationship between reported speed and subjective probability of apprehension ($r = +.15$, $p < .01$), and no relationship between subjective probability of apprehension and observed speed ($r = +.04$, *NS*).

In summary, perceived probability of apprehension was hardly related to driving speed and no more than a weak trend in relation to objective level of apprehension could be established. Attitude towards speeding of both fined and not-fined speeders was not affected by objective level of apprehension.

EXPERIMENT 2: OPTIMIZATION OF POLICE ENFORCEMENT

A second experiment lasting six months focused on the optimization of the police effort. The previous experiment showed that stopping every sixth offender produced the largest speed-reducing effect. To find out whether intensity of enforcement had to remain at this level to conserve an effect, this second study was carried out. Basically, game theory (see Bjørnskau and Elvik 1992) applies to this situation. Game theory states that after an initially high level of enforcement, the proportion of speeding drivers will decrease quickly. This decrease in offenders will automatically lead to a reduction of detected Speeding vehicles and thus enhance the enforcer's decision to stop enforcement activities. Conse-

quence of the removal of enforcement activities will be an increase in the proportion of speed-limit violators.

In the second experiment this process is supported by varying enforcement level in relation to the proportion of offenders. The experiment is designed to reach a situation in which the proportion of offenders remains below a tolerance limit. A genuine equilibrium, however, cannot be reached, since a just too-low level of enforcement will increase the proportion of offenders and a too-high level of enforcement will further reduce the proportion of offenders. It is expected that ultimately a very small increase in enforcement level is sufficient to have an effect on the proportion of speeding drivers.

Method

In the second study offenders were again stopped on-view, but now intensity level of enforcement was adapted each week to the proportion of speed-limit offenders. If a high number of offenders was detected, the enforcement intensity would increase, and if a low number of offenders was detected, the intensity of enforcement would decrease. During a five-week pre-enforcement phase, driving speeds at the motorway section were monitored using classification induction loops. Based on these data, it was decided that a level of 6% speed-limit offenders would be tolerated. Every week, the level of offenders was calculated and the next week's enforcement level was established. This procedure was followed for 12 weeks, and enforcement activities took place between 10 A.M. and 3 P.M. from Monday to Thursday. Speed effects were compared to the pre-enforcement phase and to a control motorway section where no police enforcement activities were implemented.

The previous intensity-study had shown a marked effect on speed in the condition where every sixth offender was stopped, and this was used as the initial level of enforcement the first week. Since not-fining of detected speeding drivers during the first experiment brought about dissent among the police it was decided to follow the normal procedure and manipulate only the factor stopping alongside the road. Detected speeders who were not stopped were fined on the basis of their licence plate number.

Two questionnaire surveys were carried out. The first was mailed at the start of the enforcement phase, the second, aimed at more frequent users of the motorway section, in the 10th week of enforcement activities. Once more, questions about driving speed and opinion about enforcement were asked.

RESULTS: EXPERIMENT 2

Speed-measurement results

In the top part of Fig. 3 the proportion of cars driving at a speed of 130 km/h and over is shown per location and per week. Very prominent are the overall variations in proportion of speeders at both locations. This variation is probably due to the weather conditions. Figure 3 also illustrates an initial difference in the proportion of speeders between locations. At the bottom of Fig. 3 the difference between the two locations in the proportion of speeders is indicated. In this measure, the effect of the momentary variation present at both locations—e.g. the effect of weather conditions—is no longer present. The measure is based on 20 hourly observations per week.

Several enforcement-related effects on speed can be noted. During the first week of enforcement, the proportion of offenders at the experimental location was reduced from 9% to 5%, a reduction of more than 40%. On the basis of the results of the first week of enforcement, the intensity level was reduced from a level of stopping of every sixth offender to a level of stopping every 10th offender in the second week. In the fifth week of enforcement, offenders were no longer stopped and were ticketed only on the basis of their licence plate number. During this week, the level of offenders rose above the tolerance limit, and consequently enforcement was increased to stopping every 10th offender during the sixth week. This again reduced the proportion of speeding cars, while the proportion of violators at the control location increased that week. This is indicated by the sharp increase in the difference measure. During the following weeks an interaction between level of enforcement and the proportion of speed-limit offenders emerges, and in the 12th week a minor increase in intensity level, stopping of every 25th offender, was sufficient to decrease the proportion of offenders to a level below the tolerance limit. After the enforcement period, the proportion of offenders returned immediately to the pre-enforcement level.

