RECOGNITION OF TRAFFIC-CONTROL SIGNS

R. E. Dewar, Highway Safety Research Institute, University of Michigan;* and
H. A. Swanson, Traffic Operations Division, City of Calgary, Alberta

The paper includes a review of published and unpublished literature with respect to symbols versus word messages on traffic signs, symbolization philosophies and recognition problems, and education of motorists about meanings of symbols. The paper also reports on a laboratory study and a field study of traffic-sign recognition. The laboratory experiment was conducted to determine the ability of subjects to recognize selected turn-restriction signs under conditions of short exposure. The traffic signs were varied by types of turn restrictions and mode of indicating the sign message, i.e., words, positive and negative symbols, and combinations of these. The experiment made use of a projection tachistoscope. Subjects varied in age, driving skill, and experience. The field study compared the effectiveness of both negative and positive symbols. The effectiveness was measured in relation to the number of motorists disregarding the turn-restriction sign.

•DURING the past 2 decades there has been a considerable emphasis on the need to standardize, on an international basis, the use of traffic-control signs. The issue is particularly important because large numbers of people drive in foreign countries and are unfamiliar with verbal legends in different languages. Earlier attempts were made to establish an international standard of signing, but the first major one was the United Nations 1949 Protocol on Road Signs and Signals. A good deal of work has been done on traffic-sign recognition and the requirements for adequate traffic signs (3). However, there has been relatively little research to evaluate the relative effectiveness of different ways of conveying the same information to motorists.

SYMBOLS VERSUS WORD MESSAGES

In an early investigation of highway signs, Janda and Volk (5) used a reaction time measure to demonstrate that an arrow alone was the best indicator of directional control, words and arrows combined were the second best, and words alone were the worst. Elliot (2), in a discussion of the use of symbolic traffic signs at the international level, indicates that very few symbols communicate their meaning well without other associated symbols such as inscriptions or markings. The use of a symbol assumes that the viewer knows the meaning of it. It is generally assumed that certain symbols or pictures will be understood on the basis of some intrinsic meaning that is obvious to all; however, cultural differences do exist, and some symbols may be inappropriate for certain countries. By 1960, a large number of European and near-eastern countries were using the United Nations 1949 Protocol. However, North and South America tended to use the United States standard, which differed from the United Nations system.

Gray and Russell (4) conducted a study in which they examined the recognizability of symbolic road signs used in parts of Europe. Twelve mandatory and warning signs that carried no words were examined. Easily interpreted signs such as STEEP HILL were understood by more than 90 percent of the drivers. However, signs with more abstract

Sponsored by Committee on Motorist Information Systems.

*This research was conducted while Mr. Dewar was with the University of Calgary.

symbols were recognized by as few as 50 percent. They concluded that signs that relied on purely abstract symbolism were difficult to understand.

Markowitz et al. (7), in a laboratory study of traffic-sign recognition, examined 2 versions of 5 separate traffic signs. These were YIELD, DO NOT ENTER, NO RIGHT TURN, SCHOOL CROSSING, and STOP. Although the signs without written messages appeared to be slightly more recognizable, when individual signs having the same meaning were compared with each other (e.g., 2 different NO RIGHT TURN signs), those composed of a written message were slightly easier to recognize than those depicted with a symbol.

Walker, Nicolay, and Stearns (9) investigated the hypothesis that symbol road signs are more easily recognized than verbal signs. The signs tested were NO RIGHT TURN, NO LEFT TURN, DO NOT ENTER, and their symbol counterparts (similar to the international signs used in Europe). They were presented with a tachistoscope for 0.06 sec to small groups of subjects. Correct recognition occurred for approximately 84 percent of the symbols and 55 percent of the written messages.

Using motion picture film, Tierney and King (8) examined glance legibility for written messages and for symbols from the Canadian-Pan American system and from the Quebec-United Nations system. The 2 groups of symbols were more readily recognized than were the words. Subjects were asked the meanings of the symbols before the recognition test. Errors in identification were 52.5 percent for the Quebec-United Nations symbols (all of which were prohibition signs) and 27.3 percent for the Canadian-Pan American symbols (all of which were regulatory or warning signs). The former series of symbols had a high proportion of "opposite" interpretations. Unfortunately, this study did not use different versions of signs having the same meaning, so a direct comparison of symbol systems was not possible.

