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A Preliminary Laboratory Investigation of Passive Railroad Crossing Signs

Research and Development
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FOREWORD

This report presents the results of a laboratory study involving seven candidate railroad crossbucks, including the Manual of Uniform Traffic Control Devices (MUTCD) standard, examining recognition distance, conspicuity, and comprehension. This study was conducted at the Turner-Fairbank Highway Research Center, McLean, Virginia in the Federal Highway Administration's Human Factors Laboratory. Although subjects' performance on some signs was better than on others, further testing in the field is strongly recommended. The results of this study will be useful to researchers, planners and others working in the signing and railroad areas.

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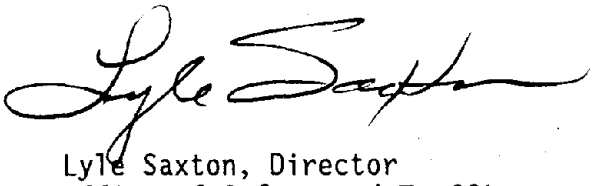

Lyle Saxton, Director
Office of Safety and Traffic
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16. Abstract
In 1990, 2,378 accidents, or 47 percent of all accidents that occurred at grade crossings, occurred at passively signed crossings. This demonstrates the need for an effective passive device at railroad crossings to warn motorists and reduce the number of train-vehicle accidents. The object of this study was to determine the relative effectiveness of seven candidate passive railroad crossing signs, including the current standard crossbuck. Forty-two Young/middle aged (25 to 45 years) and forty-two Older (65 to 85 years) subjects were tested in the experiment. Data on recognition distance, conspicuity, comprehension were collected. The results showed no differences between signs for recognition distance. There were statistically significant differences for the conspicuity measure, with the signs falling into three overlapping groups. The Standard-Yield combination, Standard with Barber-Striped pole, and the Canadian-Conrail combination scored in the highest conspicuity group. The Standard-Conrail combination sign was at the midrange of the conspicuity scores. The Manual of Uniform Traffic Control Devices (MUTCD) Standard and the Canadian Crossbuck showed the worst conspicuity scores. Detailed analyses of the comprehension (meaning and action) responses showed that subjects would take the correct action between 33 percent and 100 percent of the time as a function of the different signs. The best responses were for the Yield to Trains configuration and the Standard-Yield combination. The worst responses were for the MUTCD Standard and the Canadian Crossbuck. The results of this study suggest that further evaluation is needed. The Standard-Yield combination, the Standard-Conrail combination, and the Yield to Trains combination appear to be good candidates for additional field testing.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
	AREA			
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
	VOLUME			
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
	ILLUMINATION			
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
	FORCE and PRESSURE or STRESS			
lbf	poundforce	4.45	newtons	N
psi	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
	AREA			
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	ac
ha	hectares	2.47	acres	mi^2
km^2	square kilometers	0.386	square miles	
	VOLUME			
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
	ILLUMINATION			
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
	FORCE and PRESSURE or STRESS			
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	psi

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised August 1992)

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1. INTRODUCTION

As of 1990, there were 176,572 public railroad-highway grade crossings in the United States.[1] Only 36 percent of these crossings are marked by active warning devices such as gates, flashing lights, highway signals, wigwags, or bells, which are activated by an approaching train. The remaining crossings use passive warning devices, including advance warning signs, pavement markings and crossbucks. The most commonly used passive sign at highway grade crossings is the X-shaped standard crossbuck sign (R15-1).[2] Crossbucks are the only indication provided at 99 percent of the passive warning grade crossings, or 58 percent of all grade crossings.[1] Survey research has revealed that 54 percent of drivers surveyed believe that if a crossing does not have an active device, it is rarely used by trains.[3] Because of this misconception, the actual danger at these sites is often underestimated.

In 1990, 2,378 accidents, or 47 percent of all accidents that occurred at grade crossings, occurred at passively signed crossings.[1] These accidents resulted in 291 deaths and 1,113 injuries. A study examining train-vehicle collisions in Michigan showed that in over 52 percent of all fatal accidents involving trains and vehicles, the vehicle operator failed to respond to a traffic control device.[4] These findings demonstrate the need for an effective passive device at railroad crossings to warn the motorist and reduce the number of train-vehicle accidents.

The ratio of accidents per crossing is lower for passively signed grade crossings than it is for active grade crossings, possibly due to exposure. Active warning is generally reserved for crossings that are more heavily travelled by both cars and trains, increasing the potential number of conflicts, and therefore accidents.

Having trains and motor vehicles cross at the same point introduces a major conflict for highway users, however, costly grade separations are not always feasible. Implementing active warnings at all grade crossings is also not considered cost effective. Many tracks, and therefore many grade crossings, are used only a few times a week by trains, or cross low volume roads. The infrequent traffic at many grade crossings does not justify the expense of installing active devices which cost in excess of $100,000 per crossing.

Given that passively signed grade crossings will continue to exist, improvements in the safety at these crossings may depend on improved signing. Drivers must have sufficient warning of a crossing to have time to execute the required actions – to stop if a train is approaching or in the crossing – and must be made aware of the correct actions.

Many passive warning grade crossings occur on roads where the right-of-way is not strictly maintained and the crossbuck may blend into the scenery surrounding it. The combination of the potentially obscured crossbuck and an obstructed view of the crossing itself reduces advance warning of the crossing. Various combinations of crossbucks and advance warning signs have been evaluated at existing grade crossings and compared to the standard to see if they were more effective than the present system.[5] It was found that an alternative sign configuration elicited more head movements than the standard, although there was no difference in approach speed profiles between signs. Different combinations of advance signs and alternative crossbucks have been

evaluated.[6] It was found that the red and white Canadian crossbuck was better in terms of recognition distance than an alternative yellow and black sign. In another study, three alternatives to the standard crossbuck were compared using recognition distance as a dependant variable.[7] This study revealed that the crossbuck is usually identified by its shape and not the words "RAILROAD CROSSING." Most of the drivers questioned in this effort felt that the present crossbuck provides inadequate warning.

Lack of understanding of appropriate behavior at crossings has been demonstrated in a number of research efforts. In a survey study, it was found that 56 percent of the drivers questioned thought they were supposed to stop at all passive warning crossings.[3] They also found that drivers who were exposed to various safety-educational efforts did no better than drivers who were not exposed to the programs on a quiz testing crossing responses and knowledge.[3] Other researchers observed drivers at a specific crossing and found that many did not slow down or even look before crossing the railroad tracks.[8]

A variety of methods exist to increase the conspicuity of the current sign, including use of colors other than the standard black and white, application of color to the sign post or addition of a second sign. Appropriate driver responses at crossings may be increased if additional information regarding what drivers are expected to do at crossings is added to the sign. If drivers are made aware that they are only required to proceed with caution and not actually stop when no train is in the vicinity, they may be more likely to perform this simple, but possibly life saving, task.

2. OBJECTIVES

The primary objective of this laboratory-based research study is to determine the relative effectiveness of seven candidate passive railroad crossing signs, including the current Manual of Uniform Traffic Control Devices (MUTCD) standard.[2] A definitive determination of the "best" sign cannot be made in a study of this scale, but recommendations regarding those signs which should be investigated further are made, and particular issues requiring further research are described.

3. METHOD

Subjects

Eighty-four subjects, equally split between males and females, participated in this investigation. Subjects were categorized into one of two age groups: young/middle aged (25 to 45 years of age) and older (65 to 85 years of age) with half of the total in each group. Subjects were required to have a valid driver's license and pass a visual acuity examination (20/40 minimum Snellen acuity). Subjects were paid $20.00 for their participation in the study. The average age of the young/middle aged subjects was 34 years of age (range 25 to 45 years of age). The average age of the older subjects was 72 years of age (range 65 to 85 years of age).