Correlation of the intensity-level of enforcement that the police had actually realised with the classification loop data registered the same week showed a highly significant negative relation between intensity of stopping offenders and the proportion of speeders ($r = -.70$, $p < .001$).

In the Figs. 4 and 5 classification data of both locations are displayed for each phase. Figure 4 demonstrates that during police enforcement relatively fewer cars are classified as driving above 120 km/h. There is not a specific speed class that showed

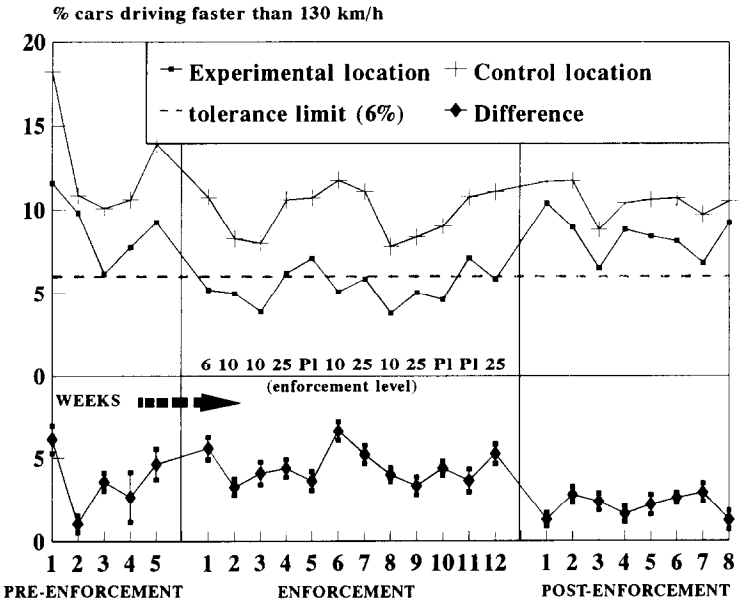


Fig. 3. Percentage of cars driving faster than 130 km/h at the experimental and at the control location, per week. At the experimental location a level of 6% offenders was tolerated. Whenever the week's average percentage of offenders rose above 6%, the intensity level of enforcement for the next week was increased. This is indicated by a higher figure above the centre-axis, meaning that offender number X was stopped alongside the road. "PI" means that no offenders were stopped and all fines were mailed on the basis of the cars' licence plate numbers. The bottom line shows the difference in proportion speeders between the two locations, with indicated standard error.

an extra decline in percentage of speeders. At the control location (Fig. 5) no consistent changes were found.

Driver survey results

At the start of the enforcement phase, 758 questionnaires were sent to equal-sized groups of speed-limit offenders and nonoffenders on both the experimental and the control motorway sections. Half (378) of the mailed questionnaires were returned. In the 10th week of police enforcement, 243 questionnaires were sent to drivers who had indicated in the first questionnaire that they drove at least once a month at either the experimental or the control location. This second questionnaire was a short version of the first one. Due to a small gift-voucher, the

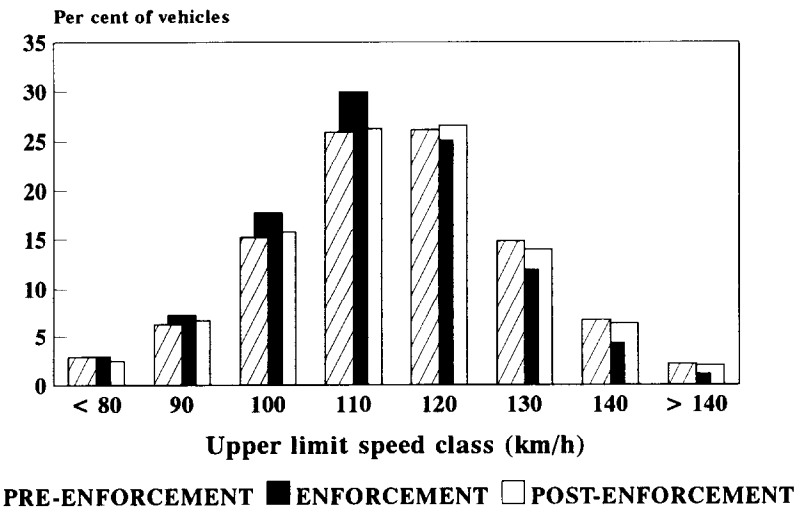


Fig. 4. Classification data, experimental location, per phase (cars up to 6 metres in length).

