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Development and Driver Understanding of Hazard Warning and Location Symbols for IVSAWS

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UMTRI The University of Michigan Transportation Research Institute

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16. Abstract

This report describes research on an In-Vehicle Safety Advisory and Warning System (IVSAWS). A system of this type could receive radio signals from beacons on hazards and display in-vehicle warning messages to drivers. Possible hazards include accidents, new traffic signals, police cars, and school buses.

Appropriate hazards were identified from the literature. Based on drawings from 10 UMTRI employees, candidate hazard warnings were developed for 30 hazards. Next, 75 drivers at a driver licensing office ranked these warning symbols from best to worst, leading to recommended symbols in many cases. Text messages were slightly preferred over graphical messages. Symbols based on signs in the standard set (MUTCD) were not always preferred.

Finally, in an understandability experiment, 20 drivers were shown warnings and location cues while either driving a test route or parked. Ten hazard location symbol designs were tested: 2 text, 4 arrow, 3 overview, and 1 inside-out. Each driver identified 10 hazard symbols shown individually, a single hazard symbol combined with a location cue, and 40 combinations of warning and location cues. Of the location cues, text ("on right," "behind," "ahead to left," etc.) was best understood.

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PREFACE

The United States Department of Transportation (DOT), through its Intelligent Vehicle-Highway Systems (IVHS) program, is aiming to develop solutions to the most pressing problems of highway travel. The goal is to reduce congestion and improve traffic operations, reduce accidents, and reduce air pollution from vehicles by applying computer and communications technology to highway transportation. If these systems are to succeed in solving the nation's transportation problems, they must be safe and easy to use, with features that enhance the experience of driving. The University of Michigan Transportation Research Institute (UMTRI), under contract to DOT, has undertaken a project to help develop driver information systems for cars of the future, one aspect of IVHS. This project concerns the driver interface — the controls and displays that the driver interacts with, as well as their presentation logic and sequencing. This is 1 of 16 reports that documents that work.

The project had three objectives:

- Provide human factors guidelines for the design of in-vehicle information systems.
- Provide methods for testing the safety and ease of use of those systems.
- Develop a model that predicts driver performance in using those systems.

Although only passenger cars were considered in the study, the results apply to light trucks, minivans, and vans as well. Another significant constraint was that only able-bodied drivers were considered. Disabled drivers are likely to be the focus of future DOT research. A complete list of the project reports and other publications is included in the final overview report.[1]

To put this report in perspective, the project began with a literature review and focus groups examining driver reactions to advanced instrumentation.[2,3,4] Subsequently, the extent to which various driver information systems might reduce accidents, improve traffic operations, and satisfy driver needs and wants, was analyzed.[5,6,7] That analysis led to the selection of two systems for detailed examination (traffic information and cellular phones) and contractual requirements stipulated three others (navigation, road hazard warning, and vehicle monitoring).

Each system was examined separately in a sequence of experiments. In a typical sequence, patrons at a local driver licensing office were shown mockups of interfaces, and driver understanding of the interfaces and preferences for them was investigated. Interface alternatives were then compared in laboratory experiments involving response time, driving simulation, and other methods.[8] The results for each system are described in a separate report. To check the validity of those results, several on-road experiments were conducted in which performance and preference data for the various interface designs were obtained.

In parallel with that work, UMTRI developed test methods and evaluation protocols, UMTRI and Bolt Beranek and Newman (BBN) developed design guidelines, and BBN worked on the development of the driver model.

Many of the reports from this project were originally dated May, 1993, the initial end date of the project when reports were to be delivered. However, the reports were drafted when the research was conducted, over two years earlier for the literature review and feature evaluation, and a year earlier for the laboratory research and methodological evaluations. While some effort was made to reflect knowledge gained as part of this project, the contract plan did not call for re-writing reports to reflect recent findings.

This IVSAWS report concerns the development of hazard warning and hazard location symbols for use with an in-vehicle road hazard warning system, specifically IVSAWS. It also includes the subsequent evaluation of drivers' understanding of the resulting symbols.

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 (or "metric ton")	Mg (or "t")
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
	ILLUMINATION			
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
	FORCE and PRESSURE or STRESS			
lbf	poundforce	4.45	newtons	N
lbf/in^2	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	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
	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 (or "t")	megagrams (or "metric ton")	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	lbf/in^2

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

(Revised September 1993)

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INTRODUCTION

This report describes research on the driver interface for a road hazard warning system, that is, the design of the information displayed to drivers. The basic idea behind this system and its predecessors is that fixed hazards (e.g., narrow underpasses), mobile hazards (e.g., police cars on a run) or temporary hazards (e.g., accidents) could have low power radio beacons placed on them. The beacon would send out a message indicating the type of hazard. These messages would be received by nearby vehicles and a warning system, such as IVSAWS (In-vehicle Safety and Advisory Warning System), would present a warning to drivers on a display. The experimenters attempted to separate the design of the human interface from the final IVSAWS implementation. It was necessary, however, to use this working concept to define the scope of the information to be displayed.

For this study, appropriate hazards were identified from the literature. Based on drawings from 10 UMTRI employees, candidate hazard warnings were developed for 30 hazards. Next, 75 drivers at a driver licensing office ranked these warning symbols from best to worst, leading to recommended symbols in many cases. Text messages were slightly preferred over graphical messages. Symbols based on signs in the standard set, the Manual on Uniform Traffic Control Devices (MUTCD), were not always preferred.[9]

Finally, in an understandability experiment, 20 drivers were shown warnings and location cues while either driving a test route or parked. Ten hazard location symbol designs were tested: 2 text, 4 arrow, 3 overview, and 1 inside-out. Each driver identified 10 hazard symbols shown individually, a single hazard symbol combined with a location cue, and combinations of warning and location cues. Of the location cues, text ("on right," "behind," "ahead to left," etc.) was best understood.