Only 72 of the 84 subjects participated in the Conspicuity portion of the evaluation, with an average age in the young/middle aged group of 34 years of

age (range 25 to 45 years of age) and an average age in the older group 72 years of age (range 65 to 81 years of age).

Test Signs

Seven versions of a passive railroad crossing sign were evaluated (see figure 1):

1. The MUTCD standard crossbuck (R15-1), ("Standard").

2. The MUTCD standard crossbuck (R15-1) on a "barber striped" pole, ("Std Barber").

3. The MUTCD standard crossbuck (R15-1) with a standard yield sign (R1-2) mounted below, ("Std Yield").

4. The MUTCD standard crossbuck (R15-1) with the "Conrail" yield sign mounted below, ("Std Conrail").

5. The modified Canadian crossbuck, ("Canadian").

6. The modified Canadian crossbuck with the "Conrail" yield sign mounted below, ("Can Conrail").

7. The standard yield sign (R1-2) with a regulatory plaque below reading "TO TRAINS", ("Yield To Trains").

The last sign (standard yield plus "TO TRAINS" regulatory plaque) was not included in the conspicuity trials. To maximize the usable area of the stimulus slides, all signs appeared on poles 0.305 m (1 ft) shorter than the MUTCD standard.[2]

Measures of Effectiveness

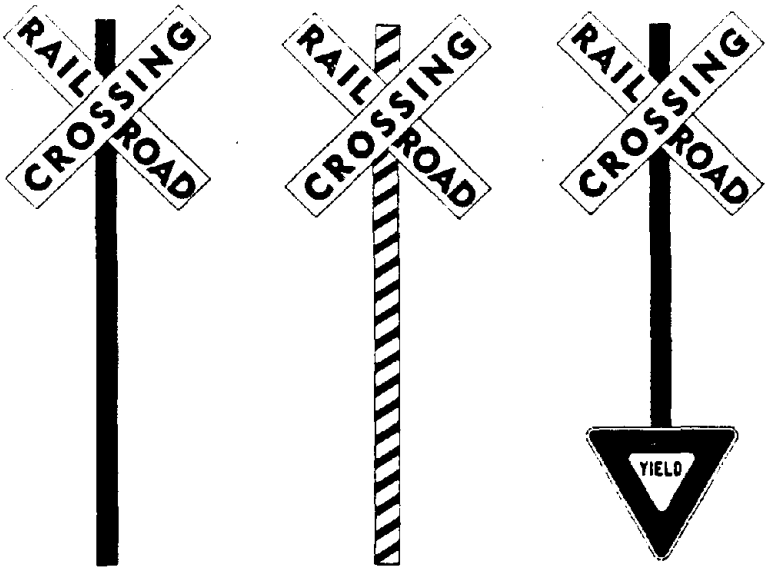
Three measures of effectiveness were utilized in this study: (1) recognition distance, (2) conspicuity, and (3) comprehension. Recognition distance and comprehension were applied in evaluation of all seven signs, conspicuity was used for the first six signs.

Operational definitions, apparatus, procedures, and stimuli utilized for each will be discussed in turn.

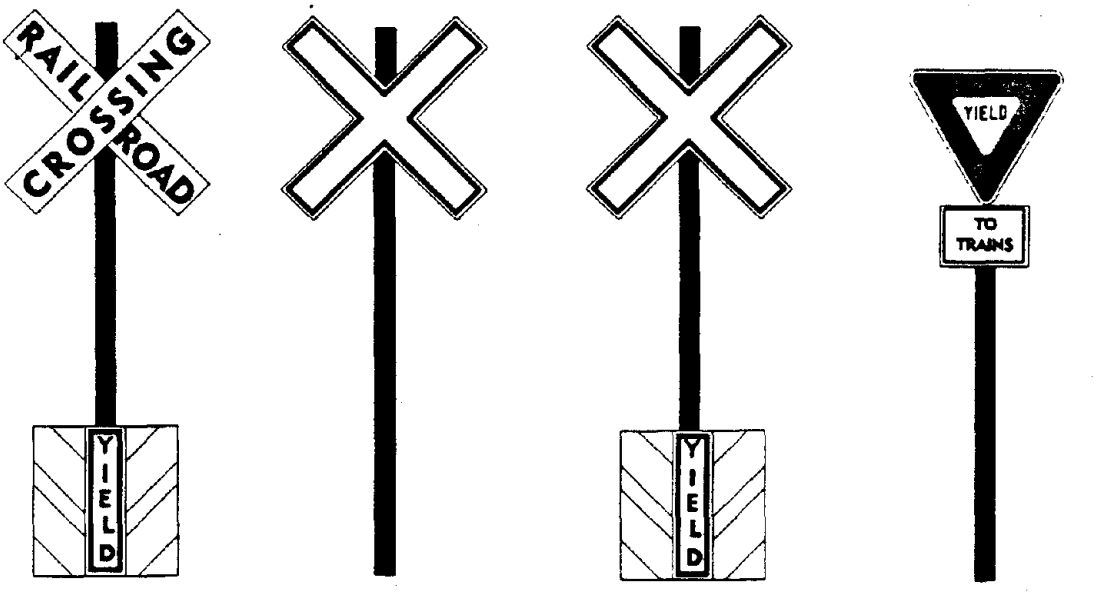
Recognition Distance

Operational Definition: The distance at which a subject correctly identified all critical features of a sign.

Apparatus: A random access slide projector with a computer controlled zoom lens was used to present stimuli to subjects in this portion of the study. This equipment (see figure 2) allows slides of signs to be initially presented at a very small scale, and then gradually grow larger, as if the subject were approaching the sign in a vehicle. Visual angle calculations were used to convert the actual sign size to a comparable "real world" size. In this



Standard* Std Barber* Std Yield*



Std Conrail* Canadian* Canadian Conrail* Yield to Trains*

* Bottom 30 cm (12 in) of poles not shown

Figure 1. Seven experimental signs.