Until recently, the United States system differed from many others in that it tended to use written messages rather than symbols. A symbol may be visible at a greater distance than the written message on a sign of equal size. The length of different messages requires different sign shapes and sizes and varying letter types and sizes to accommodate those messages; therefore, uniformity is impossible, particularly in signs that are meant to be regulatory. The symbol does not pose these problems. Not all messages can be represented in a symbol. For example, how would one symbolize KEEP RIGHT EXCEPT TO PASS or SLOW DOWN? It seems reasonable to conclude that to date the evidence comparing symbols and word messages in traffic control signs is inconclusive and insufficient.

SYMBOLIZATION PHILOSOPHIES AND RECOGNITION PROBLEMS

There are contradictory philosophies reflected in the current use of symbols. For example, they may reflect the nature of a hazard, such as a bump in the road, or the result of a hazard, such as a skidding car on a slippery road. Another example of inconsistency is the positive versus negative instructions (a problem of stimulus-response compatibility). The need for visual consistency is overlooked here. The basic problem is whether these signs should indicate to a driver what he must do or tell him what he must not do. Research on the relative merits of these 2 approaches is difficult to find. Frequently, in determining recognizability of traffic control signs, researchers are concerned with simply whether the sign is recognized or can be named. Perhaps it would be better to be more concerned about determining what action the driver would take in response to a sign and less concerned about producing a textbook definition.

A study by Kershaw (6), conducted in 1968 at the Central Canada Exhibition in Ottawa, employed a questionnaire with 10 items in which subjects were asked the meaning of a variety of traffic symbols. The ones of primary relevance here were 2 versions of the DO NOT ENTER sign. More than 2,500 subjects completed the questionnaire. Two symbolic versions of the DO NOT ENTER sign were used—a white horizontal bar on a red circle (the European interdiction symbol) and an arrow pointing straight ahead with a red slash through it and a red square around it. The former sign was correctly interpreted by approximately one-third of the respondents, and the latter sign was

responded to correctly by two-thirds of the respondents. However, 18 percent of respondents indicated that the latter symbol meant to proceed straight ahead (a serious error).

A study conducted in Winnipeg (1) examined several traffic-control signs. The positive NO LEFT TURN symbol was identified correctly by 77 percent of the subjects (recognition dropped to 66 percent when the sign included a time restriction). Correct identification of 3 versions of the DO NOT ENTER sign varied from 56 to 87 percent, but when a time restriction was added performance was reduced from 20 to 38 percent. For some reason the time restrictions seemed to interfere with correction recognition.

The desirability of having a worldwide system of traffic-control signs is evident. Although some research has been done to determine what symbols are most adequate for communicating information to drivers, a good deal more is needed. The first study reported here was intended to meet this need in a small way by comparing the recognizability of different versions of 4 traffic-control signs used in Canada.

LABORATORY STUDY OF TRAFFIC-SIGN RECOGNITION

Method

An experiment was conducted to determine ability to recognize selected traffic-control signs under conditions of short exposure. The experiment was carried out in 2 parts. Part 1 involved recognition of full colored slides of traffic signs flashed on a screen by a LaFayette model T-2K projection tachistoscope for a duration of $\frac{1}{25}$ sec. An interval of 10 sec elapsed between slides. So that no signs would be unfamiliar to them, subjects were shown slides of all signs for 30 sec each and told the meaning of each before the experiment began. Subjects were required to identify each sign and write their answers in the appropriate places on an answer sheet provided. Additional information gathered included age and sex. Twenty-three signs were presented in part 1. Table 1 gives a description of the sign messages; Figure 1 shows examples.

Part 2 involved recognition of the same signs in a photograph taken of an intersection at a distance of 100 ft from the near side of the intersection. The traffic signs were hung above the far side of the intersection, a distance of 232 ft from where the photograph was taken. Slides of this scene were presented to subjects for $\frac{1}{5}$ sec. Two additional NO TURN signs were presented in part 2—positive symbol with words and words with time. The order in which slides were presented was randomized within each part of the experiment. There was a rest period of 2 min between parts 1 and 2. Part 1 was administered first in all cases, and the procedure was identical for both parts.

Samples

Three samples of subjects were used. The first involved a group of 148 volunteers who were employees of the city of Calgary. They ranged in age from 18 to 63 years. Those subjects, tested in groups of 6, were seated at tables in a semicircle 18 ft from the screen on which the slides were projected. The projector was located 24 ft from the screen.