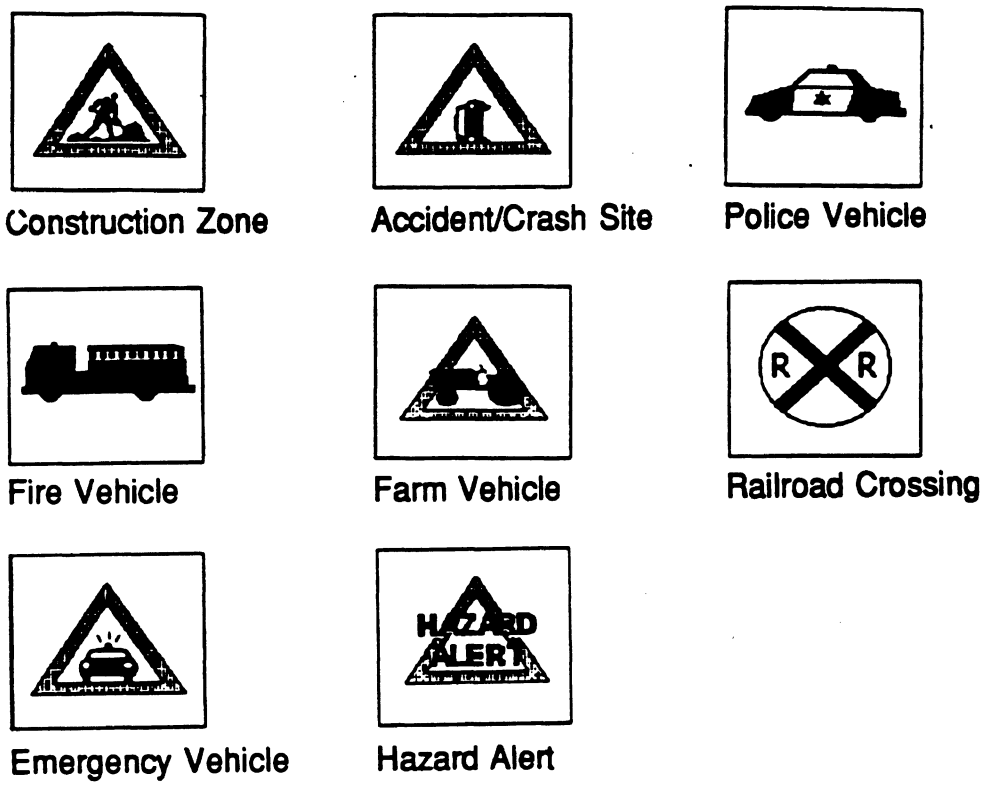
Background

This report concerns IVSAWS, a successor to SHAWS (Safety Hazard Advance Warning System), both systems of interest to Federal Highway Administration. The predecessor system, deemed not cost effective, was proposed to reduce crashes at grade crossings and with emergency vehicles.[10] A second version (the "radio flare") was designed to warn against a wider range of hazards, such as blind curves, one lane bridges, accidents, etc.[11] Neither of those reports says much about the driver interface, nor contains usability tests of proposed designs.

More recently, Hughes, under contract to FHWA (contract DTFH61-90-R-00030) has been working to refine the design of IVSAWS. At the time the work for this report was started, no reports had been released from Hughes under that contract except for an UMTRI report completed under subcontract, which identified some of the hazards of interest.[12] To maximize the number of ideas explored, UMTRI worked independently of Hughes in designing the interface, though the authors have utilized the same accident research to identify the warnings required. The exact implementation has a large impact on the features, and subsequently, the interface, of the system. The

experimenters tried to approach the interface design from a driver needs/capability view separate from the implementation details, but this was not entirely possible.

After much of the research was completed, the authors learned of the results of a Hughes test of IVSAWS warnings (Erlichman, 1992).[13] Eight pictograms (shown in figure 1) were presented to 13 Hughes employees. (No signs based on the MUTCD standard set were tested.) A Macintosh II color display via software written in SuperCard was used for presentation. Apparently this was done statically in the laboratory. Six formats were explored: monochrome, color, flashing in color (at four per second), audio tone, long voice messages, and short voice messages. In general, subjects preferred colored icons with warning tones and associated spoken text. It is uncertain if the same preferences would be obtained if this experiment were repeated on the road, especially if the warnings occurred frequently.



Source: Erlichman, 1992, p 481.

Figure 1. IVSAWS symbols examined by Hughes.

Purpose

The purpose of this report is to examine alternative IVSAWS interface concepts, and, as part of that process, to develop design guidelines and evaluation methods. Central elements of the guidelines include recommendations concerning the format and content of messages. To make these recommendations, specific messages needed to be developed and tested.

The purpose of this research was not to complete the design of an IVSAWS driver interface or to examine the merits of an IVSAWS system. It is precompetitive research; final design is left up to the manufacturers.

The design questions therefore became:

- Which hazards would be appropriate for warnings?
- What graphics best represent those hazards?
- By what methods can the relative location of the hazard be communicated to drivers, and how well are they understood?

Because the system was intended in some cases to supplement existing auditory warnings (emergency vehicle sirens, railroad crossing bells), an auditory format was ruled out. IVSAWS, unlike navigation, will be interrupting unexpectedly, and if auditory, would have to compete with a car stereo or with passengers' conversation, for example. The track record of auditory warnings in cars has been poor. ("Your door is ajar." "No, a door is a door, not a jar.") Carryover from those experiences could diminish the attention paid to, and public acceptance of, an auditory IVSAWS system.

As a result, the IVSAWS system interface explored in this study primarily was designed as an icon-based system. By minimizing linguistic elements, international harmonization would be promoted, as well as compatibility with other dashboard warnings. In addition, using common warnings for all markets can result in significant cost savings.

Determination of Hazards Appropriate for Warnings

Initial selection of the hazards for which warnings were desired was determined primarily from the data in Streff, et al. and, to a lesser extent, from Serafin, et al. and Meyer, et al.[10,6,9] The experimenters were interested not only in exploring warnings for the most system-applicable hazards, but also in exploring a broad range of hazard categories.

The final total rankings for IVSAWS hazards from Serafin, et al. (1991) are shown in table 1.[6] These are the rankings and scores based on experimenter estimates of each information element's effect on traffic operations, accidents, and driver comfort and convenience: the greater the score, the higher the supposed benefit. Readers interested in the method by which the scores in this table were developed should see Serafin, et al.[6] Since this matrix was based mostly on experimenter judgment, more

weight was given to the Streff et al. report. The Streff, et al. report's list of hazards with applicability to IVSAWS is given in table 2.[10]

Table 1. IVSAWS ranked information elements.

Rank	Information element	Score	Rank	Information element	Score
1	Curve (excessive speed)	0.766	19	Refuse removal truck	0.310
2	Accident ahead	0.722	20	Distance to construction	0.296
3	Train approaching/ crossing	0.549	21	Construction equip	0.281
4	Lanes closed/open	0.538	22	Plow/gravel truck	0.257
5	Curve (fog, slippery)	0.494	23	Disabled traffic signal	0.191
6	Grade (fog, slippery)	0.494	24	Tow truck -- at scene	0.174
7	Speed limit	0.477	25	New yield sign	0.167
8	School bus -- loading/unloading	0.422	26	Lane shifts	0.161
9	Police -- on run	0.412	27	Farm vehicle	0.161
10	Construction ahead	0.405	28	Horse drawn vehicle	0.161
11	New signal light	0.394	29	Slow moving vehicle	0.161
12	New stop sign	0.394	30	Wide load	0.161
13	Mail delivery	0.386	31	Police -- in chase/pursuit	0.155
14	Police -- at scene	0.365	32	Ambulance -- at scene	0.145
15	Lanes closed/open	0.339	33	Public utility vehicle	0.076
16	Ambulance -- on run	0.336	34	Fire truck -- at scene	0.069
17	Fire truck -- on run	0.336	35	Number of tracks	0.000
18	Directions affected	0.317	36	Funeral procession	0.000

Scoring Key: 2=Highly Beneficial
1=Beneficial
0=No Effect
-1=Detrimental
-2=Highly Detrimental

Source: Serafin, et al., 1991, p 88.