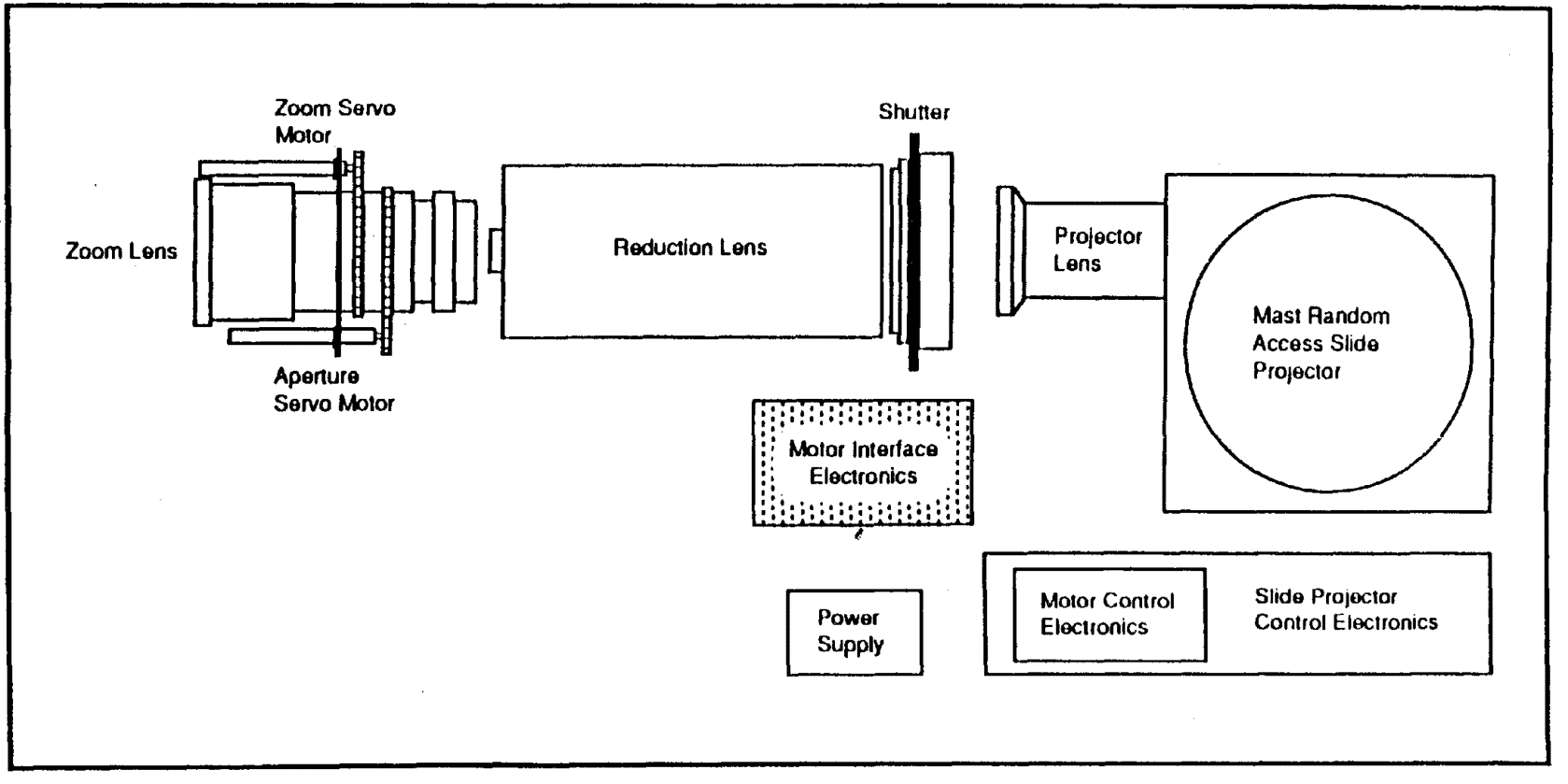


Figure 2. Configuration of zoom apparatus.

study, the "real-world" initial distance at which signs were presented was 172.2 m (565 ft), and the point at which the stimuli were extinguished without subject response was 11.3 "real-world" meters (37 ft).

Procedure: After reading and signing an informed consent form, providing basic biographic information (see appendix A), and completing a vision screening on the ortho-rater, subjects began the first experimental task. Each subject participated in 15 trials in this portion of the study. The first two trials were considered "practice" trials, to allow the subject to become accustomed to the task. The next nine trials consisted of standard traffic control devices from the MUTCD and the Standard Highway Signs Manual; the 12th trial was one of the seven passive railroad signs; and the last three trials were standard highway signs.[2,9] Independent groups (each subject exposed to only one of the seven passive railroad crossing signs) were used in this study. The distinctive shape and configuration of the railroad crossbuck made repeated railroad crossing trials impractical, as a large number of "distractor" signs would have been needed to avoid cuing subjects to the sign of interest.

For this first experimental task, subjects were seated in a chair in a darkened laboratory 4850 mm (191 in) from the front of a rear projection screen. Standardized instructions were presented for each subject on an audio cassette (see appendix B). Subjects were permitted to dark adapt while the experimenter collected demographic and biographic data. Subjects were instructed to watch the screen, and to press a hand button when they could accurately describe the approaching sign. When the button was pressed, the slide extinguished and the subject described the sign. If the description of the sign was accurate, the next trial began. If the description was inaccurate, the experimenter informed the subject that more detail was needed and the slide presentation began at the point it was stopped. Data regarding the point at which the subject correctly identified the signs was collected automatically by the system. The instructions emphasized that the subject should respond as soon as he/she could describe the sign, rather than give the meaning of the sign. Because the resolution of the slides did not allow for useful legibility trials, subjects were not required to read any textual information on the sign, but only to identify that there was text.

When the subject depressed the hand switch, the last voltage reading from the zoom lens was displayed on the experimenter's computer screen and recorded. This number was later entered into the following conversion formula: $Y = A * X^B$: $A = 4.4*10^8$, $B = -1.5$, X = voltage, to yield appropriate real-world recognition distances.

Test Sign Stimuli: Stimuli in this portion of the study consisted of the 7 passive railroad signs (see figure 1) and 14 other standard highway signs. Because of the distinctive shape found in the railroad crossbuck, some of the signs chosen as "distractors" were those infrequently encountered in normal highway driving. The distractor signs (with MUTCD identifiers in parentheses) were:

1. LIBRARY (I-8).
2. RESTRICTED LANE AHEAD (POST-MOUNTED) (R3-10).
3. PAVEMENT ENDS (SYMBOL) (W8-3a).
4. STOP (R1-1).

5. WINDING ROAD (W1-5R).
6. NO PARKING (SYMBOL) (R8-3).
7. KEEP RIGHT (WITH HORIZONTAL ARROW) (R4-7a).
8. NO U-TURN (SYMBOL) (R3-4).
9. TWO WAY TRAFFIC (SYMBOL) (W6-3).
10. CIVIL DEFENSE EVACUATION ROUTE MARKER (CD-1).
11. SCHOOL CROSSING (S2-1).
12. EMERGENCY MEDICAL SERVICES (D9-13).
13. DETOUR ARROW SIGN (M4-10R).
14. CROSS ROAD (W2-1).

Conspicuity

Operational Definition: The number/percent of times a railroad crossbuck was correctly identified when briefly presented within a matrix of nine signs. Subjects responses were coded based on a priori definitions of individual critical features on signs, i.e. saying "a large X" for the standard.

Apparatus: A yoked tachistoscope was used to present stimuli. In this set-up, the shutter on the first projector was open for 2.0 s. After a 30 ms interval with no image presented, the shutter on the second projector was opened.

Procedure: This task was always performed after the recognition distance task and before the comprehension task. Subjects were allowed a short break between tasks if needed. Each subject participated in 52 trials. The first 16 trials were practice trials, the last 36 were test trials. A modified partial recall Sternberg procedure was used in this portion of the study.

Subjects were seated in a darkened laboratory 2.13 m (84 in) from the front of a rear projection screen. Once again, recorded instructions were presented (see appendix c). On a "ready" signal, a set of nine signs in a three sign by three sign matrix (see figure 3) was presented for 2.0 s. After an interval of 30 ms, a "probe" slide, with an arrow pointing to one of the three rows of a blank matrix (see figure 4) was presented. The subject's task was to describe anything he/she recalled about the probed row of signs. The probe slide remained visible throughout the subject's description. The experimenter collected verbatim notes regarding subject responses.

In the 16 practice trials, no railroad crossbucks appeared in the matrices. In the test trials, one-third (12 trials) had no railroad crossbuck; one-third (12 trials) had a railroad crossbuck, but not in the probed row; and one-third (12 trials) had a railroad crossbuck in the probed row. Of the trials with a railroad crossbuck in a probed row, each of the six experimental signs appeared twice. Each subject was presented with a different presentation order for the 36 test trials.