The second sample involved driver trainees who were taking a 4-week (40-hour) driving course through the Alberta Motor Association. Students were tested both before and after the driver training course (on the first and last days). One hundred and thirty-three subjects were tested in the before phase, and 83 in the after phase. These subjects were much younger than those in the preceding sample; most of them were between 15 and 22 years of age. One additional driver-training class, 57 students, was tested after training was completed to assess the possible practice effect that might be operating in the samples tested both before and after driver training. The driver-trainee samples were divided into groups ranging in size from 42 to 68 and tested in a classroom 40 ft in length where the projector was 36 ft from the screen. The distances from the screen ranged from 15 to 40 ft for different subjects, who were required to indicate on their answer sheets the row in which they were sitting. Subsequent

analyses indicated no differences in accuracy of recognition of the traffic signs on the basis of distance from the screen. Therefore, the data of all the subjects were pooled for the purpose of statistical analysis.

Results

The percentage of correct responses to each of the different types of traffic-control signs is given in Table 2 for all of the samples. A composite score for the 4 versions of the left- or right-turn restriction signs comprised the total correct out of the 4 responses—combining NO LEFT TURN and NO RIGHT TURN (e.g., there were 4 turn-restriction signs in the form of the negative symbol; a subject recognizing 3 of these correctly received a score of 3 for that sign).

Selected comparisons were made by the use of the t-tests. Table 3 gives the signs that were compared and the t-values and the levels of significance. This analysis was conducted for the city employee sample as well as the driver trainees tested before and after training and trainees tested after training only. There were no systematic differences across the different samples for the signs presented in part 1 of the experiment. However, the driver trainees before training did consistently better in part 1 on traffic signs that contained symbols than on those that contained words only. Consistent trends in part 2 indicate 3 comparisons to be statistically significant for all 3 samples: the positive turn-restriction symbol was more easily recognized than either the negative symbol or words alone; the positive turn-restriction symbol with words was more easily recognized than words alone. The only sign in which words alone were better recognized than the symbol was the NO U-TURN sign. In general, where a sign was compared with a similar sign containing additional information, such as time or words or both, the simpler version was more easily recognized. Adding something to a sign appears to increase confusion and make the symbol more difficult to recognize.

A series of chi-square analyses conducted on the city employee sample compared the subject's performance in recognizing each of the traffic signs with age and sex. There were no systematic sex differences in this sample of 116 males and 32 females, with the exception that males performed better on the negative turn-restriction symbol, RN2, ($\chi^2 = 11.47$, $df = 4$, and $p < 0.025$).

A few age differences did emerge. All differences favored younger subjects, who performed better on the following signs:

Sign Code	χ^2	df	p
RN1	15.70	6	0.02
RW2	15.19	6	0.02
TPt1	9.67	3	0.05
UNW2	9.68	3	0.05

(Degrees of freedom are not the same for all signs because data had to be collapsed in instances where there were too few cases per cell.) Older subjects generally had more difficulty with words alone than with symbols.

A comparison of the performance of driver trainees tested both before and after training and trainees tested only after training (to eliminate practice effect) indicated that the training had a possible enhancing effect on the recognition of only 3 signs. Substantial improvement after training occurred on sign TW2, and slight improvement occurred on signs TW1 and UNW2.

Because of the large number of comparisons made, one would expect a certain number of significant results by chance. Therefore, any differences statistically significant at < 0.025 were not considered reliable differences.

FIELD TEST OF NO-LEFT-TURN SYMBOLS

Additional information concerning the relative effectiveness of the negative and positive symbols for NO LEFT TURN was gathered in a study that was carried out at an intersection in the city of Calgary during a period of 2 years. The particular intersection involved a main north-south street that carries traffic between downtown and residential areas and a main east-west street (4-lane, undivided) that is also part of the Trans-Canada Highway. Left turns off the east-west street were prohibited between 4 and 6 p.m. Before May 1969, this had been indicated by a positive symbol for NO LEFT TURN with the written message NO LEFT TURN 4-6 PM. On Monday, May 6, 1969, this sign was replaced by a negative symbol with the same words and time.