Table 2. Rankings of possible IVSAWS applications.

IVSAWS application	Crash data rank		Overall rank
	Crash frequency	Injury severity	
Signal emergency vehicle presence	5	2-3	1
Railroad grade crossings	6	1	2
Multiple (compounding) hazardous conditions	3	2-3	2
Highway construction zones	2	5-6	3
Supplemental traffic control device	NA	NA	4
Crash site -- Police activated	NA	NA	4
School bus or other special vehicle hazard	4	4	5
Temporary detour routes	NA	NA	5
Disabled truck at roadside	NA	NA	6
"Mini-zones" involving roadside work	NA	NA	7
Traffic backups	NA	NA	7
Accident-involved or disabled vehicles	1	5-6	8

Source: Streff, et al., 1991, p 60.

Also pertinent, but given less influence on the hazard selection, were the situations warranting SHAWS application shown in Meyer et al.[9] See table 3. Their recommendations were determined primarily by accident data.

Table 3. Road/traffic situations selected for analysis.

Hazard type	Typical Condition	Hazard Classification
Permanent	Four-way 90 degree intersection with cross street accident problem	Highway condition
Permanent	Three-way 90 degree rural intersection with accident problem on cross street	Highway condition
Permanent	Two-way rural road with one lane bridge accident problem	Object (fixed)
Permanent	Rural railroad grade crossing accident problem	Object (moving)
Temporary	Disabled vehicle on rural roadway	Object (fixed)
Temporary	Accident occurring on rural roadway	Object (fixed)
Transitory	Paint truck maintenance operation of rural roadway	Object (moving)
Combination	Accident occurring at four-way 90 degree rural intersection with cross street accident problem	Situation (combination)
Combination	Poor visibility, slick road surface, improper elevation design on approach to "S" curve	Situation

Source: Meyer et al., 1982, p 6-6.

Also taken into consideration were ease of installation and operation. For instance, installation in police cars could be mandated and operation tied to the siren. An ice-on-bridge detector, however, would require technology innovations and an enormous infrastructure investment, in addition to the investment in the IVSAWS system. The experimenters tried to investigate those warnings most easily installed, and hence most likely to be installed first.

Finally, the experimenters spoke with people who work in areas possibly affected by a system of this type, as a preliminary means of exploring user needs for individual warnings. While anecdotal, these comments were insightful for this stage of the study. The safety office of the postal service was consulted as to the types of accidents that occurred, and which vehicles were the most vulnerable. According to the office in Detroit, most accidents involve privately-owned mail-delivery vehicles driven on roads with a soft shoulder, although all mail vehicles were at risk. Reaction to a description of the system was very favorable. A tow truck driver that was consulted felt that backing up was a particularly dangerous operation, but otherwise felt safe. A local funeral home was consulted regarding the usefulness of a funeral procession warning. While he had not had any accidents in the last seven years, he noted a problem with non-procession drivers cutting into the funeral procession line. A local long-time fire-fighter stated that there had never been a fire-truck collision in his memory because their trucks stop at all the traffic lights. He added, however, that ambulances have more problems since they slow down less through large intersections.

These efforts led to the identification of 30 hazards for which warnings should be considered. They are listed in the next section.

PART 1: IVSAWS POPULATION STEREOTYPE METHOD STUDY

Purpose

The purpose of the population stereotype method study was to develop ideas for candidate symbols in a quick and simple manner.

Method

This study involved 10 drivers drawing symbols for the 30 situations previously identified as important. (While the small number of participants cannot represent the entire population, this method was useful as a quick means of generating symbols.) Based on the ideas generated by this first part, candidate warnings for each of the situations will be developed for part two. Text equivalents (of the graphics) and standard road signs were added where applicable.

Test Participants

Ten UMTRI employees (7 men and 3 women) from various departments who were licensed drivers volunteered to participate in this study. Drivers ranged in age from 21 to 47, with a mean age of 33.

Test Materials and Equipment

Test materials consisted of a nine page form with descriptions of hazardous situations and a 35 mm square box for participants to draw what they thought a device should display to warn for each hazard. (See figure 2 for example question.)

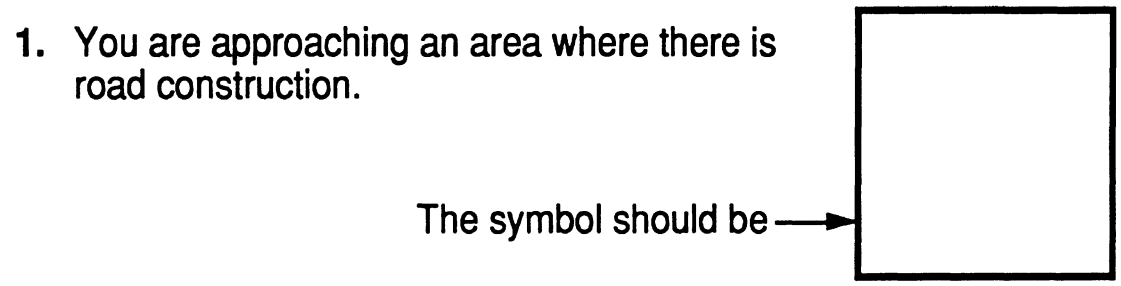


Figure 2. Example question from the population stereotype method study.

The 30 hazards used were:

- Road construction.
- Road construction area, speed limit 45 MPH.
- Sharp curve, speed limit 30 MPH.
- Accident ahead.
- High speed ambulance with siren and flashers.
- Parked ambulance with flashers.
- High speed fire truck with siren and flashers.
- Parked fire truck with flashers.
- High speed police car with siren and flashers.
- Parked police car with flashers.
- High speed police car with siren and flashers in pursuit.
- High speed police car with siren and flashers approaching from right.
- High speed police car with siren and flashers approaching from behind.
- Train approaching railroad track.
- School bus loading or unloading children.
- Slow moving vehicle.
- Farm vehicle.
- Wide load.
- Mail delivery truck.
- Trash truck.
- Plow/gravel vehicle plowing or sanding.
- Parked utility company vehicle.
- Tow truck with flashers aiding a disabled vehicle.
- Traffic light out of order.
- New traffic light.
- New stop sign.
- Right lane closed, merge into left two lanes.
- Lanes shift/jog to the right.
- Hazard approaching in opposite direction.
- Hazard 1 mile ahead.

Participants were provided with a wide point marker to reduce the temptation to draw details; however, not all participants used the writing instrument provided. The participants were not limited in the amount of text or numbers they could use in their drawings.

In the last blank, participants were asked to draw what they thought the directional icon should look like on a two-icon system in which a police car was approaching their car from the right. (See appendix A for the complete form used.)