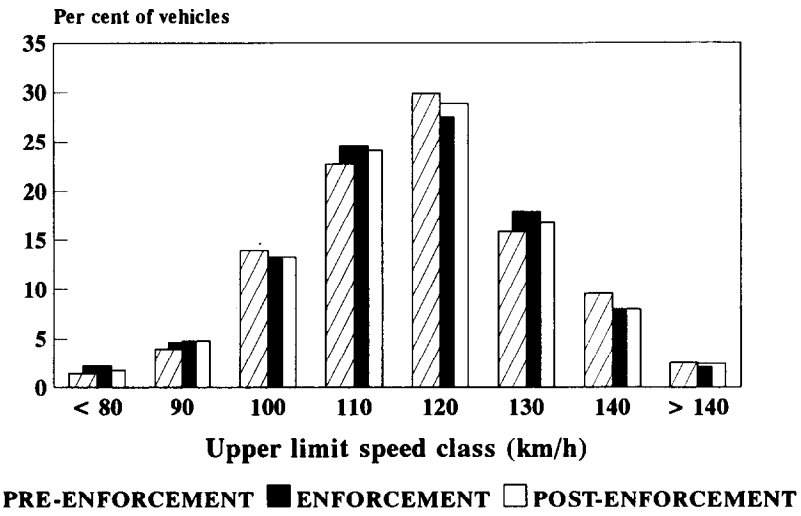


Fig. 5. Classification data, control location, per phase (cars up to 6 metres in length).

response rate on this survey was high; 81% returned it.

Again, very few drivers were found to pass a section of motorway frequently, 70% of the respondents stated that they drove at the location less than once every fortnight. Not unexpectedly for a sample taken on motorways between 10 A.M. and 3 P.M., most of the respondent drivers used their car for business purposes. During these hours, 20% of the nonoffenders and 28% of the offenders used their cars to commute, while 55% of the nonoffenders and 64% of the offenders used their cars for business. Private use is particularly low in the group offenders, 8%, opposed to 25% in the group non-speed-limit offenders [$\chi^2(2, N = 375) = 18.0, p < .001$].

Important differences between the two groups were found on reported driving speed [$F(1,375) = 39.5, p < .001$], preferred driving speed ($F(1,373) = 27.2, p < .001$), and attitude towards speeding [$F(1,374) = 16.7, p < .001$]. Speed-limit offenders had a more positive attitude towards speeding than nonoffenders (+1.60 versus +0.31), reported a higher driving speed (129.0 km/h versus 122.2 km/h), and would prefer to drive on motorways at an average speed of 133.8 km/h opposed to 126.8 km/h for the group non-limit-offenders. Use of a company car or lease car is generally high. In the group offenders, the largest proportion of lease-car or company-car users was found: 43% of the speed-limit violators opposed to 25% of the nonviolator respondents. Private-car users have, on average, a lower registered driving speed (117.7 km/h) and a less positive attitude towards speeding (+0.38) compared to company car (124.6 km/h and +1.58, respectively) and lease car drivers (124.9 and +1.94, respectively). The Student-Newman-Keuls procedure run after the significant analysis of variance [$F(2,369) = 13.6, p < 0.001$ and $F(2,372) = 8.4, p < 0.001$, respectively] shows that differences between company-car and lease-car drivers are not significant in contrast to differences between private-car users and the two groups of business drivers.

The correlations between the speed variables are positive and significant, including those between the observed speed and the top speed of the car (Table 4). A positive attitude towards speeding correlated positively with kilometrage ($r = +.28, p < .001$); reported driving speed ($r = +.36, p < .001$); preferred speed ($r = +.25, p < .001$), but negatively with age ($r = -.30, p < .001$).