Method

The relative effectiveness of these 2 symbols was measured by counts of the number of vehicles that made illegal left turns during the specified 4 to 6 p.m. period. The count was first taken during the week before the sign was changed (April 28 to May 4, 1969). The immediate impact of the new sign was measured by the number of violations immediately following its installation (May 6 to 18). A follow-up was conducted 6 weeks later (June 16 to 22) after motorists had become accustomed to this new sign (very few were in use in the city at the time). The measure was repeated in the spring (April 20 to 26 and June 15 to 21) of the following year after any novelty effect or unfamiliarity with the meaning of the new sign had dissipated. An additional follow-up 2 years later (April 26 to May 2, 1971) was also conducted to further determine the long-term effects.

An index of the daily traffic volume was determined by counts of the number of vehicles that traveled eastbound and westbound during 16 specified green-light periods during the 2-hour interval. From 4 to 6 p.m., traffic volume in each direction was counted once every $7\frac{1}{2}$ min.

Results

In the analysis, account was taken of the volume of traffic as well as of the number of violations. A daily "violation index" was calculated as follows:

$$\text{Violation index} = \frac{\text{violations}}{\text{average number of vehicles per green light}}$$

The main findings for eastbound and westbound vehicles are given in Table 4. These data and all statistical tests are based on violations during weekdays only. Frequency of violation and the violation indexes increased by a factor of 3 to 7 on weekends. This was probably due to motorists' assumption that the restriction did not apply on weekends. The violations for westbound vehicles were consistently higher that those for eastbound vehicles, even though the volume of traffic was approximately equal in both directions. This difference is likely due to the large number of out-of-town vehicles turning left to travel southbound to the city center. During April and June 1970, the daily average number of violations by out-of-town drivers was 7.5 for westbound vehicles and 1.1 for eastbound vehicles.

In addition to the mean daily violations and the violation index, Table 4 also gives a second mean daily violation count and violation index. These second measures were calculated because of the large number of violations that occurred just after 4 p.m. and just before 6 p.m., at which time drivers were possibly unaware of the exact time or were more likely to commit violations because the traffic is lighter. The second measures omitted the 15 min after 4 p.m. and the 15 min before 6 p.m. The results show a somewhat smaller daily mean and a considerably smaller violation index when they are based on these restricted data. Violations decreased and traffic volume increased during this time.

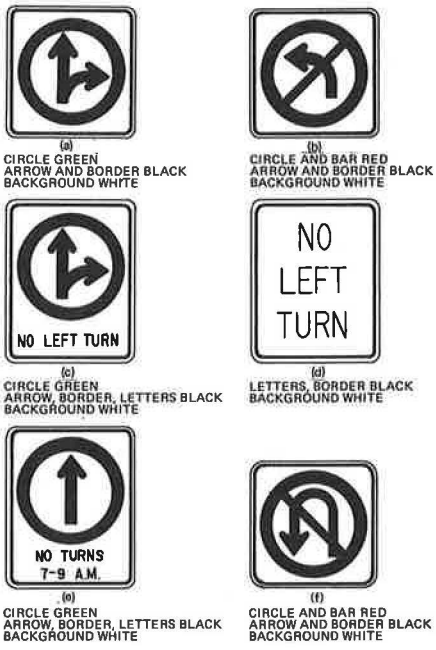
The results indicate no systematic change in the number of violations for eastbound traffic. Westbound traffic, however, showed a somewhat higher violation index for

Table 1. Messages on signs showed to subjects.

Part	Sign Type	Sign Message: Symbol	Sign Message: Other	Sign Code
1	No left turn	Positive		LP1
		Negative		LN1
			Words	LW1
		Positive	Words	LPW1
	No right turn	Positive		RP1
		Negative		RN1
			Words	RW1
		Positive	Words	RPW1
	No turns	Positive		TP1
		Positive	Time	TPt1
		Positive	Words and time	TWWt1
			Words	TW1
	No U-turn		Words	UW1
		Negative		UN1
		Negative	Words	UNW1
2	No left turn	Positive		LP2
		Negative		LN2
			Words	LW2
		Positive	Words	LPW2
	No right turn	Positive		RP2
		Negative		RN2
			Words	RW2
		Positive	Words	RPW2
	No turns	Positive		TP2
		Positive	Words	TPW2
		Positive	Words and time	TPWt2
		Positive	Time	TPt2
			Words	TW2
			Words and time	TWt2
	No U-turn		Words	UW2
		Negative		UN2
		Negative	Words	UNW2

Note: Left- and right-turn signs were presented twice.

Figure 1. Examples of traffic signs used in experiment.