Test Activities and Their Sequence

The experimenter handed out surveys and pens. The instructions were explained and participants' questions answered. (In following days, the experimenter collected the completed forms.) Participants completed the forms in their offices or at home, typically taking 45 minutes.

Results

Figures 3 through 33 show the drawings generated by the participants.

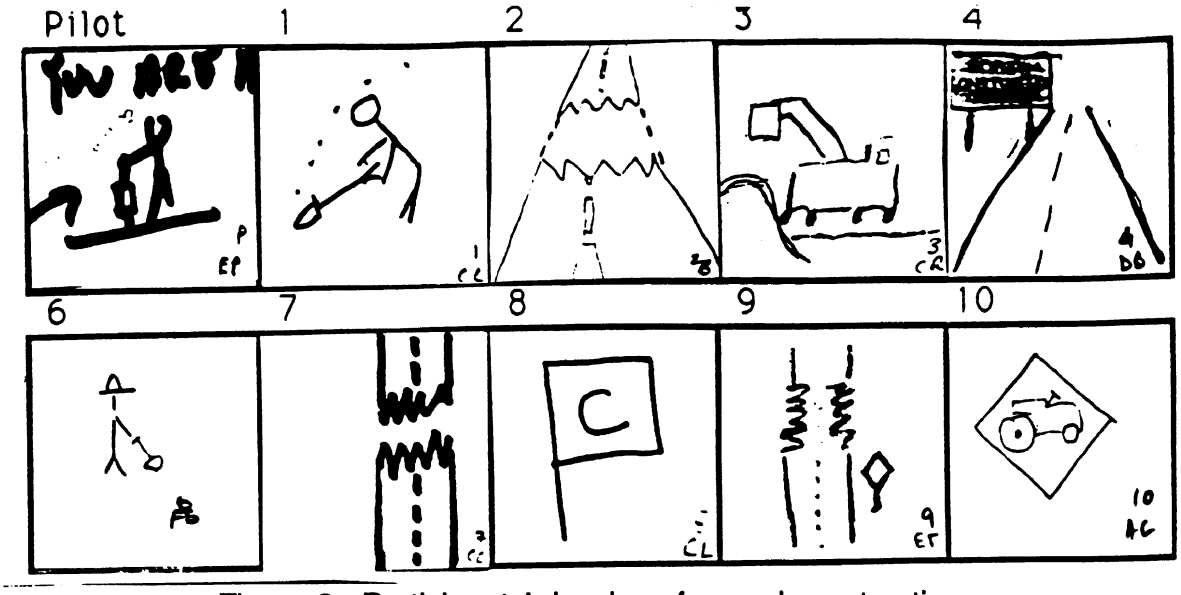


Figure 3. Participants' drawings for road construction.

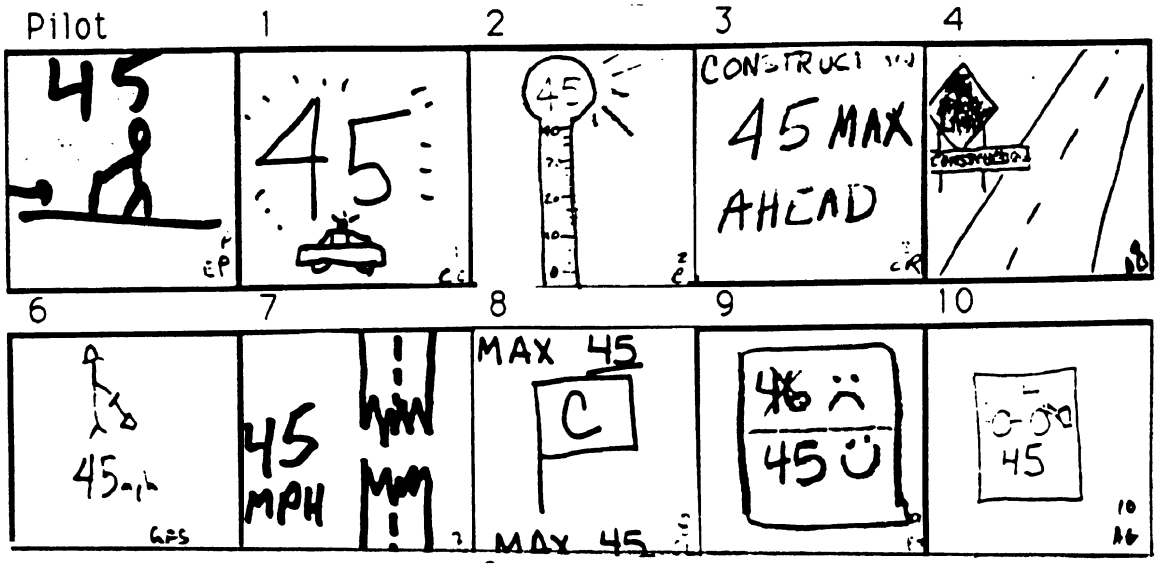


Figure 4. Participants' drawings for road construction area, speed limit 45 MPH.

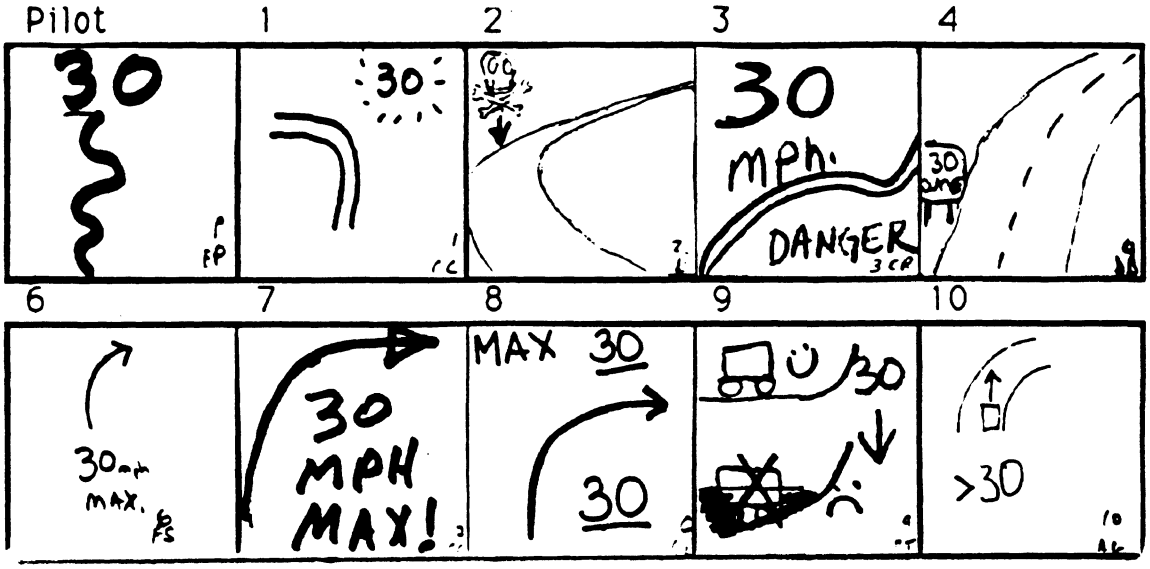


Figure 5. Participants' drawings for sharp curve, speed limit 30 MPH.

