EVALUATIONS OF VALIDITY OF TWO RESEARCH METHODS FOR STUDYING PERCEPTION OF ROAD SIGNS

Juha Luoma

The University of Michigan
Transportation Research Institute
Ann Arbor, Michigan 48109-2150
U.S.A.

Report No. UMTRI-91-15
March 1991

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTRI-91-15		

4. Title and Subtitle	5. Report Date
EVALUATIONS OF VALIDITY OF TWO RESEARCH METHODS FOR STUDYING PERCEPTION OF ROAD SIGNS	March 1991
	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s)	UMTRI-91-15
Juha Luoma	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
The University of Michigan Transportation Research Institute Ann Arbor, Michigan 48109-2150 U.S.A.	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	
The Academy of Finland Hämeentie 68 SF-00550 Helsinki, Finland	14. Sponsoring Agency Code

15. Supplementary Notes

Partial support for this research was also provided by the Henry Ford Foundation and the Traffic Safety Committee of Insurance Companies (VALT).

16. Abstract

The present study was designed to evaluate validity aspects of the eye movement method and the recall method used frequently in studies concerning perception of road signs.

One problem of the eye movement method is that drivers are alerted because they know they are participating in an experiment. Therefore they may behave differently from unalerted drivers. The first experiment was designed to compare speed changes of 77 alerted and 311 unalerted drivers while encountering a road sign. Three conditions were evaluated: a game crossing sign, a speed limit sign, and a control condition with no sign. The results indicated that in the speed limit condition, the alerted drivers reduced their speed more than did the unalerted drivers. In addition, the variance of speed of the unalerted drivers was always more substantial than the variance of the alerted drivers.

Two problems of the recall method are the delay between the passing of the sign and the inquiry, and the anxiety caused by a sudden request to stop. The second experiment compared the recall of road signs after two different delays. 102 subjects encountered the same stimulus conditions as described above. Either immediately after passing a road sign or 670 m downstream, the subjects were asked a question about the last road sign. The results showed that subjects recalled the speed limit sign regardless of the delay, but the recall of the game crossing sign decreased substantially when the inquiry was delayed.

The implications of this study are that the behavior of alerted drivers differs at least in some degree from the behavior of unalerted drivers, and that the recall delay affects especially the recall of a road sign of subjectively minor importance.

17. Key Words	18. Distribution Statement
Perception, road sign, validity, eye movement, recall, response	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	31	

ACKNOWLEDGEMENTS

The support of this study by the Academy of Finland, the Henry Ford Foundation, and the Traffic Safety Committee of Insurance Companies (VALT) is gratefully appreciated. Appreciation is also extended to the Helsinki University of Technology and the Technical Research Centre of Finland, whose measuring devices were used in experiments, and to the Finnish Road Administration for permission and help to post experimental signs on a public road.

This report was written while the author was a Visiting Scholar at the University of Michigan Transportation Research Institute (UMTRI) in Ann Arbor, Michigan.

The author wishes to thank Mr. Pekka Hytönen, Mr. Erkki Ritari and Olli Saarinen, M.Sc. for assistance with carrying out the experiments, and Michael Flannagan, Ph.D. and Michael Sivak, Ph.D. at UMTRI for valuable discussions and for their helpful suggestions on an earlier draft of this report. He would also like to thank all 102 individuals who participated in experiments.

CONTENTS

INTRODUCTION

This study concentrates on the research methods used in studies that have investigated the question of how drivers perceive the information in road signs in real life. At the same time, an attempt has been made to obtain more general information about driver visual information acquisition and processing during driving.

Perception of road signs has been investigated in field experiments by many research methods. However, according to Luoma (1989) all of the methods have been modifications or combinations of three basic methods: the registration of (1) eye movements (2) recalls, or (3) responses. Each method involves the description and explanation of a different characteristic of driver information acquisition, and each method has its own advantages and problems. In the following, the main results, advantages, and problems of these research methods are analyzed briefly.

Because attention is directed mostly in the same direction as the eyes, it often has been assumed that registration of eye movements best indicates the perception of road signs (e.g., Zwahlen, 1980). The results of eye movement studies indicate that usually 90-100% of subjects fixate on regulatory and warning signs, and that there are no significant differences between percentages of fixations for different signs (e.g., Zwahlen, 1980; Luoma, 1988, 1989).

In some studies, head movements are registered instead of eye movements. However, the nature of these studies is so similar that only the eye movement studies will be discussed here.

Eye movements are, to some extent, involuntary and thus relatively free of bias due to instructions (Bhise and Rockwell, 1973). The problems of the eye movement method are that the extent of further processing of the information is unknown, the role of peripheral vision in perception is unclear, and the time-consuming nature of the method means that it will usually involve a small number of drivers, who are aware of being subjects (Luoma, 1986). In other words, the subjects are alerted drivers who may be more attentive, drive more slowly, better obey traffic rules, etc.

Drivers' recalls have been studied by stopping vehicles that have recently passed a test sign and inquiring about the last sign they remember having passed (Häkkinen, 1965; Johansson and Rumar, 1966; Johansson and

Backlund, 1970; Syvänen, 1968; Hanscom, 1976; Reiss and Robertson, 1976; Aberg, 1981; Drory and Shinar, 1982; Shinar and Drory, 1983; Milosevic and Gajic, 1986). The studies of Johansson and his co-workers, Häkkinen, and Aberg conducted in Sweden and Finland revealed substantial differences between the probabilities of the recall of different signs. For example, 69-80% of drivers correctly recalled a speed limit sign, 61-77% a special police control sign, 46-67% a game crossing sign, and 18-39% a general warning sign. Drory and Shinar (1982), Shinar and Drory (1983), and Milosevic and Gajic (1986) found substantially lower probabilities of recall, but confirmed the tendency for higher recall probabilities for significant signs.