(a) CIRCLE GREEN ARROW AND BORDER BLACK BACKGROUND WHITE

(b) CIRCLE AND BAR RED ARROW AND BORDER BLACK BACKGROUND WHITE

(c) CIRCLE GREEN ARROW, BORDER, LETTERS BLACK BACKGROUND WHITE

(d) LETTERS, BORDER BLACK BACKGROUND WHITE

(e) CIRCLE GREEN ARROW, BORDER, LETTERS BLACK BACKGROUND WHITE

(f) CIRCLE AND BAR RED ARROW AND BORDER BLACK BACKGROUND WHITE

Table 2. Percentage of subjects correctly recognizing traffic-control signs.

Sign Code	City Employees	Driver Trainees Before	Driver Trainees After	Driver Trainees After Only
RP1	77.7	69.6	83.7	48.7
RN1	77.9	73.7	82.5	67.1
RW1	78.1	62.9	69.0	59.7
RPW1	76.9	77.8	86.2	54.4
RP2	69.9	64.3	62.4	50.5
RN2	47.3	23.3	28.3	28.1
RW2	22.9	19.6	23.2	15.4
RPW2	63.7	42.1	59.3	45.2
TP1	89.2	88.0	91.6	75.4
TPt1	83.1	80.5	90.4	49.1
TPWt1	79.7	69.2	89.2	63.2
TW1	35.8	21.8	36.1	29.8
TP2	73.7	33.8	50.6	36.8
TPW2	62.2	37.6	42.7	38.6
TPWt2	72.9	41.4	50.6	26.3
TPt2	64.8	50.0	54.1	33.3
TW2	61.5	27.8	53.0	49.1
TWt2	37.8	27.1	36.1	38.6
UW1	91.2	92.5	97.6	91.2
UN1	90.5	85.7	90.4	75.4
UNW1	91.2	63.9	90.4	68.4
UW2	64.9	19.6	27.7	26.3
UN2	52.7	17.3	22.9	15.8
UNW2	46.0	18.8	31.3	29.8

Table 3. t-test comparisons of traffic-control signs.

Codes of Signs Compared	City Employees	Driver Trainees Before	Driver Trainees After Only
RN1 and RP1	0.048	1.127	2.970[a]
RP1 and RW1	-0.107	12.961[a]	-1.852
RN1 and RW1	-0.057	14.623[a]	1.391
RPW1 and RW1	-0.384	15.357[a]	-0.836
RP2 and RN2	5.325[a]	6.174[a]	4.133[a]
RP2 and RW2	12.749[a]	7.828[a]	7.105[a]
RN2 and RW2	6.661[a]	1.248	2.857[a]
RPW2 and RW2	11.284[a]	7.090[a]	5.680[a]
TP1 and TPWt1	2.260[b]	3.805[a]	1.399
TP1 and TPt1	1.514	1.673	2.757[a]
TPt1 and TPWt1	0.748	2.124[c]	-1.313
TP2 and TPW2	2.102[c]	-0.642	-0.195
UW1 and UN1	0.208	1.776	2.537[a]
UW2 and UN2	2.134[c]	0.460	1.363

Note: Positive values indicate that the first of each pair of signs was more easily recognized.

[a]$p < 0.01$. [b]$p < 0.02$. [c]$p < 0.05$.

Table 4. Main daily violations and violation indexes.

Date	Eastbound: Violations 1	Eastbound: Index 1	Eastbound: Violations 2[b]	Eastbound: Index 2[b]	Westbound[a]: Violations 1	Westbound[a]: Index 1	Westbound[a]: Violations 2[b]	Westbound[a]: Index 2[b]
April 28-May 2, 1969	8.8	0.60	4.8	0.18	12.4	0.81	5.6	0.20
May 6-9, 12-16, 1969	8.8	0.48	4.1	0.15	12.7	0.79	7.3	0.25
June 16-20, 1969	9.4	0.74	4.0	0.18	29.8	2.11	15.2	0.58
April 20-24, 1970	9.4	0.48	5.0	0.14	23.0	1.21	14.0	0.40
June 15-19, 1970	10.2	0.45	4.8	0.15	26.4	1.10	15.2	0.44
April 26-30, 1971	13.2	0.72	7.4	0.20	**	**	**	**

[a]Data for westbound traffic in April 1971 were not obtained because the turn restriction had been removed at that time to allow a temporary rerouting of traffic entering the city from the north.
[b]Based on violations committed between 4:15 and 5:45 p.m.

both total and restricted data after May 1969. There is no evidence to suggest that the negative-symbol version of the NO LEFT TURN sign improved traffic control for the purpose for which it was intended. The only statistically significant differences were (for violation index 2) between April 1969 and June 1969, when there were more westbound violations in June ($t = 2.99$, $df = 8$, $p < 0.05$), and between April 1969 and April 1970, when there were more westbound violations in April 1970 ($t = 2.56$, $df = 8$, $p < 0.05$). This first difference may be attributable partly to the large number of westbound out-of-town cars committing violations (an average of 9.3 per day during the June 1970 period).