The six-point scale on which respondents indicated the subjective probability of apprehension while driving at a speed of 140 km/h was recoded to a two-point scale. At the experimental location, 28% of the nonoffenders and 24% of the speeding

Table 4. Correlation (Pearson's r) between different motorway speed variables, all groups of respondents taken together. All correlations are significant ($p < .001$)

	Registered	Reported	Preferred
Reported speed	+.39		
Preferred speed	+.30	+.69	
Top speed of car	+.19	+.40	+.41

drivers estimated the probability of apprehension to be "large". At the control location, 14% of the nonspeeders and 16% of the speeding drivers were of this opinion. Only the differences between locations were statistically significant [$\chi^2(1, N = 378) = 5.4$, $p < .02$]. In this sample, the subjective probability of apprehension correlated neither with observed ($r = -.07$, *NS*) nor with reported speed ($r = +.01$, *NS*). When asked whether police enforcement should be increased, 44% of the nonoffenders agreed. Offenders were less inclined to agree with this statement—only 25% did so. No differences between locations were found on this variable. To assess the preventive effect of enforcement on driving speed, drivers had been asked whether they would drive faster if they would be certain that they would not get caught when speeding. Fifteen percent of both the offenders and the nonoffenders indicated that they definitely would drive faster in that case; another 25% indicated that they would probably do so.

The second questionnaire

Two weeks before the enforcement phase was finished, the second questionnaire was mailed to habitual users of the motorway sections. Several variables have been tested using MANOVA's repeated measures.

Although reported speed choice at both locations did not change significantly between the two measurements [$F(1,194) < 1$, *NS*], a significant interaction (Group × Measurement) was found at the experimental location [$F(1,88) = 4.8$, $p < .04$]. A paired t-test per group and location showed that the effect is caused by a decrease in reported driving speed by the nonoffenders at the experimental location ($t = 2.1$, $p < .05$). Neither the increase in reported driving speed of the offenders at the experimental location ($t = -1.1$, *NS*) nor the increase ($t = -1.6$, *NS*) and decrease ($t = 1.4$, *NS*) found at the control location were statistically significant. Figure 6 illustrates the average reported driving speeds.

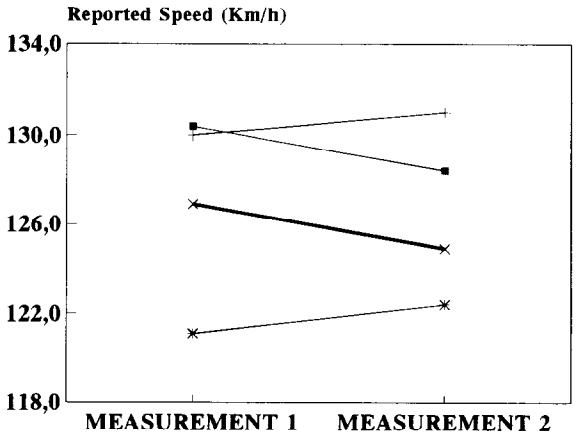
In the smaller group that was surveyed twice, the previously found difference in subjective probability of apprehension between locations during the first measurement is only marginally significant [$\chi^2(1, N = 195) = 3.7$, $p < .06$]. The differences between locations disappeared completely in the second survey; the percentage of respondents at the control location that rated the subjective probability of apprehension while speeding to be "large" had increased from 14% to 23%. At the experimental location, the percentage decreased from 25% to 22%.

In the second survey drivers were also asked whether they had noticed an increase in police enforcement. No differences were found between the offender and nonoffender groups [$\chi^2(2, N = 196) = 0.31$, *NS*], but differences between locations were significant [$\chi^2(2, N = 196) = 10.2$, $p < .01$]. At the control section, 78% had not noticed an increase in enforcement, while at the experimental location still 59% of the drivers, who passed the motorway section at least monthly, had not noticed an increase. Contrasting of the variables "subjective probability of apprehension" with "noticed an increase in enforcement" showed an effect of perceiving increased police activity. Forty-one percent of all respondents who had noticed an increase estimated the probability of apprehension to be "large", while only 14% of the respondents who had not noticed an increase were of this opinion [$\chi^2(1, N = 195) = 15.6$, $p < .001$]. Differences were larger in the group nonoffenders (47% versus 10%, $\chi^2(1, N = 115) = 17.9$, $p < .001$) but were small and not significant in the group speed-limit offenders (32% versus 20%, $\chi^2(1, N = 80) = 0.78$, *NS*).