This simple research method has obvious advantages. The number of drivers can be substantial, the drivers are unalerted when they are encountering the sign, and the results indicate at least something about how the drivers process information. The method has been criticized because of the potential effects of the delay between the passing of the sign and the inquiry, and the anxiety caused by a sudden request to stop by a policeman (see e.g., Summala and Näätänen, 1974; Cohen 1987). However, Johansson and co-workers argued that it seems improbable that any driver who had read the police control sign would forget its message: (1) some of them were 'home made' (2) it must have been considered subjectively too important to forget and (3) it received reinforcement after a few seconds. Johansson and Backlund (1970) also collected half of the data when the vehicles were stopped by a policeman in uniform and the other half by a policeman in plain clothes. No differences were found.

Another possible way to study the recall of signs is to use subjects whose task is to answer questions concerning targets that they recently passed. The questions concerning road signs are included among questions concerning different kinds of targets (Luoma, 1988, 1989). This modification of the recall method also allows recording the driver's eye movements when the driver is encountering the sign. Luoma's (1989) results showed that about 80% of subjects recalled warning signs and 92% recalled the speed limit sign, although each of the signs was fixated on by over 90% of subjects.

This method can avoid most of the potential effects of delay but the problems of having alerted drivers remain. It is also uncertain how the driver has processed the information in the sign, if at all, if he or she has fixated on the sign but is not able to recall it in few seconds. Moreover, these experiments

have to be planned carefully, because the subjects easily pay more attention than usual to traffic control devices. The same problems concern the recall method used by MacDonald and Hoffmann (1984). The subjects in this study were asked to report everything of relevance to driving that they had seen just before a sudden occlusion of vision (see also Hughes and Cole, 1986).

The third basic method involves drawing conclusions about perception of road signs from drivers' behavioral responses (Hanscom, 1976; Reiss and Robertson, 1976; Summala and Hietamäki, 1984). Summala and Hietamäki measured immediate speed changes of drivers on a steeply rising curve where an experimental sign suddenly came into view. Their results showed that a speed limit sign resulted in a significant decrease in speed, but warning signs did not.

The advantages of this method are that there are no delays or confusing aspects in the experimental arrangement, the measurement concerns unalerted drivers, and data can be obtained from a large number of drivers in a short period of time. But this method also has many disadvantages. It tells us nothing about the earlier stages of information acquisition, the responses are often minimal, and, finally, a driver can respond to a sign in many ways (to reduce speed, to increase his activation level, to change his eye movement patterns, etc.). Many of the responses, except for the speed of the vehicle, are difficult to measure.

This study was designed to analyze two of the above mentioned problems: (1) Do alerted drivers (subjects) behave differently from unalerted drivers, because they are participating in an experiment and they know that? This question concerns, primarily, the eye movement method but also other methods involving the use of alerted drivers. (2) Does the delay between the passing of a sign and the inquiry in a recall experiment affect the probability of recall of different signs? Two experiments were conducted in order to answer these questions.

The first experiment was designed to compare speed changes of alerted and unalerted drivers. The experimental set up was designed to replicate the main set up used by Summala and Hietamäki (1984). In contrast to that study, which involved only unalerted drivers, the present experiment measured speed changes of both unalerted and alerted drivers, thus allowing an evaluation of the validity of the method of recording immediate speed changes. Unfortunately, it was not possible to carry out the present experiment in the

same site as the one used by Summala and Hietamäki, because the road geometry of that site had been modified.

The second experiment was designed to compare the recall of road signs after two different delays. The experimental set up was intended to replicate that used by Häkkinen (1965), Johansson and Rumar (1966), Johansson and Backlund (1970), and Aberg (1981), because these experiments were carried out in comparable circumstances in Finland and Sweden. One of the main differences was that the previous studies used unalerted drivers, while the present study used alerted drivers. Another important difference was that in the present experiment the delay between the passing of the sign and the inquiry was varied.

EXPERIMENT 1
METHOD

Experimental site

The experimental site was located on a Finnish secondary road, with a speed limit of 80 km/h and an average daily traffic of 2900 vehicles. An experimental road sign was erected on a slightly rising right curve so that the presentation could be timed exactly (Figure 1). Drivers were able to see the sign 72 m away. At the site, the road was pointing approximately to the north.

Figure 1. The site of measurement with an experimental road sign.

Stimulus conditions

Three conditions were evaluated: (1) a symbolic game (animal) crossing sign with a supplemental 0.5 km sign which showed that the sign was valid for the next 500 m, (2) a 50 km/h speed limit sign, and (3) a control condition with no sign. These signs were selected because Summala and Hietamäki (1984) found that a speed limit sign and a warning sign affected responses differently. The game crossing was selected as a warning sign because it is one of the most natural signs expected to be seen on a rural road of this kind. The background of the sign was a forest.

Equipment

The test vehicle driven by the alerted drivers was a small passenger car with a manual transmission. The car was equipped with a portable personal computer (Toshiba T3200) connected to sensors which recorded the following variables at intervals of 1 second: the actual distance from 3 km upstream from the experimental site, the actual speed of the car, and the actual use of the brake and clutch pedals, and the gear. The distance and speed information were recorded to determine the speed of the car when it was encountering the sign. The other variables were measured in order to describe driver behavior more specifically. These variables were observed during 5 sec upstream from the sign. The eye movements were recorded by an eye movement recorder (EMR-NAC Model 5).

The speed of unalerted drivers was measured with four pairs of photocells that were connected to a data storing system. All devices were hidden so that a driver passing the site was not able to detect them without a specific search. The wheels of each passing car produced three time intervals between the four beams. Based on that data the mean speed of each passing car could be computed. The first speed was measured just before the driver was able to see the sign and the other two speeds produced the speed change values. The distances of the photocell pairs were 79, 69, and 25 m upstream and 25 m downstream from the sign. Consequently, the control points of the speed were 74, 47, and 0 m upstream from the sign (in the center of each two photocell pairs).

Drivers

The alerted drivers included technical or secretarial staff of the Helsinki University of Technology and the Technical Research Centre of Finland. All were licensed drivers who volunteered for the study. Their ages ranged from 19 to 55 years and their vehicle kilometreage during the previous year ranged from 1,000 to 100,000 km. Most of them were quite unfamiliar with the test road. Eighty-eight percent of them were men. None of them wore glasses. More detailed data about the background of the alerted drivers are given in Appendix 1.