Stimuli: Stimuli in this portion of the study consisted of projected images of matrices of signs. The height of the projected matrix was 457 mm (18 in), individual Railroad Crossbucks were 146 mm (5 3/4 in) tall, and other signs were scaled accordingly. The 6 Railroad Crossbucks (see figure 1) were used in conjunction with 48 other standard signs from the MUTCD. The "Yield to trains" sign was not included in this portion of the study. The other signs used (with MUTCD identifiers in parentheses) were:

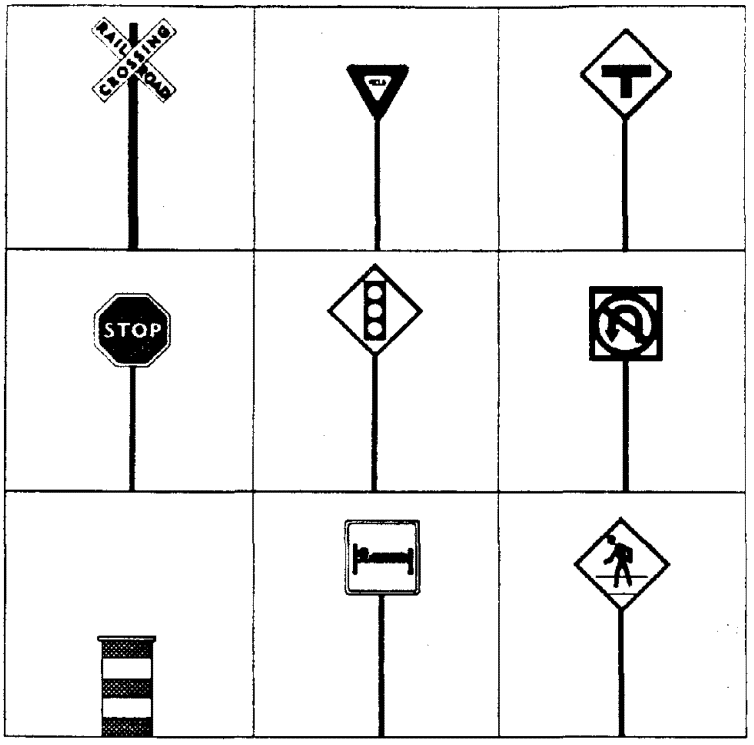


Figure 3. 9 Sign conspicuity matrix.

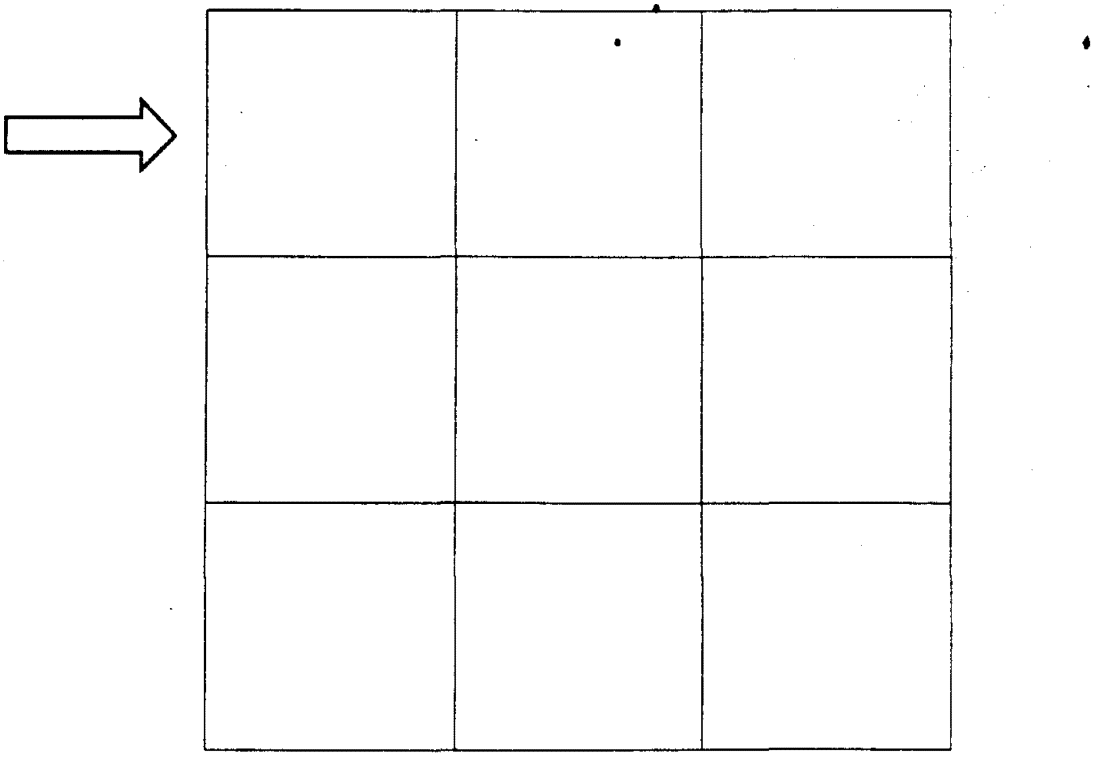


Figure 4. Blank conspicuity matrix.

- YIELD (R1-2).
- STOP (R1-1).
- SPEED LIMIT (R2-1).
- NO LEFT TURN (SYMBOL) (R3-2).
- NO U TURN (SYMBOL) (R3-4).
- LEFT TURN ONLY (SYMBOL) (R3-5).
- DO NOT PASS (R4-1).
- KEEP RIGHT (R4-7).
- DO NOT ENTER (R5-1).
- NO PEDESTRIANS S(R9-3a).
- ONE WAY (R6-1r).
- NO PARKING (SYMBOL) (R8-3a).
- RESTRICTED LANE AHEAD (R3-10).
- LANE CONTROL (R3-6).
- COW CROSSING S(W11-4).
- RIGHT TURN ONLY (SYMBOL) (W1-1r).
- SLIPPERY WHEN WET (SYMBOL) (W8-5).
- WINDING ROAD (SYMBOL) (W1-5r).
- TYPE III OBJECT MARKER (OM-34r).
- T INTERSECTION (SYMBOL) (W2-4).
- PAVEMENT ENDS (SYMBOL) (W8-3a).
- STOP AHEAD (SYMBOL) (W3-1a).
- SIGNAL AHEAD (SYMBOL) (W3-3).
- RIGHT LANE ENDS (SYMBOL) (W4-2).
- RIGHT LANE ENDS (W9-1).
- TRUCK ON A HILL (SYMBOL) (W7-1).
- PEDESTRIAN CROSSING (SYMBOL) (W11-2).
- NO PASSING ZONE (W14-3).
- CROSS ROADS (W2-1).
- CHEVRON (W1-8).
- BIKE ON A HILL S(W7-5).
- BIKE ROUTE (D11-1).
- DETOUR 500 FT (W20-2).
- FLAGGER AHEAD (SYMBOL) (W20-7a).
- TWO WAY TRAFFIC (W6-3).
- DETOUR (W4-10r).
- TYPE II BARRICADE.
- BARREL.
- ADVANCE SCHOOL CROSSING (S1-1).
- SCHOOL CROSSING (S2-1).
- ADVANCE GRADE CROSSING (W10-1).
- ADVANCE GRADE CROSSING WITH GEOMETRY (W10-2).
- NO STOPPING ON TRACKS (R8-8).
- LIBRARY (I-8).
- EMERGENCY MEDICAL SERVICES (D9-13).
- INFORMATION (D9-10).
- FIRST AID STATION (RM-040).
- CIVIL DEFENSE EVACUATION ROUTE MARKER (CD-1).

Comprehension

Operational Definition: The number/percent of times a sign elicited a correct identification of its meaning and the appropriate action for a driver to take when the sign is encountered along a roadway.