Experiment 2 demonstrated that the efficiency of police enforcement can be optimized without a reduction in enforcement effectiveness. A complete balance between effort and effect will not be reached, but eventually a minor increase in enforcement level will suffice to reduce the proportion offenders to a level below the tolerance limit. The questionnaire survey indicates that enforcement has more effect on law-abiders than on speed offenders. Recurrence of enforcement activities was found to have an effect on the subjective level of apprehension of the group nonviolators of habitual motorway section users only.

CONCLUSIONS AND DISCUSSION

In Experiment 1, the effects of intensity level, method of enforcement, and time delay on driving speed were studied. The intensity study showed that an actual probability of being caught of 1 : 25 leads to a measurable reduction of the average speed and the distribution of driving speed on motorways, if offenders are obtrusively stopped alongside the road. Using the same method and realizing an actual probability of being apprehended of only 1 : 100, no effects on average driving speed can be measured. It was also found that the larger the actual probability of being apprehended, the larger the decrease in average speed and the smaller the variance in speed distribution. This is in agreement with earlier findings indicating that the actual probability of appre-



EXP Non Offender	126,9	124,9
EXP Offender	130,0	131,0
CTR Non Offender	121,1	122,4
CTR Offender	130,4	128,4

Fig. 6. Average reported driving speed per location (EXP = experimental, CTR = control), group (offender versus nonoffender) and measurement.

hension is an important factor in speed choice (Rothengatter 1988).

In the method study, two methods of police enforcement were compared. Speeding drivers had an equal probability of apprehension in both conditions. Comparison of the two methods, stopping of offenders versus mailing of fines, shows that the first method leads to a larger and longer lasting reduction in driving speed.

In the time-delay study, the effect of reducing the time delay between registration of the offence and feedback to the driver concerning this registration was studied. A shorter delay did not have additional effects on driving speed compared to the normal procedure.

Experiment 1 shows that there is a relationship between level of enforcement and speed choice of drivers. Obtrusive stopping of offenders provides them with feedback about detection of the offense without delay. The method of stopping violators also has a preventive effect on other speeders. However, the relative large effects on driving speed that were found during the period that speeders were photographed in the mailing conditions can probably not be solely attributed to a repressive effect. Since repeat traffic is rather limited, it seems very likely that enforcement activities were not performed completely unobtrusively and that drivers noticed the speed radar and/or photo flash.

The effect of the enforcement activities on accidents has not been established. The main reason for this is that the number of accidents that happen on motorways is rather low. No accidents were reported to have happened at the selected motorway sections during the enforcement activities.

Although the proportion of repeat traffic between the rush hours is rather small, Experiment 2 shows that optimization of police enforcement is possible on motorways by relating the intensity level of stopping of offenders to the percentage of offenders. After an initially high level of enforcement—stopping of every sixth offender—, the obtained reduction in driving speed can be maintained during the following week(s) with a lower intensity enforcement level.

A large part of a speed reduction effect at a location, however, is probably attributable to what people see alongside the road. Since most drivers pass an enforcement site only once, the main deterrent is what they actually see at that moment. This probably also accounts for the relative success of the method on-view stopping of offenders. The amount of repeat traffic at a specific section of motorway is also an important factor in the other described studies. In the condition in which the feedback letter was sent to offenders, this manipulation could have had an effect only on drivers who had received the letter and passed the same section again. The questionnaire survey showed that this group consists of, at best, half of the drivers in the group offenders. Stronger (location-specific) retention effects can probably be expected if surveillance activities are planned for rush hours. The proportion (daily) of commuters would be larger, and these driv-

ers would probably soon notice the recurrence of enforcement. However, the police did not want to apply enforcement during the rush hours, as they believed increases in traffic flow prevent drivers from speeding. This increase in flow would also make it very difficult for the police to stop offenders alongside the road. The restriction of enforcement activities to time between rush hours somewhat limits its generalization of results. Furthermore, on nonmotorways the amount of repeat traffic may well be larger. In that case, more drivers could notice the recurrence in enforcement activities on these roads and this is likely to affect their speed choice.

Another aspect of the method stopping of offenders is that it does not discriminate between groups of private and nonprivate drivers. In the present study, one in every three drivers used a car owned by a (lease) company. Rooijers (1989) found that important motives for business drivers to break the speed limit are arriving in time, making up lost time, and driving pleasure (see also Rothengatter 1988). Being stopped after being detected by the police necessarily leads to a loss of time. Slowing down, even if it is for just a short while, prevents offenders from being stopped and arriving late at an appointment.