Background data were not collected concerning the unalerted drivers. However, based on the information about the Finnish driver population and the nature of the road, it can be assumed that the differences between the alerted and the unalerted drivers were generally small, except that familiarity with the road differed because the unalerted drivers might have included a substantial number of local inhabitants who use the road frequently.

Procedure

The alerted drivers participated in the experiment individually and only once. They were told that the purpose of the experiment was to analyze normal visual information acquisition during highway driving. Furthermore, they were told that their eye movements would be recorded, and that they would be asked some questions concerning what they had perceived (although the question was asked later as part of Experiment 2). Their task was to drive a route of 60 km as normally as possible, but following the experimenter's directions. They were asked to familiarize themselves with all controls before the start. They drove a practice route of 15 km without the eye mark recorder so that they could get used to the car.

After the practice session the eye mark recorder was placed on drivers' heads and calibrated. After driving 9 km they passed the experimental site. The experimenter observed the calibration of the eye mark recorder in a monitor and, if necessary, recalibrated the recorder. However, the recalibration was completed at least 2 km upstream of the experimental site. The experimenter also checked the calibration of the recorder 2 km downstream from the experimental site.

A total of 102 alerted drivers participated in the experiment, but cases with an opposing vehicle or a vehicle in front of the experimental car with a gap

less than 15 sec during the section where the speeds were measured were omitted, as were cases with some errors in data collection. Consequently, the final data included 77 alerted drivers (25-27 cases in each sign condition).

The alerted drivers were run on 28 days during a period of 53 days. Three or four drivers were run daily from 9 a.m. to 3 p.m. and one of those was a control condition with no sign. The type of sign was alternated after each 7 days of data collection.

The speed measurements of the unalerted drivers were collected during the same time of day, on two separate days scheduled after one third and two thirds of the data of unalerted drivers had been collected. The stimulus condition was always changed after one hour. The final data included the speeds of 311 passenger cars and vans driven in an uphill direction (97-110 in each sign condition).

Because the speed of the alerted drivers was measured at intervals of 1 second, the speeds at the control points for alerted drivers were interpolated. The measurements were also calibrated.

All measurements were carried out in the fall. The weather was not matched, but it is assumed that the change of the sign resulted in a randomized experimental design.

RESULTS

Initial speed

The initial speeds were submitted to an analysis of variance using the following two factors: driver group (alerted or unalerted) and sign condition. The effect of driver group was marginally not significant, $F(1,386) = 3.01$, $p < .08$, with unalerted drivers tending to drive faster than alerted drivers (70.0 km/h vs. 68.1 km/h). The effect of sign condition was not significant and the interaction of sign condition and driver group was also not significant. The detailed speed data are given in Appendix 2.

However, Bartlett's test (Snedecor and Cochran, 1967) showed that the driver group had a significant effect on the variance of the initial speed, $\chi^2(1) = 116.76$, $p<.001$, with unalerted drivers having a greater speed variance.

Speed changes

Figure 2 shows the average speed change, with respect to the initial speed.

The overall F-ratio between the speeds of all six driver groups was marginally not significant at the distance of 27 m from the first control point (the second control point), $F(5,382) = 2.10$, $p<.06$, but it was significant at the distance of 74 m (the third control point), $F(5,382) = 10.63$, $p<.0001$. Scheffe's test (see, for example, Kirk, 1968) showed that the speed of the alerted drivers in the speed limit condition deviated significantly from all other speeds at the third control point (Table 1). The speed of the unalerted drivers for the speed limit condition also differed significantly from the speed of the unalerted drivers in the no-sign condition. None of the other differences was significant.