CONCLUSIONS

The purpose of these investigations was to examine the recognizability and effectiveness of selected traffic-control signs. The laboratory approach, in which the projection tachistoscope is used, is a good method for studying traffic-sign recognition under controlled conditions. However, there are limitations here in that the subject is not exposed to the many distractions that he encounters while driving. In addition, the primary concern in traffic control is not whether the driver recognizes a sign but whether he obeys it. The field study was an attempt to examine this aspect of the problem.

There is evidence from both studies to suggest that the positive symbol was better than the negative symbol for the turn-restriction signs. This may be due to the positive sign being more intrinsically meaningful, or possibly to the fact that they have been in more common use in Alberta and are simply more familiar. Word messages were generally more poorly recognized than symbols.

Comprehension of a symbol is reduced by the addition of information such as words or a time. In such cases, the subject is required to process more information and will often miss part of it.

Evidence from the field study is not conclusive. The increase in violations for westbound traffic 6 weeks after the negative sign had been installed may be due to factors such as weather conditions and type of drivers. The most meaningful comparison is that between violations of the original sign and violations of the new sign during the same time of the year 1 year later (April 1970). In this comparison, the westbound traffic between 4:15 and 5:45 committed more violations in April 1970—tentative evidence that the negative turn-restriction symbol was less effective than the positive symbol under these particular circumstances. Ideally, data should have been collected during May and June before the negative symbol was installed so that more meaningful comparisions could be made. Another desirable modification would be to repeat the field study at a location where drivers are unfamiliar with both the positive and negative symbols.

A number of suggestions for future research emerge from this and other studies on traffic signing. Of particular interest from a psychological point of view is the problem of stimulus-response compatibility. Should the message indicate what the driver can do, or what he cannot do? The present research hints that the former may be desirable. Basic research on the use of unfamiliar symbols (not traffic signs) is warranted to determine the information processing requirements of the task.

The dozens of symbols used in traffic control need to be examined for their recognizability. Comparisons of different ways of presenting the same message should be made. This is especially important with abstract symbols that have no intrinsically obvious meaning to most motorists. Such research must, of course, be done cross-culturally if an adequate set of symbols is to be developed for international use.

REFERENCES

1. Campbell, L. R. Unpublished Research on Traffic Sign Identification, 1964.
2. Elliot, W. G. Symbology on the Highways of the World. Traffic Engineering, Vol. 31, 1960, pp. 18-26.

3. Forbes, T. W., Snyder, T. E., and Pain, R. F. A Study of Traffic Sign Requirements: II—An Annotated Bibliography. Michigan State Univ., 1964.
4. Gray, P. G. and Russel, R. Drivers' Understanding of Road Traffic Signs. Social Survey Central Office of Information, Vol. 55, No. 347, Oct. 1962.
5. Janda, H. F., and Volk, W. N. Effectiveness of Various Highway Signs. HRB Proc., Vol. 14, 1934, pp. 442-447.
6. Kershaw, B. An Investigation of the Results of a Traffic Questionnaire Performed at the 1968 Central Canadian Exhibition. Department of Traffic Engineering Services, City of Ottawa, 1968.
7. Markowitz, J., Dietrich, C. W., Lees, W. J., and Farman, M. An Investigation of the Design and Performance of Traffic Control Devices. Bolt, Beranek and Newman, Inc., Report 1726, 1968.
8. Tierney, W. J., and King, L. E. Traffic Signing—Symbols Versus Words. Paper presented at the 6th World Highway Conf. of Internat. Road Federation, Oct. 1970, Montreal.
9. Walker, R. E., Nicolay, R. C., and Stearns, C. R. Comparative Accuracy of Recognizing American and International Road Signs. Jour. of Applied Psychology, Vol. 49, 1965, pp. 322-325.