Two aspects of police enforcement can be emphasised in the studies. First, the method of enforcement is an important factor in police enforcement. Obtrusively stopping speeding motorists is an effective method; the enforcement activities can be observed by most other road users and the effect on driving speed is correlated to the intensity level of enforcement. Secondly, the difference between preventive and repressive effects of enforcement is of interest. Repressive effects of enforcement on the driving speed of offenders are usually small and disappear rapidly, both in time and space. The current study also shows that the attitude of fined and nonfined speed-limit violators towards speeding does not differ. Being apprehended for a speeding violation does not change the attitude towards the target behaviour. While the attitude towards speeding was not affected, the average and *SD* of driving speed were. It seems likely that Rothengatter's statement (Rothengatter 1988) that enforcement is an external variable that affects behaviour without affecting the attitude towards displaying that behaviour is correct.

Enforcement may fail to alter a positive attitude towards speeding, it does prevent many current nonviolating drivers from speeding. The (assumed) probability of apprehension prevents many drivers from speeding. This effect, however, would become apparent only if police enforcement is (temporarily) discarded. Examples of increasing speeds, especially of serious violations, were actually found during a police strike in Finland (Summala, Näätänen, and Roine 1980). The questionnaire survey results demonstrate that speed enforcement has a preventive effect on nonoffenders, in particular. The perceived probability of being apprehended prevents almost 40% of all drivers from speeding. No differences were found in perceived probability of apprehension between speed-limit offenders and nonoffenders, contrary to findings of Guppy (1993) who had categorized respondents based upon reported speed-violation detection experience. If, in the current study, only respondents who had noticed an increase in enforcement activities are considered, Guppy's conclusion that offenders tend to estimate the probability of apprehension as being lower is supported.

Experiment 2 demonstrates that a reduction in police enforcement level is possible without directly resulting in an increase in the proportion of speeding drivers. Although this experiment was not set up to test game theory (see Bjørnskau and Elvik 1992)—the major objective was to optimize the effect of enforcement with a minimum of police effort—the theory can be applied to the experiment. In game theory, a two-way relationship between road-user behaviour and enforcement level is assumed. The correlation of enforcement level with the proportion of offenders here demonstrates that there is a direct relationship between the two. However, there is an important factor that game theory does not pay specific attention to: memory effects. Although the theory seems to work, it works with a delay: a reduction in enforcement effort is later followed by an increase in the proportion of speeding drivers. Bjørnskau and Elvik (1992) state that violations and accidents can be permanently reduced if enforcement is not reduced once it is successful. Experiment 1 demonstrates that if the level of enforcement is adequately high, aftereffects can be found without continuation of enforcement activities. This experiment is more or less what Bjørnskau and Elvik (1992) call a chance mechanism: enforcement activities were carried out, not according to the police's estimate of violation probability, but systematically, following the procedure described above. Experiment 2 shows that if enforcement activities are continued, the level of enforcement can be reduced without reducing its effect. However, after removing the (reduced) enforcement activities, no aftereffects were found. This is what game theory predicts, termination of enforcement activities will lead to an increase in violation rate. Bjørnskau and Elvik (1992) predict that using a chance mechanism

instead of the violation rate trigger may lead to more lasting effects. From the present studies it seems that in order to achieve aftereffects at a specific location, a high level of enforcement is more important than continuation of enforcement activities. If enforcement activities are aimed at maintaining a constant low level of offenders at a specific location, then the optimization strategy can be followed, which is less demanding in terms of police force personnel required.

Acknowledgements—This study has been supported by the Dutch Ministry of Justice and the Ministry of Transport.

REFERENCES

Bjørnskau, T.; Elvik, R. Can road traffic law enforcement permanently reduce the number of accidents? Accid. Anal. Prev. 24:507–520; 1992.

Blokpoel, A. De verkeersonveiligheid in 1988. Een kwantitatieve beschrijving van de verkeersonveiligheid in 1988 [Traffic safety in 1988. A quantitative description of traffic safety in 1988]. Report R-89-34. Leidschendam, The Netherlands: SWOV; 1989.