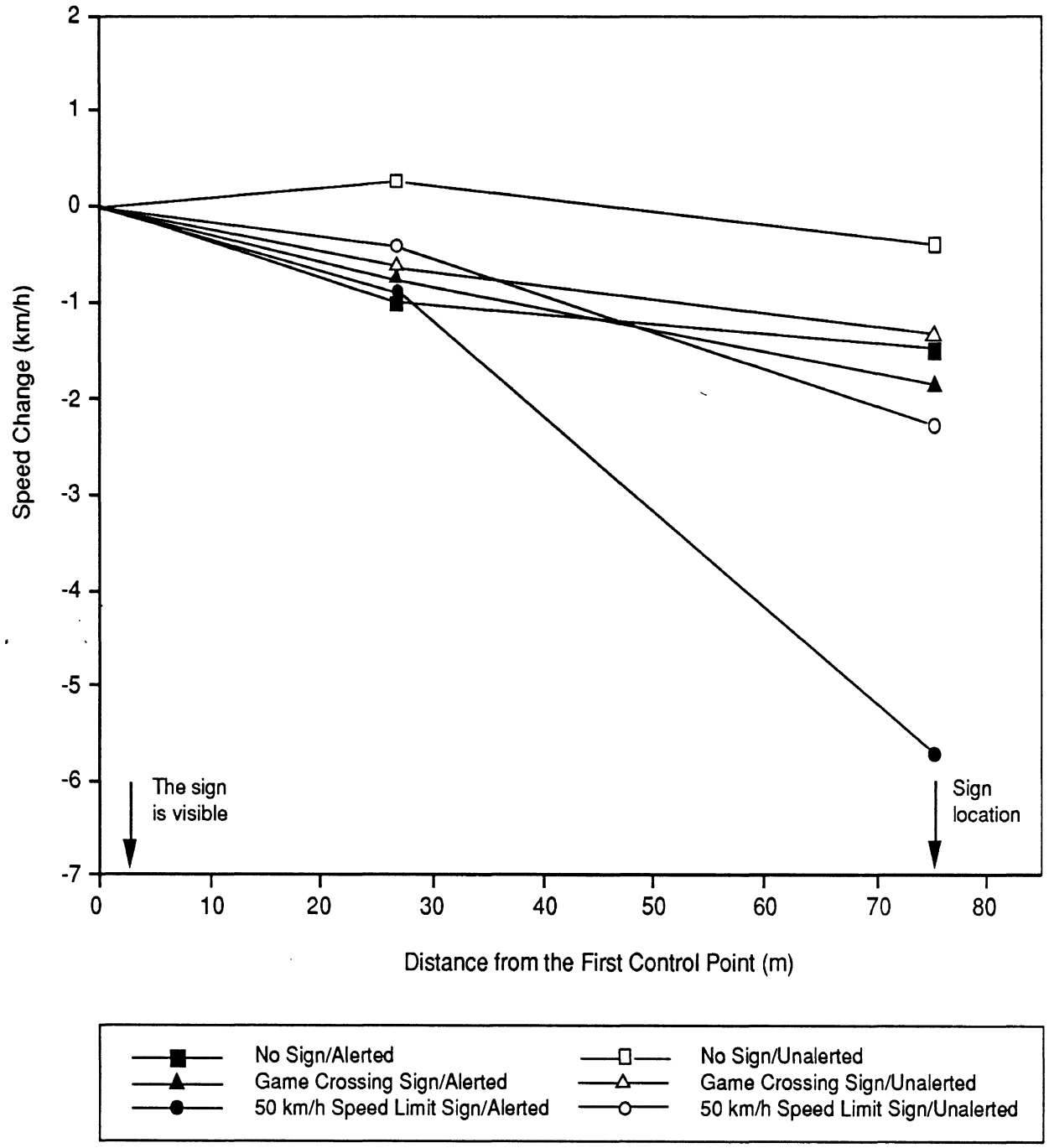

Figure 2. Average speed change in different experimental conditions. The location of the experimental sign and the point where it came into the driver's view are indicated on the horizontal axis.

TABLE 1. Statistical Significance (p<) of Speed Change Differences between Groups at the Third Control Point according to Scheffe's Test (ns= not significant).

Group	Group 1	2	3	4	5
1. Alerted drivers/No sign					
2. Alerted drivers/Game crossing sign	ns				
3. Alerted drivers/50 km/h speed limit	.01	.01			
4. Unalerted drivers/No sign	ns	ns	.001		
5. Unalerted drivers/Game crossing sign	ns	ns	.001	ns	
6. Unalerted drivers/50 km/h speed limit	ns	ns	.01	.01	ns

As was the case for initial speed, Bartlett's test showed that the driver group affected significantly the variance of the speed changes, with greater variance of the speed chances of unalerted drivers.. This effect was found in all sign conditions at the second and third control points.

Eye movements of the alerted drivers

An eye fixation was defined when the eye mark of the recorder stopped on the sign. The number of eye fixations and fixation durations were analyzed.

In both sign conditions, 92% of the alerted drivers fixated on the sign. Drivers with eye fixations on the sign fixated on the sign on average 2.2 times (s.d. = 0.90) and the mean fixation duration was 420 msec (s.d. = 195 msec). No significant differences were found between the sign conditions.

The small number of drivers with no fixation makes it difficult to analyze the effect of eye fixations on speed changes. Nevertheless, it was found that the drivers who did not fixate on the sign decreased speed as much or more than drivers with eye fixations on the sign.

In either sign condition, neither the number of eye fixations nor total fixation duration correlated with speed reduction. Pearson correlation coefficients were less than 0.20 and statistically not significant in both sign conditions.

Use of brake and clutch

All drivers who used the clutch changed to a lower gear, apparently in order to reduce the speed. Only one driver used the clutch and none braked in each of the control and the game crossing sign conditions. In the speed limit condition, one driver used the clutch pedal as well as braked, four drivers used the clutch pedal only, and three drivers braked only. Because of the small number of drivers who used the brake or clutch, only responses to the speed limit were analyzed. The results showed that in response to the speed limit sign, the drivers with the use of brake or clutch tended to reduce their speed more than did the drivers without the use of any control (6.7 vs. 5.3 km/h). However, the difference was statistically not significant.

Effects of driver's background

In the speed limit condition, driver's age and annual kilometreage affected the speed reduction: drivers older than 36 years of age reduced their speed more than did the younger drivers, $F(1,25)=14,64$, $p<.0008$, and drivers who had driven less than 20,000 km in the last year reduced their speed more than did the more experienced drivers, $F(1,23)=4.37$, $p<.05$. Neither driver's sex nor familiarity with the experimental route affected the speed reduction. No effects were found in the game crossing sign or no-sign conditions.

DISCUSSION

This experiment evaluated one validity aspect of the eye movement method. Specifically, the experiment compared speed changes of alerted and unalerted drivers when they were encountering a road sign. In terms of average speed, the overall pattern of speed behavior of the alerted drivers was similar to that of the unalerted drivers: the effect of driver group on initial speed was marginally not significant, and the speed limit sign (but not the game crossing sign) caused a significant decrease in speeds of both groups. However, in response to the speed limit sign, alerted drivers reduced their speeds more than did the unalerted drivers. In addition, the variance of the speed of the unalerted drivers was always greater than the variance of the alerted drivers.

The similarity between initial speeds of the alerted and the unalerted drivers may be considered surprising because the experimental car driven by the alerted drivers was a small car and they had driven it only for 24 km. Thus, one could expect that the alerted drivers would have driven more slowly.

Two explanations for the difference between alerted and unalerted drivers in speed reduction in response to the speed limit sign are possible: (1) alerted drivers respond more substantially than unalerted drivers to explicit speed restriction, or (2) alerted drivers respond more substantially to many signs or all signs. Because there was no evidence for speed reduction in response to the game crossing sign in either group, the present data do not allow differentiation between these two hypotheses.

The differences in the variance of the speeds suggest that the general speed behavior of the alerted drivers is more uniform than the speed behavior of the unalerted drivers. In other words, the behavioral deviation seems to decrease among the drivers who are participating in an experiment.

The eye movement data showed that over 90% of alerted drivers in the both sign conditions fixated on the sign. This suggests that they detected the signs similarly but the decrease in speed depended on the sign contents. It was found also that those few drivers who did not fixate on the speed limit sign decreased speed as much or more than drivers who did. This may have occurred because of mistakes in the analysis of eye movements, or because the drivers perceived the sign with peripheral vision. Both explanations are possible, but the first one is unlikely because each case with no-fixation was

reanalyzed, and because Luoma (1986) found that two estimators analyzed the eye fixations similarly. Thus the analyses of eye movements should be reliable.