Apparatus: Subjects' verbatim responses were recorded by hand.

Procedure: This was the final experimental task. Each subject was presented with a print of one of the seven passive railroad signs (see figure 1). The print the subject saw corresponded to the sign configuration he/she was exposed to in the recognition distance portion of the study. Subjects were told "If you saw this sign on the road, what would you think it meant, and what action would you take?"

If the subject reported a completely inappropriate meaning (not related to railroad crossings), he/she was shown the advance railroad crossing sign (W10-1). This is the familiar round yellow sign with the large black X quartering it and R's in the left and right quadrants. Subjects were asked if seeing this sign before the passive railroad crossing sign would change their responses. Responses were recorded verbatim by the experimenter. The experimenter also recorded the degree of experience subjects had with passive highway-rail crossings.

Stimuli: Individual color prints of the seven passive railroad signs and a color print of the advance railroad crossing sign (W10-1) were used in this portion of the study.

RESULTS

Subject Variability

Visual Acuity

An initial analysis was run to ensure that the seven independent subject groups exposed to the different signs were not significantly different from each other in visual acuity. Figure 5 shows the mean visual acuities by age across the test signs.

An analysis of variance (ANOVA) was performed to identify any significant differences across test groups. Age group had a significant effect on visual acuity across all test groups, (F = 21.06, p < .001), with older drivers having significantly worse acuity. Otherwise, no statistically significant differences were found in visual acuity between the test groups. The results of this ANOVA are found in table 1.

Table 1. Table of visual acuity analysis of variance.

Source	Sum of Squares	DF	Mean-Square	F-Ratio	P
Age Group	629.762	1	629.762	21.062	0.000**
Test Sign	104.167	6	17.361	0.581	0.745
Age Grp X Sign	40.738	6	0.790	0.227	0.967
Error	2,093.000	70	29.900		

** p < 0.001

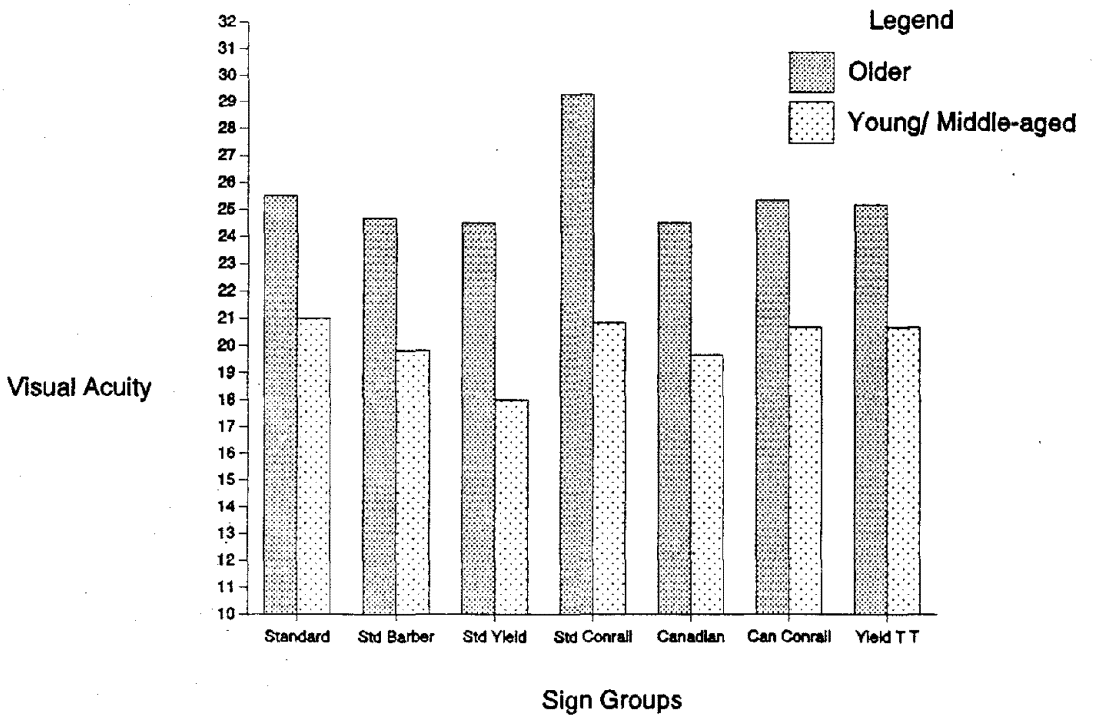


Figure 5. Mean visual acuity by age group and sign group.

Recognition Distance

The mean recognition distances for each railroad crossing sign tested, shown in figure 6. Although there was a large range of recognition distances, from 66.5 m (218 ft) for the Standard, to 36.9 m (121 ft) for the Std Barber, an ANOVA showed no significant differences. Analysis of Covariance (using recognition distance for STOP (R1-1) and Visual Acuity as covariates) also found no significant difference between signs.

Conspicuity

For each sign, there were 144 opportunities for correct identification, (72 subjects X 2 exposures of each sign per subject). Figure 7 shows the number of correct identifications for each sign. The "Yield to Trains" sign was not included in this portion of the study. Using the total number of "correct" identifications for each sign, Chi-squared comparisons were performed on the conspicuity data to identify differences between signs. The overall Chi-square value was 22.691 ($p < 0.001$). Further comparisons were run comparing individual signs with each other. Based on statistically significant differences, three overlapping groups of signs occur, as shown in figure 8. The "Std Yield", "Std Barber" and "Canadian Conrail" all have conspicuity scores in the 70's; the "Std Conrail" and "Standard" in the 50's and the "Canadian" in the 40's.

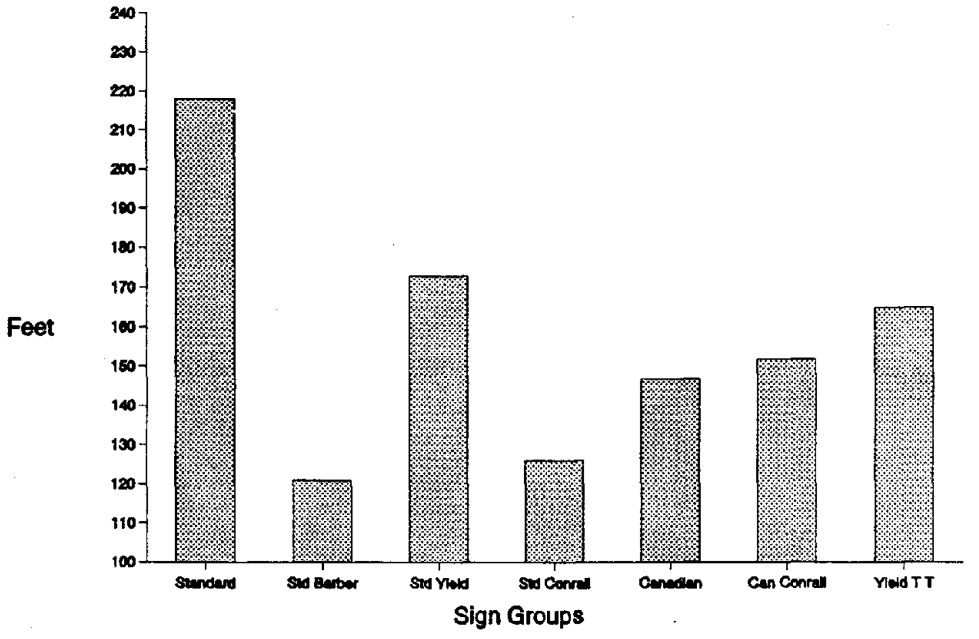


Figure 6. Mean recognition distances for crossbucks.