CBS. Statistiek van de verkeersongevallen op de openbare weg 1992 [Statistics of traffic accidents on public roads 1992]. The Hague, The Netherlands: Centraal Bureau voor de Statistiek, SDU uitgeverij; 1993.

Christensen, J. Effects of changes in speed limits on traffic accidents on Danish roads. In: Proceedings of the OECD symposium "The effects of speed limits on traffic accidents and transport energy use." Dublin, Ireland: An Foras Forbartha; 1981.

DVK, Dienst Verkeerskunde Rijkswaterstaat, Beleidsinformatie Basisgegevens-Produktgroep Verkeer, Rotterdam, July 7, 1992.

Guppy, A. Subjective probability of accident and apprehension in relation to self-other bias, age, and reported behavior. Accid. Anal. Prev. 25:375–382; 1993.

Hale, A. R. Safety and speed. A systems view of determinants and control measures. In: Michon, J. A.; de Bruin, R. A., eds. First ISIRT Round Table, IATSS Research 14 (1):59–65; 1990.

IIHS. Insurance Institute for Highway Safety Status Report 28 (10):7; 1993.

Johnson, P.; Klein, T. M.; Levy, P.; Maxwell, D. The effectiveness of the 55 mph national maximum speed limit as a lifesaving benefit. In: Proceedings of the OECD symposium "The effects of speed limits on traffic accidents and transport energy use". Dublin, Ireland: An Foras Forbartha; 1981.

NHTSA. General estimates system 1991. A review of information on police-reported traffic crashes in the United States. Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration; 1991.

Nilsson, G. The effects of speed limits on traffic accidents in Sweden. In: Proceedings of the OECD symposium "The effects of speed limits on traffic accidents and transport energy use". Dublin, Ireland: An Foras Forbartha; 1981.

Nilsson, G. Speed limits and accident consequences and risks. Proceedings of "Roads and traffic safety on two continents". VTI report 332 A. Linköping, Sweden: Swedish Road and Traffic Research Institute; 1988.

Rooijers, A. J. Meningen en motieven van automobilisten ten aanzien van rijsnelheid een jaar na de limietswijziging op autosnelwegen [Opinion and motives of drivers regarding driving speed one year after the motorway speed-limit change]. Report 89-05. Haren, The Netherlands: University of Groningen, Traffic Research Centre; 1989.

Rothengatter, J. A. The effects of police surveillance and law enforcement on driver behaviour. Curr. Psychol. Rev. 2:349–358; 1982.

Rothengatter, J. A. Risk and the absence of pleasure: A motivational approach to modelling road user behaviour. Ergonomics 31:599–607; 1988.

Rothengatter, J. A.; Riedel, W. J.; Vogel, R. Invloed van gericht verkeerstoezicht op het snelheidsgedrag op 80 km wegen [Influence on speed behaviour of systematic enforcement on 80 km/h-speed-limit roads]. Report 85-01. Haren, The Netherlands: University of Groningen, Traffic Research Centre; 1985.

Salusjärvi, M. Speed limits and traffic accidents in Finland. In: Proceedings of the OECD symposium "The effects of speed limits on traffic accidents and transport energy use". Dublin, Ireland: An Foras Forbartha; 1981.

Salusjärvi, M. The speed-limit experiments on public roads in Finland. In: Proceedings of "Roads and traffic safety on two continents". VTI report 332 A. Linköping, Sweden: Swedish Road and Traffic Research Institute; 1988.

Shinar, D.; McKnight, A. J. The effects of enforcement and public information on compliance. In: Evans, L.; Schwing, R. C., eds. Human behavior & traffic safety. New York: Plenum Press; 385–415.

Shinar, D.; Stiebel, J. The effectiveness of stationary versus moving police vehicles on compliance with speed limit. Hum. Factors 28:365–371; 1986.

Summala, H., Näätänen, R.; Roine, M. (1980). Exceptional condition of police enforcement: Driving speeds during the police strike. Accid. Anal. Prev. 12:179–184; 1980.

Van Opheusden, P. Legal requirements for automatic policing information systems. Report 1033/D4 to the Commission of the European Communities. Haren: University of Groningen, Traffic Research Centre; 1990.

Wagenaar, A. C.; Streff, F. M.; Schultz, R. H. (1990). Effects of the 65 mph speed limit on injury morbidity and mortality. Accid. Anal. Prev. 22:571–585; 1990.