We do not know how many unalerted drivers detected the sign. The present data do not provide that information and neither do data from Summala and Hietamäki (1984). It is only reasonable to assume that the unalerted drivers did not differ in terms of eye fixations between the different sign conditions because alerted drivers did not differ.

EXPERIMENT 2
METHOD

Experimental site

The experimental site was located on the same secondary road as the site of Experiment 1, about 1.5 km downstream. The speed limit on this part of the road was 60 km/h. An experimental road sign was posted in a normal manner on a slightly descending left curve (Figure 3). Drivers were able to see the sign about 200 m away and there were no other road signs within about 1 km upstream and downstream from the experimental sign. As in Experiment 1, the road was pointing approximately to the north.

Figure 3. The site of measurement with an experimental road sign.

Stimulus conditions

Three conditions were evaluated: (1) a symbolic game crossing sign with a supplemental 1 km sign, (2) a 40 km/h speed limit sign, and (3) a control condition with no sign. These signs were selected because previous studies have shown that the basic difference in the recall of signs is between warning signs and speed-restriction signs, with a lower percentage in the recall of warning signs. Moreover, on rural roads of this kind, the game crossing sign is rather common, but the speed limit of 40 km/h can be considered as an extreme restriction. Because the game crossing sign was supplemented with a 1 km sign, both signs were valid for a similar distance. The background of the sign was a forest.

Equipment

The test vehicle and the equipments in the vehicle were the same as in Experiment 1.

Subjects

The subjects were the alerted drivers in Experiment 1, including the 25 drivers whose data were not used in Experiment 1 because other vehicles were present when they passed the Experiment 1 sign position. Results of this experiment will be broken down by whether other traffic was present at the Experiment 2 sign position. Subject characteristics for Experiment 2 are given in Appendix 1 using that dichotomy.

Procedure

The subjects encountered the experimental sign when they had driven approximately 1.5 km after the sign in Experiment 1. Between passing the experimental signs, no interruption or discussion occurred. Thus the procedure (instruction, the change of the signs, the schedule etc.) of Experiment 1 is applicable to Experiment 2, except for the following changes and additions.

Either immediately after passing a road sign or 670 m downstream, the subjects in the sign condition were asked one or two questions:

(1) What was the last road sign you passed?

(2) Was there anything else? (Only asked in the game crossing sign condition if Question 1 was answered correctly.)

In the nominally immediate condition, there was actually a delay of about 2 sec before the subject heard the first question. In the other condition, the experiment continued without interruption until the experimenter asked the subject to stop the car at a bus stop 670 m downstream from the experimental sign. (In the experiments of Häkkinen, Johansson and co-workers, and Aberg, a police barrier was located 450, 700, 710, and 800 m downstream from the sign.)

After the stop the experimenter asked the same questions. Because subjects in different sign conditions were driving at different speeds after passing the sign, the longer delay averaged 49 sec in the game crossing sign condition and 56 sec in the speed limit condition.

The tested delay was alternated after each 4 subjects. No road sign appeared between the experimental sign and the bus stop.

The speed of the experimental vehicle was measured just before the driver was able to see the sign and about 200 m downstream from the sign. Both speed values were the average speeds during 3 sec.

A total of 102 alerted drivers participated in the experiment, but cases with an opposing vehicle, or a vehicle in front of the experimental vehicle with a gap less than 15 sec, during the section where the speeds were measured were omitted from the main analysis. The final data included 77 drivers without other traffic in the vicinity (14-18 cases in each sign/delay condition) and 25 drivers with other traffic in the vicinity. Except as noted, the following results do not concern the recall of the supplementary sign and the effect of other traffic in the vicinity.

RESULTS

Recall of the road sign

Correct recalls were defined as answers in which the essential content of the sign was correct. In all cases, the road sign was correctly reported, if at all. The recall of the two road signs in the two delay conditions is given in Figure 4.

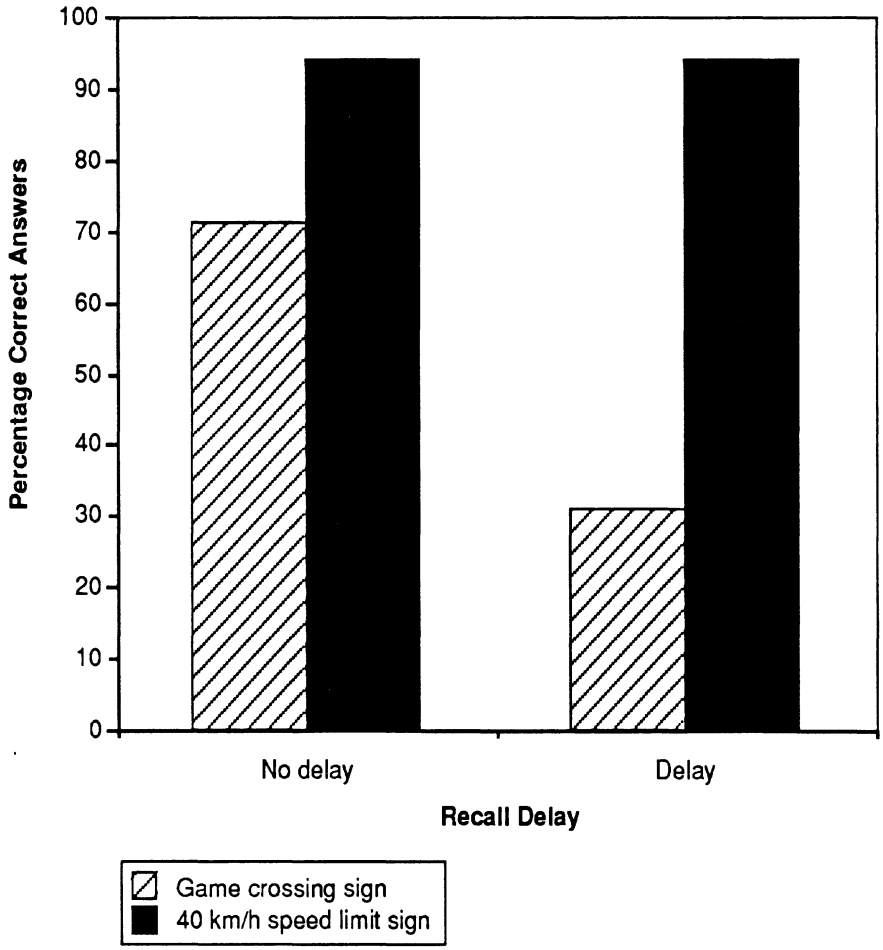

Figure 4. Correct recall of the road sign in the two sign and delay conditions.