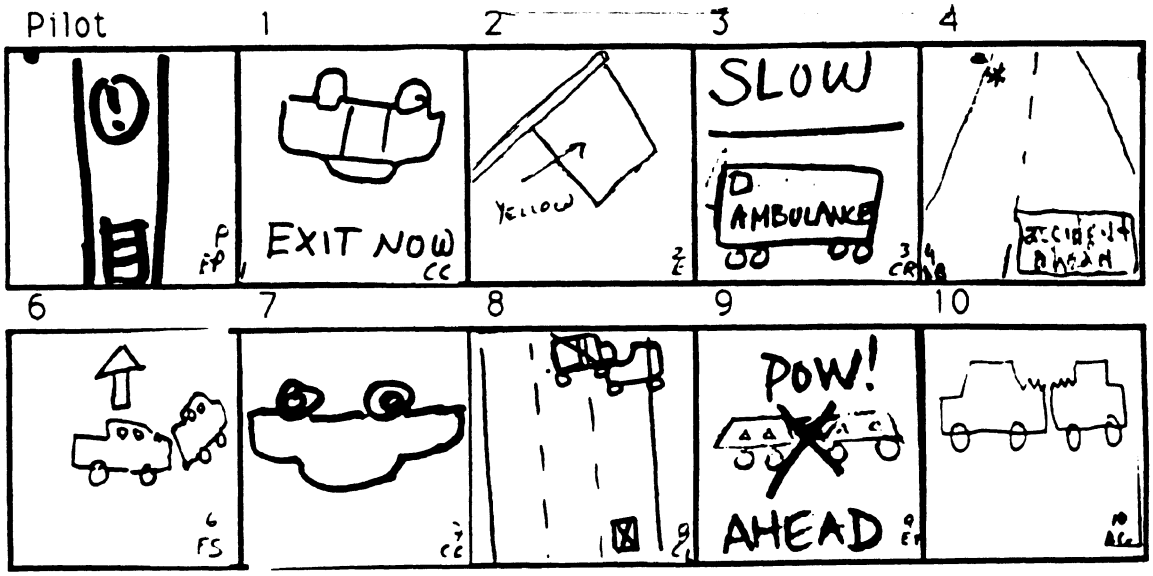


Figure 6. Participants' drawings for accident ahead.

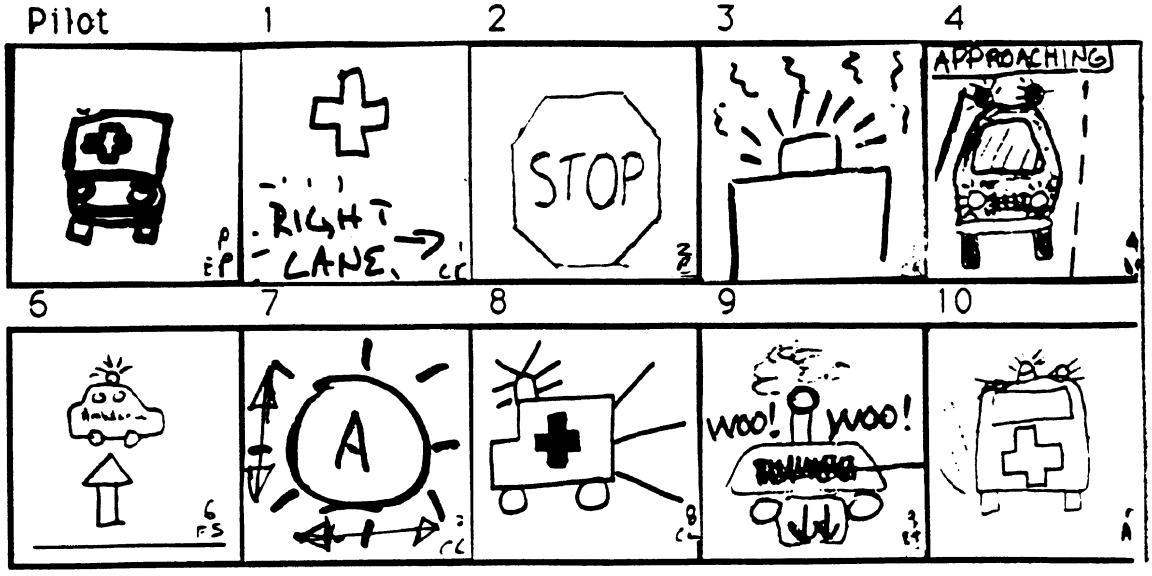


Figure 7. Participants' drawings for high speed ambulance with siren and flashers.

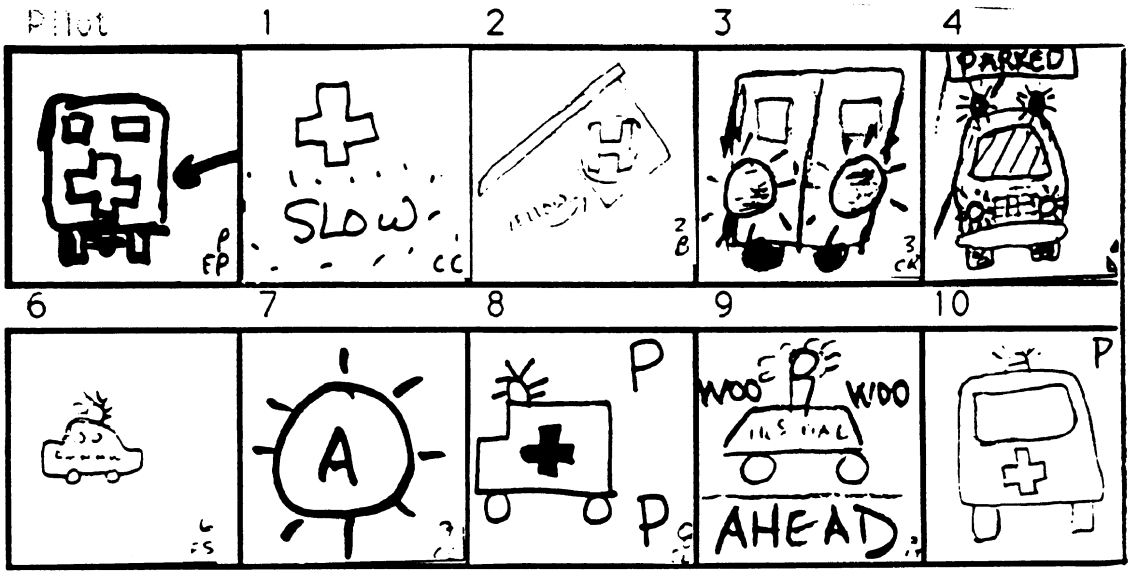


Figure 8. Participants' drawings for parked ambulance with flashers.