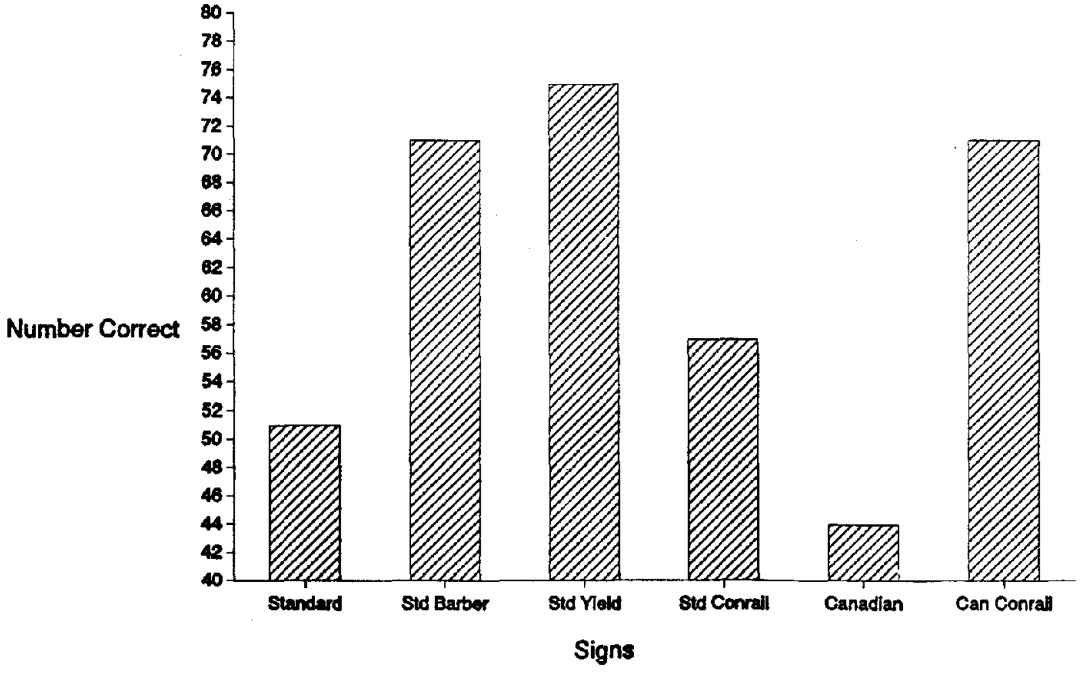


Figure 7. Number of correct answers on conspicuity trials.

Comprehension

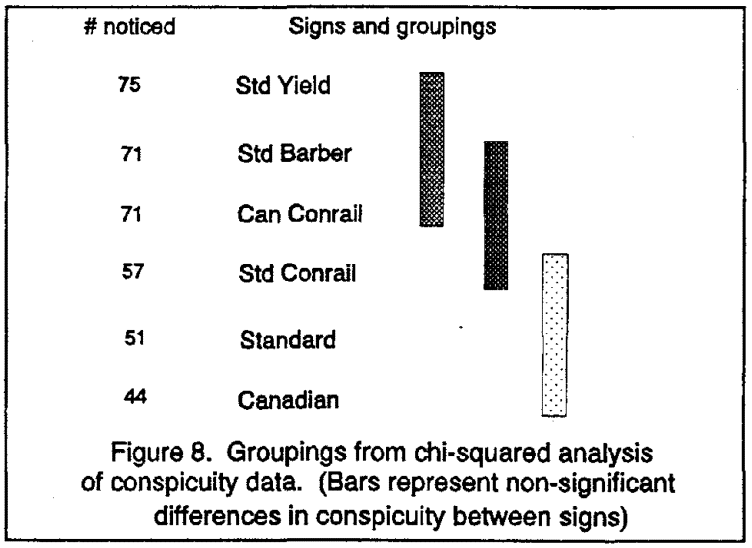


Figure 8. Groupings from chi-squared analysis of conspicuity data. (Bars represent non-significant differences in conspicuity between signs)

Two types of comprehension, the meaning of the sign and the action the person should take when seeing it, were examined. As discussed in the Measures of Effectiveness section for comprehension, if subjects' initial responses to the meaning and action questions were unrelated to railroad crossings, they were shown an advance railroad crossing sign (W10-1). Subjects were then asked if seeing the advance sign before the crossing sign would change their responses. This produced two slightly differing sets of data (before and after advance sign) for both meaning and action. Eight subjects required the advance sign, one in the "Canadian" group, three in the "Canadian Conrail" group and four in the "Yield to Trains" group. Results for meaning and action are discussed in terms of both before and after the advance sign was shown.

Meaning

Two slightly differing sets of data were gathered regarding meaning: before and after exposure to the advance sign. A breakdown of responses for before and after exposure to the advance sign for meaning data is shown in table 2. Using data before subjects were exposed to the advance sign, comparisons were performed to determine if there were differences in the number of correct meaning responses for the different test signs. Three of the test signs, "Standard", "Std Barber" and "Std Yield" had perfect scores on this measure. The "Std Conrail" and "Canadian" signs also performed well, with 83.3 percent and 91.7 percent correct, respectively. The "Canadian Conrail" and "Yield to Trains" signs performed poorly, with 58.3 percent and 66.7 percent correct respectively.

Table 2. Correct and incorrect meanings before and after advance sign.

	Before Advance		# Shown Advance	After Advance	
Sign	# Correct	% Correct		# Correct	% Correct
Standard	12	100.0	0	12	100.0
Std Barber	12	100.0	0	12	100.0
Std Yield	12	100.0	0	12	100.0
Std Conrail	10	83.3	0	10	83.3
Canadian	11	91.7	1	12	100.0
Can Conrail	7	58.3	3	10	83.3
Yield To Trains	8	66.7	4	12	100.0

Each subject who was shown the advance sign changed his/her meaning to the correct one. After being shown the advance sign, the scores on the

"Canadian," "Canadian Conrail" and "Yield to Train" signs improved to 100 percent, 83.3 percent and 100 percent correct respectively. The two subjects shown the Canadian Conrail but giving the wrong meaning to the sign gave railroad-related meanings, thus they were not shown the advance sign.

Action

Two slightly differing sets of data were gathered regarding action: before and after exposure to the advance sign. Table 3 shows a breakdown of the responses for before and after exposure to the advance sign for action data. Using data before subjects were exposed to the advance sign, chi-squared analyses were performed on the action data. Two overlapping groups were formed before exposure to the advance sign (see figure 9). The two best signs ("Std Yield" and "Yield to Trains"; 83.3 percent correct each) significantly outperformed the two worst signs ("Standard" and ""Canadian"; 41.6 percent and 33.3 percent correct respectively). The remaining signs did not differ significantly from any other signs with 50 percent correct responses.

Of the eight subjects who required the advance sign, only four changed their responses to the correct one. Given these changes, the "Yield to Trains" sign (100 percent correct) slightly outperforms the "Std Yield". After exposure to the advance sign, three overlapping groups were formed (see figure 10). Of the signs with improvements, only the "Yield to Trains" sign changed groups.

Table 3. Correct and incorrect actions before and after advance sign.