The results indicate that 94% of the subjects recalled the speed limit sign regardless of the delay ($\chi^2(1) = 0.93$, ns), but the recall of the game crossing sign decreased from 71% to 31% when the inquiry was delayed ($\chi^2(1) = 4.46$, $p<.03$). When a question about the last sign was asked immediately, the difference in recall between the two road signs was marginally not significant

($\chi^2(1) = 3.16$, $p<.08$), but after the longer delay the difference was highly significant ($\chi^2(1) = 12.59$, $p<.0004$).

The results showed also that 50% of subjects who recalled the game crossing sign when asked immediately also recalled the supplementary sign. After the longer delay, it was recalled by 75% of subjects who recalled the game crossing sign. Four subjects recalled that there was a supplementary sign but did not recall the contents. These cases were coded as incorrect recalls of the supplementary sign.

Eye movements of the subjects

Only one subject (in the game crossing sign and longer-delay condition) did not fixate on the sign. Drivers with eye fixations on the sign fixated on it on average 2.9 times (s.d. = 1.5) and the mean fixation duration was 484 msec (s.d.= 246 msec). No significant differences were found between the sign conditions. The same result was found for the effects of number of eye fixations and fixation duration on recall of the sign.

Initial speed and speed changes

Initial speed averaged 67.1 km/h. No difference was found for sign by delay conditions. However, speed changes differed significantly depending on the combination of sign, delay, and recall of the sign, $F(8,66)=28,21$, $p<.0001$ (Figure 5).

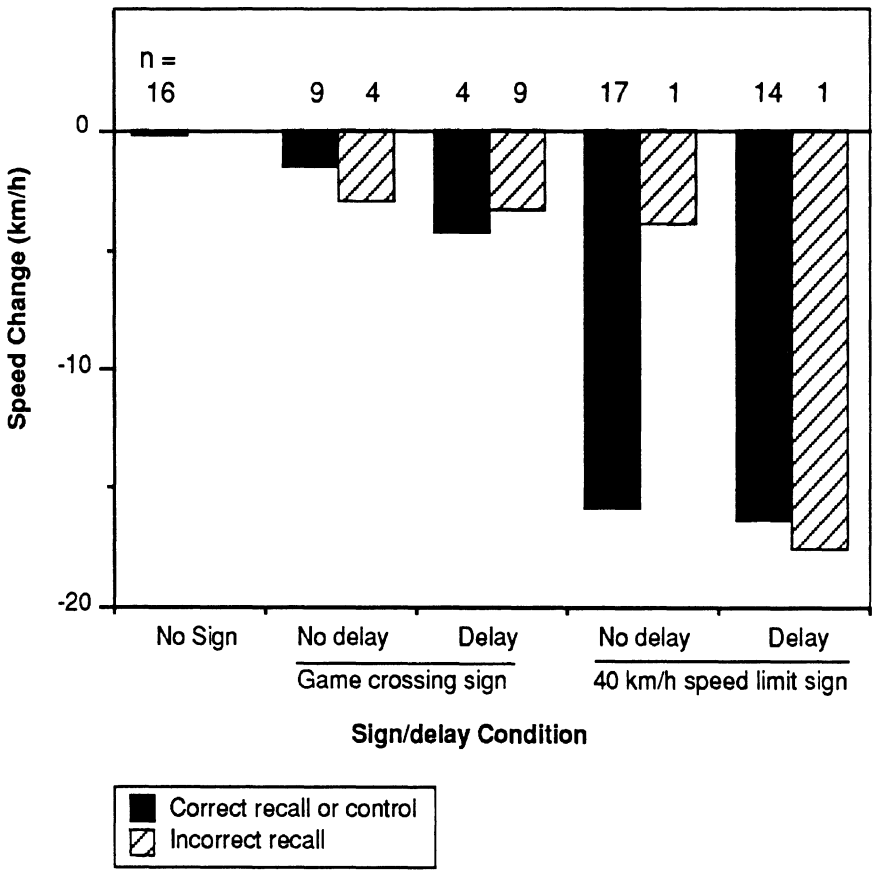

Figure 5. The average speed change depending on the sign, the delay condition, and the recall of the sign.

Scheffe's tests showed that the subjects in the speed limit condition who recalled the sign decreased their speed significantly more than the subjects who encountered the game crossing sign (whether they recalled it or not) or no sign. None of the other differences was significant.

Use of brake and clutch

As in Experiment 1, all drivers in Experiment 2 who used the clutch changed to a lower gear, apparently in order to reduce speed.

In the control condition, only two subjects braked and none used the clutch. In the game crossing sign condition, two subjects braked (one in each delay condition) and none used the clutch. In the speed limit condition 29% of subjects used the clutch pedal as well as braked, 24% used the clutch pedal only, and 21% braked only.

Because of the small number of drivers using brake or clutch, only responses to the speed limit were analyzed. The results showed that in

response to the speed limit sign, drivers using brake or clutch reduced their speed more than did the drivers without the use of any control (16.8 vs. 12.3 km/h). However, the difference was marginally not significant, $F(1,31)=3.69$, $p<.06$. The delay of questioning did not influence the use of controls.