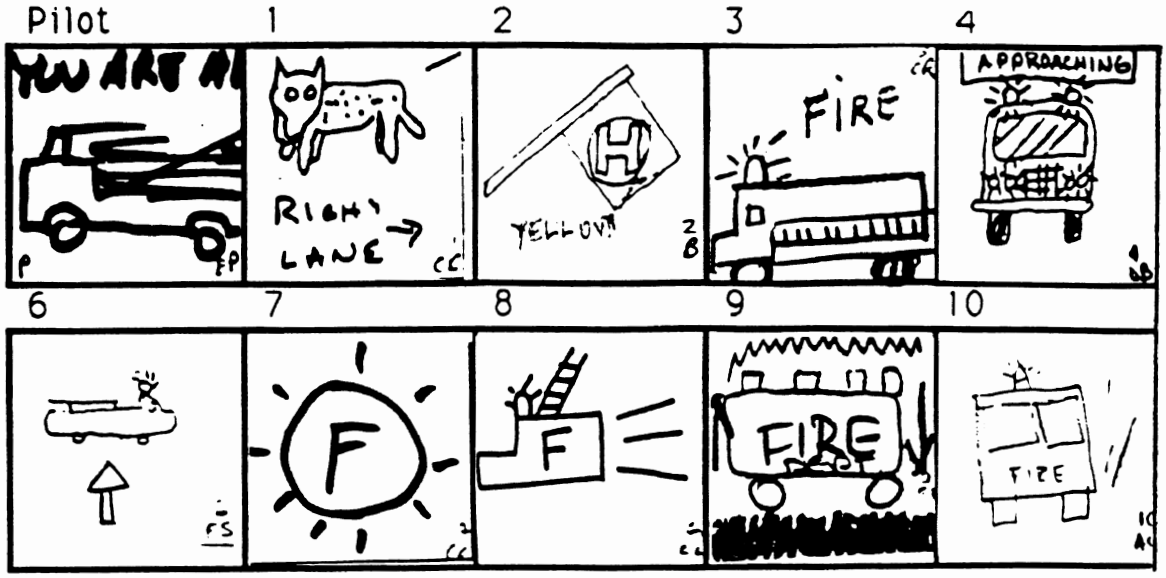


Figure 9. Participants' drawings for high speed fire truck with siren and flashers.

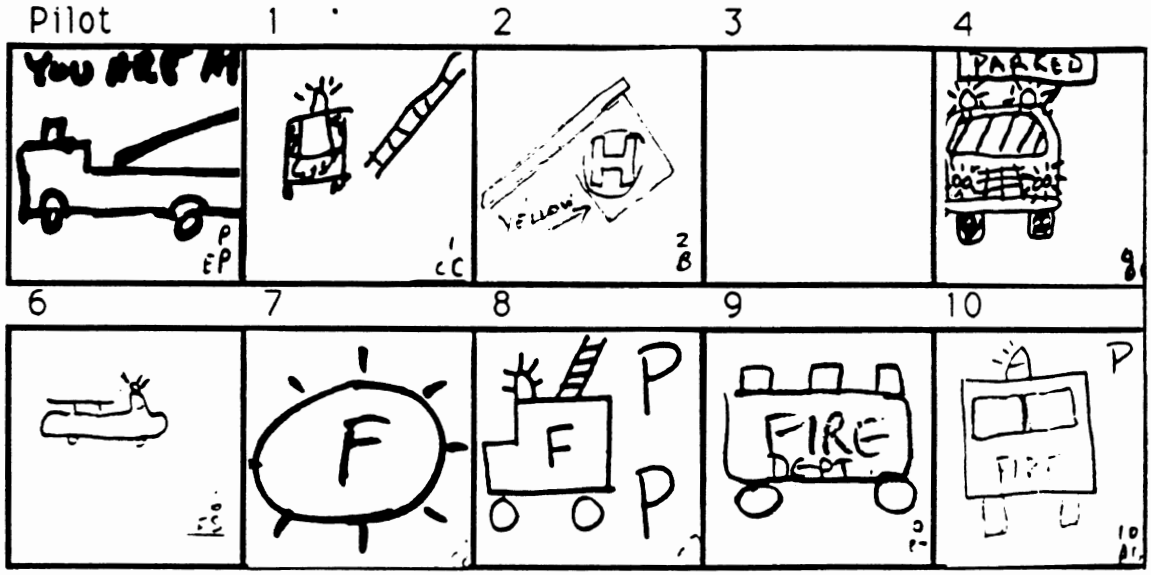


Figure 10. Participants' drawings for parked fire truck with flashers.

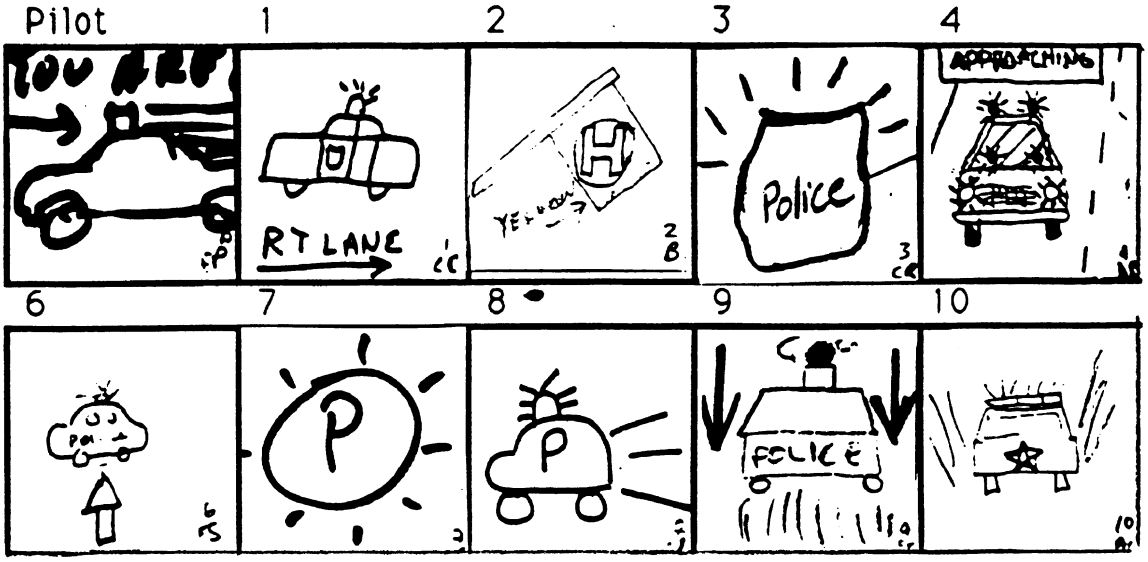


Figure 11. Participants' drawings for high speed police car with siren and flashers.