	Before Advance		# Shown Advance	After Advance	
Sign	# Correct	% Correct		# Correct	% Correct
Standard	5	41.6	0	5	41.6
Std Barber	6	50.0	0	6	50.0
Std Yield	10	83.3	0	10	83.3
Std Conrail	6	50.0	0	6	50.0
Canadian	4	33.3	1	4	33.3
Can Conrail	6	50.0	3	8	66.7
Yield To Trains	10	83.3	4	12	100.0

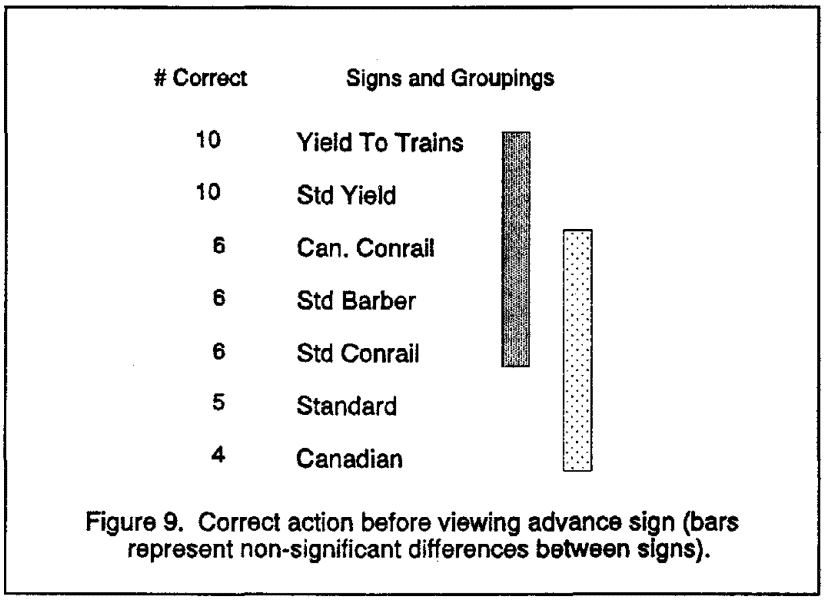


Figure 9. Correct action before viewing advance sign (bars represent non-significant differences between signs).

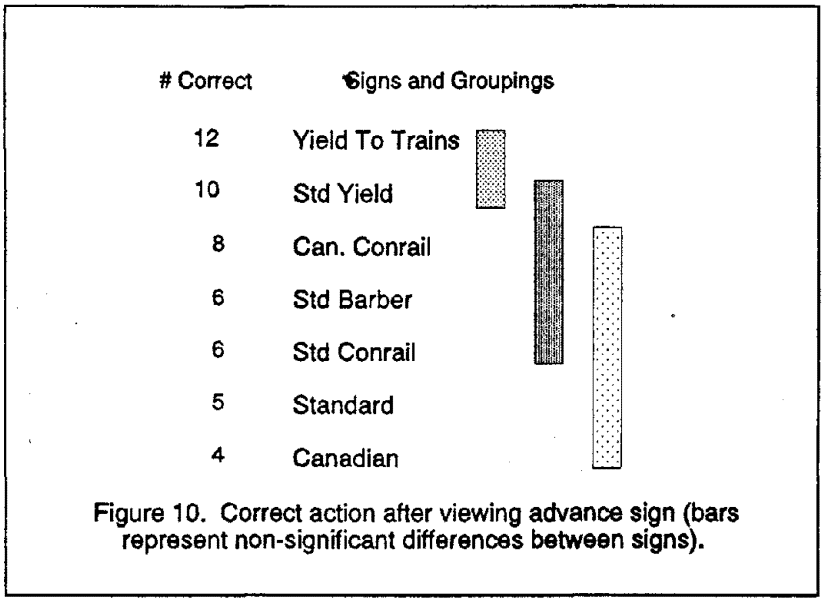


Figure 10. Correct action after viewing advance sign (bars represent non-significant differences between signs).

DISCUSSION

The standard Railroad Crossbuck had the longest recognition distance of the seven devices tested, however there were no statistically significant differences between signs. This unexpected finding may be explained by the experimental situation. Slide resolution limitations required that the recognition distance task exclude legibility of text as a critical identifying feature of the signs. There are large differences in text size on the signs (i.e. letter height on a YIELD sign is 76 mm (3 in), letter height on the "Conrail" shield is 114 mm (4.5 in), and letter height on a standard Railroad Crossbuck is 140 mm (5.5 in)) that would affect actual recognition distance in the field. Furthermore, the vertical presentation of the word "yield" on the "Conrail" shield may also affect real-world recognition distance. These issues must be addressed in future research.

The conspicuity measure addressed the "noticeability" of the signs, however this is probably a "laboratory noticeability" as opposed to noticability in a field situation. Only the six crossbuck signs were included in this portion of the study. Based on statistically significant differences on this measure, three overlapping groups of signs were found. The worst performing signs in this analysis were those containing only a crossbuck ("Standard" and "Canadian"). The addition of another element to a railroad crossing sign increases its conspicuity, and it does not appear that the additional element needs to be highly complex in nature. The two best signs on this measure were "Std Yield" and "Std Barber," which had the simplest additional element of all the signs (a standard YIELD sign and a red-and-white striped pole, respectively).

The comprehension task consisted of eliciting subjects' undersanding of the meaning of the sign and what action they should take if they were to see it on the road. Drivers who did not give railroad crossing-related responses were shown the advance railroad crossing sign. The meaning data changed significantly after presentation of the advance railroad crossing sign to those subjects. Before exposure to the advance signs, the "Canadian Conrail" and "Yield to Trains" were significantly worse than the other signs. After the advance signs, correct responses to these signs increased to 83.3 percent and 100 percent respectively.

Because drivers often obtain cues regarding sign meaning from the environment, it was necessary to provide, in the rather sterile setting of the laboratory, some indication of the surroundings so that comprehension could be "fairly" measured. In context, (after the advance sign) all of the signs performed equally well for meaning. It is quite possible for drivers in real-world settings to miss the advance signs at a railroad crossing, however. Given this, the poor performance shown by the "Canadian Conrail" and the "Yield to Trains" signs before presentation of the advance sign cannot be ignored.

Given the high percentages of correct meaning responses for most signs, the action data is rather disturbing. Comparisons of before and after presentation of the advance sign, when required, are not as dramatic as for the meaning data. Using the data set with the highest percentages of correct answers (after the advance sign) correct responses range from 100 percent (for the "Yield to Trains" sign) to only 33 percent (for the "Canadian" sign). Most disturbing is the poor action responses on the current standard (42 percent correct). The data indicate that the addition of a standard YIELD sign produces the highest number of correct action responses.

It is possible that the low percentages of correct comprehension responses overall are partially sample based. Subjects in the study were predominantly from the Washington, DC metropolitan area, where at-grade highway railroad crossings are not common. Seventeen percent of all the subjects claimed to have never encountered this particular situation, and only 14 percent encountered it on a greater than monthly basis. The remainder of the subjects stated they rarely encountered at-grade crossings. Research on the understanding of a broader sample of subjects regarding the appropriate action to be taken at crossings is needed.

CONCLUSIONS/RECOMMENDATIONS

Based on the findings of this laboratory investigation of passive railroad crossings signs, a change from the current standard is indicated. The standard sign performed very poorly in both the conspicuity task and in the action portion of the comprehension task (second to last in both cases). A useful sign must first be seen, and then understood, in order to adequately convey information. In this study, the standard Railroad Crossbuck performed poorly on both of these characteristics. Furthermore, the "Canadian" sign can safely be omitted from future investigations; it was the only sign that performed worse than the standard on these measures.

Further research on these signs is required. This study used slide projected/photographic images of the signs for stimuli. Some of the tested signs, in particular the "Conrail" signs, are not flat images, and may perform very differently in field oriented settings. In particular, the following is recommended:

1. The "Canadian" sign can be omitted from further testing. It performed very poorly on both conspicuity and action (comprehension) tests.