Effects of subject's background

The effects of the background variables on the recall of the game crossing sign were analyzed for each delay condition and for the combined data. None of the background variables was found to affect the recall of the sign statistically significantly. However, there was a tendency for the female subjects not to forget the sign, and for the subjects who recalled the sign to have driven less in the previous year than those subjects who forgot the sign. These tendencies were found in both delay conditions. Familiarity with the road and age had no effects on the recall of the sign.

Recall of the sign with other traffic in the vicinity

Previous experiments concerning recall of a road sign did not control for traffic in the vicinity of the sign. At least in principle, the experimental set up of this experiment enabled the division of subjects into two groups: with or without other traffic present in the vicinity of the sign. The preceding results are for the second group .

The size of the present data set allows examination of only overall effects of other traffic on recall of the game crossing sign. The cases with other traffic in the vicinity were divided into three types: (1) one or more oncoming vehicles but no vehicle in front of the experimental car (43%), (2) one or more vehicles in front with or without an oncoming vehicle (43%), and (3) an approaching vehicle from the secondary road without vehicles in front or oncoming (14%). The frequencies of those types were quite similar in both delay conditions, and in all cases the subjects were able to see the sign.

In cases when other traffic was present, 33% of the subjects recalled the sign if they were asked immediately and only 13% recalled it after the longer delay. In both delay conditions, the other traffic in the vicinity decreased the recall percentage by more than half.

DISCUSSION

This experiment was designed to evaluate the validity of the recall method. Specifically, the experiment compared the recall of road signs after two different delays, using the same experimental set up as the one used by Häkkinen (1965), Johansson and Rumar (1966), Johansson and Backlund (1970), and Aberg (1981).

The results indicate that when there was no other traffic in the vicinity, 94% of the subjects recalled the speed limit sign regardless of the delay, but the recall of the game crossing sign decreased from 71% to 31% when the inquiry was delayed.

In previous studies, recall of the game crossing sign after a delay has varied between 46% and 67%. The present figure of 31% is surprisingly small and it is difficult to suggest any particular reason for that except for the small number of subjects and random variation.

The speed limit sign was recalled better than in other studies. There are three factors which probably explain the difference. (1) The drivers in the present experiment were subjects (alerted drivers) who were found to behave differently from the unalerted drivers in Experiment 1. (2) In the 1960s, when the other results concerning the recall of the speed limit sign were collected, there was no general speed limit system in Finland or Sweden. Nowadays drivers know that speed limits always exist, and so they may better observe them. (3) The main results of the present experiment included only drivers who had no other traffic in the vicinity. The present findings indicated that other traffic systematically decreases recall of a sign, and the previous studies did not control the existence of other traffic. Taking these factors into account may reconcile the results of the different studies. Similarly, immediate recall of the different signs is in agreement with the findings of Luoma (1989).

The main implication of this study is that recall delay has a different effect depending on the type of the sign. Johansson and co-workers evaluated the effect of delay on recall of subjectively important signs and found the delay of minor importance. This study suggests that delay is important and its effect appears in the recall of the road signs of minor subjective importance. Thus, using delayed recall to obtain information about driver information acquisition is questionable. However, these results, as well as the previous findings, do not provide a final explanation for the recall of signs of different types.

In addition, this study indicates that a careful consideration of other traffic during the experiment is essential. The lack of this control might explain a part of the variability in the results from previous studies.

Because the eye fixation patterns of the subject groups in different sign conditions did not differ, it can be concluded that the subjects detected the signs similarly. However, recall of a sign depended on the sign contents and the delay.

Furthermore, the results showed that the subjects who recalled the speed limit sign decreased their speed significantly more than did the subjects who encountered the game crossing sign (whether they recalled it or not) or no sign. Thus, in agreement with findings of Experiment 1, the game crossing sign did not affect speed behavior but the speed limit sign did. However, it is interesting to note that the subjects who did not recall the speed limit sign decreased speed differently (see Figure 5). Although there were only two subjects in this group, it could be argued that the subject who decreased speed only slightly did not detect the sign well or immediately considered the message of the sign unnecessary and forgot it. On the other hand, the subject who decreased speed more substantially took the message of the sign into account but could not recall that the speed limit sign was the last presented.

As in Experiment 1, the effects of the background variables were minor. In general, this result is in agreement with findings of the earlier studies. However, the effects of the background variables in those studies have varied to some extent.

In the results of Experiment 1, it is interesting to note that the mean initial speed was greater than the actual speed limit. Also, the speed decrease after the speed limit sign was not as substantial as the sign required. The mean speed after the 40 km/h speed limit sign was over 50 km/h. This result suggests that even alerted drivers do not, as sometimes assumed, obey traffic rules.

With regard to the validity of the simultaneous measurement of recalls and responses, it is noteworthy that the question concerning the road sign presented immediately after passing the sign did not affect speed behavior. One would expect that the question would change the behavior of the driver, with the result that the measurements of speed behavior would be invalid. However, the present results did not indicate any such effect.

GENERAL DISCUSSION AND CONCLUSIONS

As stated in the beginning of this report, each of the three basic research methods that have been used to obtain information about the perception of a road sign has both advantages and disadvantages. This study was designed to test empirically one aspect of the validity of the eye movement method and one aspect of the validity of the recall method. Specifically, Experiment 1 compared speed changes while encountering a road sign for drivers whose were being monitored (alerted drivers) and unalerted drivers. Experiment 2 compared the recall of road signs after two delays.

The main findings were:

(1) In response to the speed limit sign, the alerted drivers reduced their speed more than did the unalerted drivers. Furthermore, the variance of the speed of the unalerted drivers was greater than that of the alerted drivers.

(2) Almost all of the subjects recalled the speed limit sign regardless of delay, but recall of the game crossing sign decreased substantially when the inquiry was delayed.

The main implications of this study are that the behavior of alerted drivers differs at least in some degree from that of unalerted drivers, and that recall delay affects especially the recall of a road sign of subjectively minor importance. In addition, this study suggests the need for careful control of other traffic during experiments.