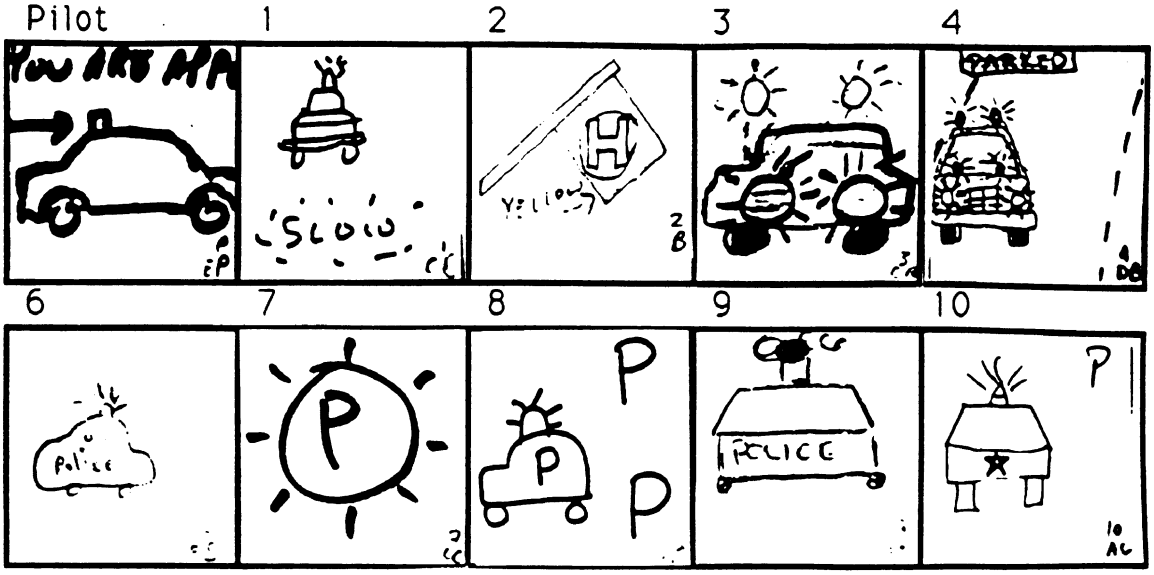


Figure 12. Participants' drawings for parked police car with flashers.

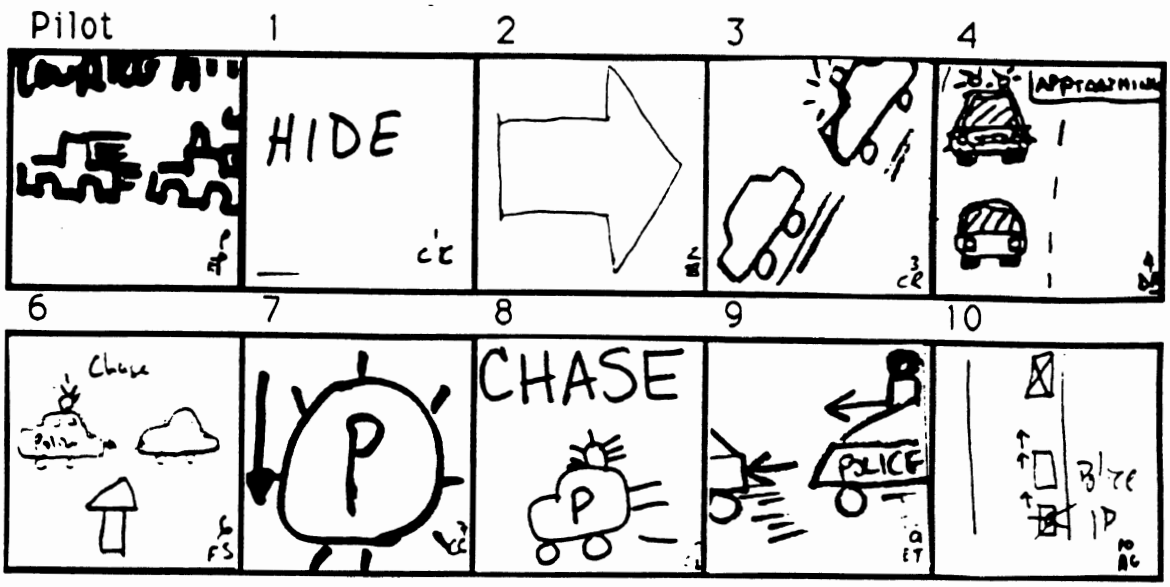


Figure 13. Participants' drawings for high speed police car with siren and flashers in pursuit.

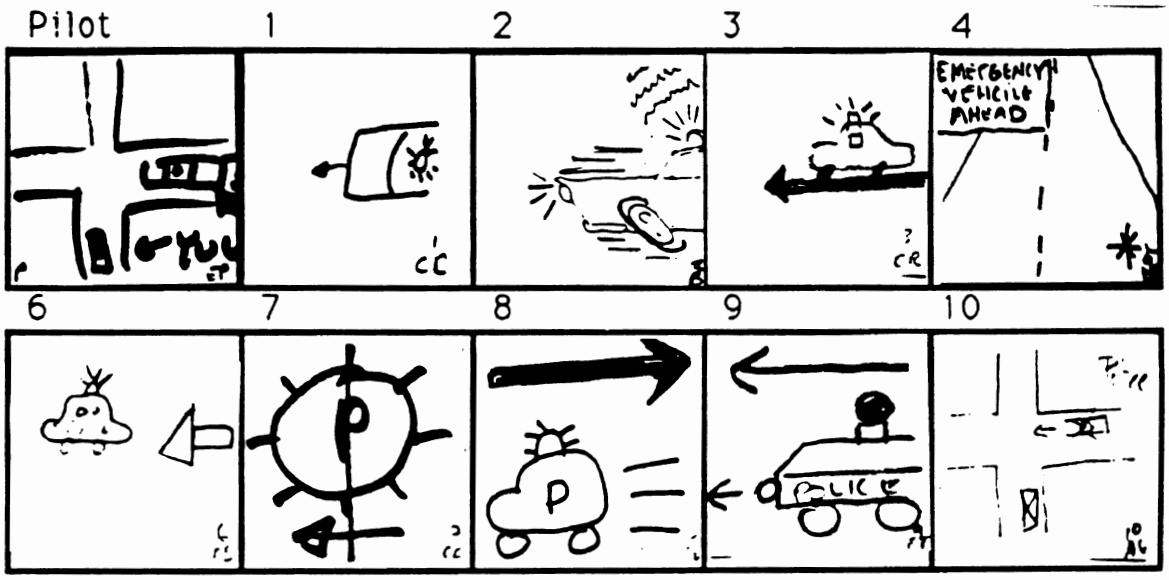


Figure 14. Participants' drawings for high speed police car with siren and flashers approaching from right.