2. A full-scale recognition distance evaluation of the signs should be undertaken. The current investigation did not allow text information to be utilized in the recognition distance evaluation, and such data is necessary to make appropriate final judgements regarding these signs.

3. A broad based comprehension study, including both meaning and action information should be undertaken. Drivers with a wide variety of experience with at-grade railroad crossings must be included in this effort.

4. An observational study, to determine actual real-world compliance with passive railroad crossing signs should be undertaken. If compliance is low, efforts should be undertaken to inform the driving public of the possible hazards at crossings.

5. Based on this study, the signs appearing to be the best candidates for further testing would be the "Standard Yield," the "Standard Conrail," and the "Yield to Trains" configurations.

APPENDIX A. RECORD OF INFORMED CONSENT

RECORD OF INFORMED CONSENT/BIOGRAPHIC INFORMATION

In accordance with 45 C.F.R., section 46.116, relating to the Protection of Human Subjects in Research, your informed consent for participation in Federal Highway Administration human factors studies is required. Please consider the following elements of information in reaching your decision whether or not to consent:

I. General:

We are asking for your voluntary participation as a paid subject in a research study of new and standard signs. Your participation will require approximately one and one-half hours. The results of this research will be useful to researchers, engineers, and others concerned with improving the safety and operational efficiency of the nation's highway system.

Upon completion of the session, you will be paid twenty-five dollars for your participation. You must complete the entire session to receive full remuneration. If you withdraw consent prior to completion of the entire session, the amount of remuneration payable to you will be calculated directly based on the percentage of time of your participation relative to the entire session time of one and one-half hours.

II. Study Procedures:

1. You will be asked for biographical information necessary to the study. All information provided is confidential and the source of information (your name) will not be disclosed to the public.

2. Prior to beginning the study, you will be given a visual acuity test. Minimum acceptable corrected vision for this study is 20/40 (binocular, far vision).

3. You will watch projected slides of highway signs as they are "zoomed" toward you, and you will stop the "zooming" when you can describe the sign. This cycle will be repeated several times.

4. You will be shown a photo of a sign and asked your interpretation of it.

5. You will watch a projected slide of a matrix of signs and, after the matrix extinguishes, be asked to describe a subset of those signs. This procedure will be repeated several times.

III. Risks:

The risks associated with this study are not greater than those ordinarily encountered in an office environment.

IV. Withdrawal of Consent:

You are free to decline consent, or to withdraw consent and discontinue participation in the study session at any time without penalty or loss of benefits to which you are otherwise entitled.

V. For Further Information:

If you have additional questions pertinent to this research, your rights as a subject, or any injury you believe to be related to this research, please contact:

Division Chief
Information and Behavioral Systems Division (HSR-30)
Federal Highway Administration
Office of Research
Washington, DC 20590

END OF INFORMATION

The basic elements of information have been presented and clearly understood by me, and I consent to participate as a subject.

SIGNATURE: _____ **DATE:** _____

NAME (Please Print): _____

ADDRESS / APT. NO.: _____

CITY, STATE ZIP: _____

HOME PHONE NUMBER: (____) _____-_____

WORK PHONE NUMBER: (____) _____-_____

DATE OF BIRTH: _____ ____, _____
Month Day Year

APPENDIX B. INSTRUCTIONS FOR RECOGNITION DISTANCE PORTION

This is a sign study. When I say "ready" a picture will appear on the screen in front of you. It will be a picture of a sign on a post. The image will start out very small, and gradually grow larger, as if you were approaching it in a vehicle. I would like you to watch the image and press the button as soon as you can adequately describe the sign. I do not want you to assign a meaning to the sign, just tell me what it looks like. For example, if the slide were this sign (show picture of "SLIPPERY WHEN WET") I would like you to tell me "it was a yellow diamond sign, with a car and two wavy lines on it.", not "it means SLIPPERY WHEN WET". If there are words on the sign, you do not need to read them, merely tell me that there are words. Please press the button before you start talking. When you press the button, the picture will disappear and then you will give your description of the sign. If your description is inaccurate or if I need to hear a little more detail, we will start again from the point where the picture was stopped, and once again you will use your button to turn off the image when you feel you can describe the sign. Once you have accurately described the sign, we will proceed to the next one.

Remember, you should hit the button when you can DESCRIBE the sign, and you do not have to read any word on the sign. You do not have to be able to assign meaning to the sign to stop the image, merely be able to tell me what it looks like. Remember to press the button BEFORE you begin talking.

There are two practice slides in the beginning of the experiment, to allow you to become accustomed to this procedure. If you don't have any questions, let's get started.

APPENDIX C. INSTRUCTIONS FOR CONSPICUITY PORTION

In this portion of the experiment, you will be asked to describe one of three rows of signs.

When I say "ready" a projected slide with nine signs in a three by three matrix like this..... will appear on the screen for a brief time. This will be immediately followed by a blank matrix like this.....that doesn't have any signs, but does have an arrow pointing to one of the three rows. Your task will be to tell me anything you can recall about that row of signs. For example, if the arrow points to the middle row, tell me about the signs on the middle row. The blank matrix will remain on the screen for you to use as a reference.

This is a very difficult task. I don't expect you to remember what signs are in the row, but I would like you to tell me ANYTHING you can about the signs on that row including their shape, color, size, etc. In this matrix, for example, (show photo of example matrix) you may not remember that the three signs in the middle row were a CROSSROADS SIGN, a STOP SIGN and a RIGHT LANE ENDS sign, but you may remember that two of the signs were yellow diamonds, and one was red. I would like to hear ANYTHING you can remember about the row.

The matrices are all different, and the placement of the arrow is random, so you can't tell which row to focus on by remembering where the last arrow was. The arrow can appear in any of the three rows on any of the trials.

We will begin with some practice slides to allow you to become accustomed to the procedure. Any questions?

8. REFERENCES

1. United States Department of Transportation, "Rail-Highway Crossing Accident/Incident and Inventory Bulletin," Federal Railroad Administration, Washington, DC, Number 13, 1990.

2. United States Department of Transportation, *Manual on Uniform Traffic Control Devices for Streets and Highways*, Federal Highway Administration, 1978, Revision No. 4, March 1986.

3. John E. Tidwell, Jr. and Jack B. Humphreys, "Improving Safety at Passive Crossings With Restricted Sight Distance," Transportation Research Record 841, Transportation Research Board, Washington, DC, 1982, pp. 29-36.

4. J. A. Green, "Fatal Train-Vehicle Collisions in Michigan," HIT LAB Reports, Highway Safety Research Institute, University of Michigan, April 1972, pp. 1-4.

5. Joseph S. Koziol, Jr., Peter H. Mengert, and Janet A. Coleman, "Railroad Grade Crossing Passive Signing Study," Report No. FHWA-RD-78-34, Executive Summary, Federal Highway Administration, Washington, DC, 1978.

6. J. G. Ells, R. E. Dewar, and D. G. Milloy, "An Evaluation of Six Configurations of the Railway Crossbuck Sign," *Ergonomics*, 1980, Vol 23, No. 4, pp. 359-367.

7. William J. Kemper, "Modified Railroad-Highway Grade Crossing Pavement Marking and Crossbuck Study," *Public Roads*, Vol. 52, No. 3, December 1988, pp. 76-82.

8. I.N. Dommasch, R.L. Hollinger, and E.F. Reilly, "Passive Control at Railroad-Highway Grade Crossings," Report No. 77-010-7707, New Jersey Department of Transportation, May 1977.

9. United States Department of Transportation, *Standard Highway Signs*, Federal Highway Administration, Washington, DC, 1979.

*U.S. G.P.O.:1993-301-717:80398