However, these critical conclusions do not mean that the research methods are unusable. For now and probably for the near future, these are our most useful research methods. The eye movement method and (in some cases) the measurement of head movements are still the best means to obtain information about the detection of signs; the recall method shows directly which message the driver remembers; and an investigation of driver responses gives indirect information about the behavior that is unobtrusively measured. Although we cannot abandon these research methods, we have to interpret earlier findings more carefully than has been done previously. In addition, this study encourages more extensive and specific evaluation of the validity of different methods. This does not necessarily mean the development of complicated and expensive techniques, but rather seeking new experimental set ups and combinations of existing research methods.

REFERENCES

Aberg, L. (1981). The human factors in game-vehicle accidents. A study of drivers' information acquisition (Studia Psychologica Uppsaliensia 6). Acta Universitatis Upsaliensis. Uppsala.

Bhise, V.D. and Rockwell, T.H. (1973). Toward the development of a methodology for evaluating highway signs based on driver information acquisition. Highway Research Record, No. 440, 38-56.

Cohen, A.S. (1987). Wahrnehmung von Verkehrszeichen (Bericht zum Forschungsprojekt 8524/8 im Auftrag der Bundesanstalt fur Strassenwesen Bergisch Gladbach). Zurich: Institut fur Verhaltenswissenschaft, Eidgenossische Technische Hochschule Zurich.

Drory, A. and Shinar, D. (1982). The effects of roadway environment and fatigue on sign perception. Journal of Safety Research 1(13), 25-32.

Häkkinen, S. (1965). Perception of highway traffic signs (Reports from Talja No. 1). Helsinki: Talja.

Hanscom, F.R. (1976). Evaluating of signing to warn of wet weather skidding hazards. Transportation Research Record, No. 600, 20-27.

Hughes, P.K. and Cole, B.L. (1986). What attracts attention when driving. Ergonomics 3(29), 377-391.

Johansson, G. and Backlund, F. (1970). Drivers and road signs. Ergonomics 6(13), 749-759.

Johansson, G. and Rumar, K. (1966). Drivers and road signs: a preliminary investigation of the capacity of car drivers to get information from road signs. Ergonomics 1(9), 57- 62.

Kirk, R.E. (1968). Experimental design: Procedures for the Behavioral Sciences. Belmont, California: Brooks/Cole.

Luoma, J. (1986). The acquisition of visual information by the driver: Interaction of relevant and irrelevant information (Reports from Liikenneturva 32). Helsinki: Liikenneturva - The Central Organization for Traffic Safety.

Luoma, J. (1988). Drivers' eye fixations and perceptions. In: A.G. Gale, M.H. Freeman, C.M. Haslegrave, P. Smith and S.P. Taylor (eds.), Vision in Vehicles-II, p. 231-237. Amsterdam: North-Holland.

Luoma, J. (1989). Perception of highway traffic signs: Interaction of eye movements, recalls and reactions. Third International Conference on

Vision in Vehicles. September 12-15, 1989, Aachen, Germany. To be published.

MacDonald, W.A. and Hoffmann, E.R. (1984). Drivers' awareness of traffic sign information (Internal Report AIR 382-1). Melbourne: Australian Road Research Board.

Milosevic, S. and Gajic, R. (1986). Presentation factors and driver characteristics affecting road-sign registration. Ergonomics 6(29), 807-815.

Reiss, M.L. and Robertson, H.D. (1976). Driver perception of school traffic control devices. Transportation Research Record, No. 600, 36-39.

Shinar, D. and Drory, A. (1983). Sign registration in day time and night time driving. Human Factors 1(25), 117-122.

Snedecor, G.W. and Cochran, W.G. (1967). Statistical methods. Sixth edition. Ames, Iowa: The Iowa State University Press.

Summala, H. and Hietamäki, J. (1984). Drivers' immediate responses to traffic signs. Ergonomics 2(27), 205-216.

Summala, H. and Näätänen, R. (1974). Perception of highway traffic signs and motivation. Journal of Safety Research 6, 150- 154.

Syvänen,M. (1968). Effects of police supervision on the perception of traffic signs and driving habits (Reports from Talja, No. 6). Helsinki: Talja.

Zwahlen,H.T. (1981). Driver eye scanning of warning signs on rural highways. In: Sugarman, R.C. (ed.), Proceedings of the Human Factors Society-25th Annual Meeting, p. 33-37.

APPENDIX 1.

The background data of the subjects.

Variable	Experiment 1	Experiment 2	
	Alerted drivers (N=77)	No traffic in the vicinity (N=77)	Other traffic in the vicinity (N=25)
Driver's age (years)			
- mean	36.6	36.2	38.6
- range	19-55	19-55	20-54
Vehicle kilometreage during the last year			
- mean	22,600	21,900	22,700
- range	1,000-100,000	1,000-100,000	3,000-11,600
Percentage of females	12	14	0
Frequence of driving on the test road in the past (%)			
- never	62	66	63
- at most once in the year	24	21	25
- more frequently	14	13	12
Pearson correlation coefficient between driver's age and driving license's age, r (p<)	0.89 (.001)	0.88 (.001)	0.96 (.001)
Pearson correlation coefficient between driver's age and kilometreage, r (p<)	0.15 (ns.)	0.10 (ns.)	0.42 (ns.)

APPENDIX 2.

Initial speed and speed changes in km/h in Experiment 1. (Speed change = the actual speed minus the initial speed. x = mean, sd = standard deviation, and n = number of drivers.)

Driver group (n)	Sign condition		Initial speed	Speed change at the distance of 27 m	74 m
Alerted	No sign	x	68.3	-1.0	-1.5
(27)		sd	4.4	0.8	1.4
Alerted	Game crossing	x	68.3	-0.7	-1.8
(25)	sign	sd	4.1	0.8	1.2
Alerted	50 km/h	x	67.8	-0.9	-5.7
(25)	speed limit	sd	5.2	0.7	2.1
Unalerted	No sign	x	70.7	0.3	-0.4
(104)		sd	8.3	3.9	4.1
Unalerted	Game crossing	x	69.6	-0.6	-1.3
(97)	sign	sd	9.3	1.3	2.5
Unalerted	50 km/h	x	69.6	-0.4	-2.3
(110)	speed limit	sd	9.5	2.3	4.3