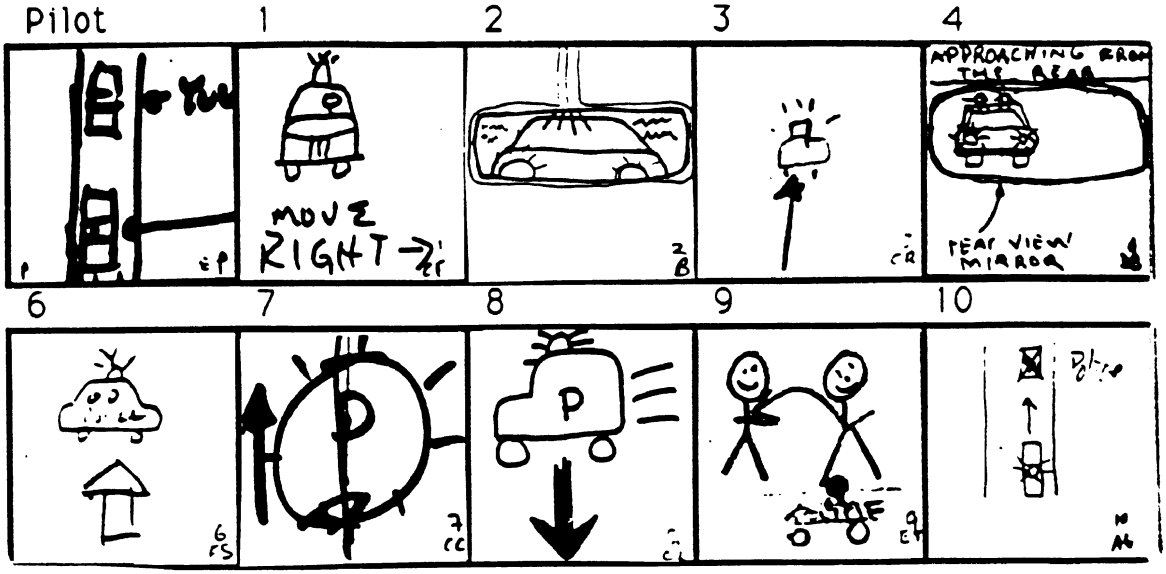


Figure 15. Participants' drawings for high speed police car with siren and flashers approaching from behind.

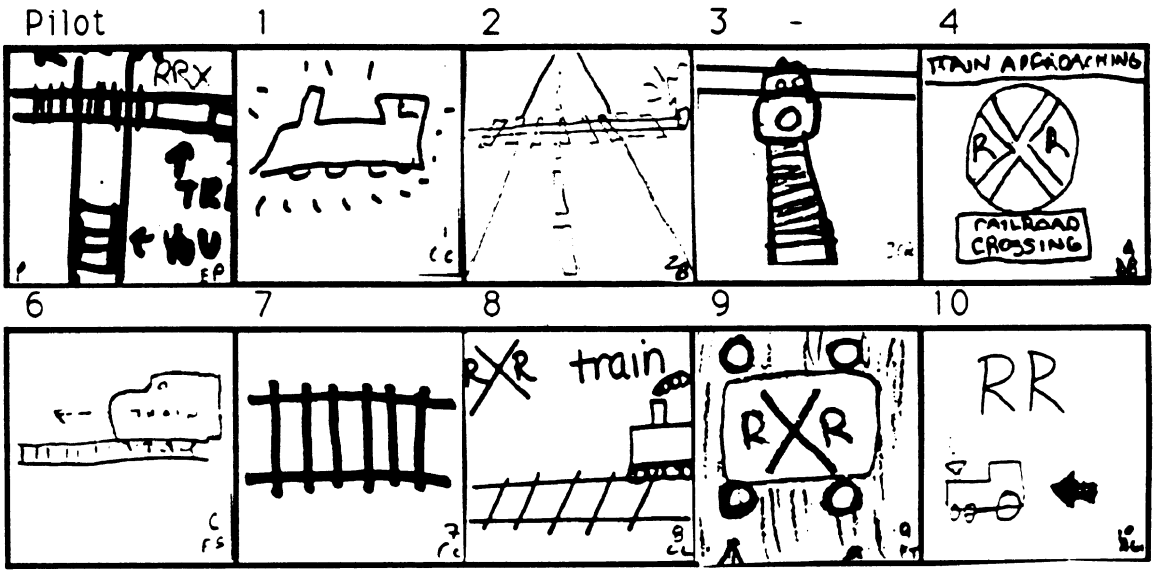


Figure 16. Participants' drawings for train approaching railroad track.

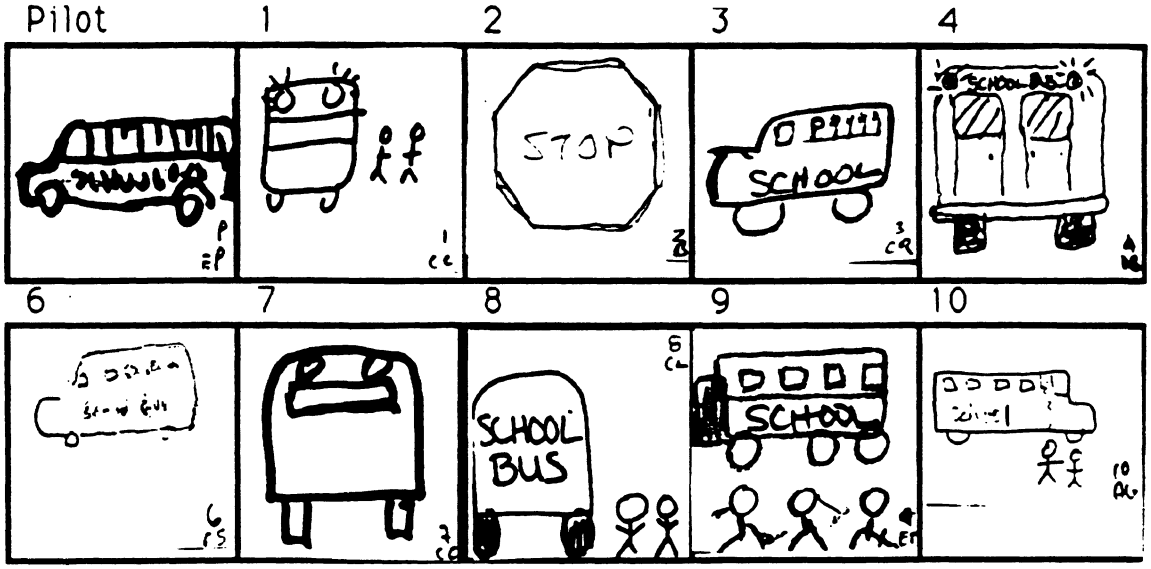


Figure 17. Participants' drawings for school bus loading or unloading children.

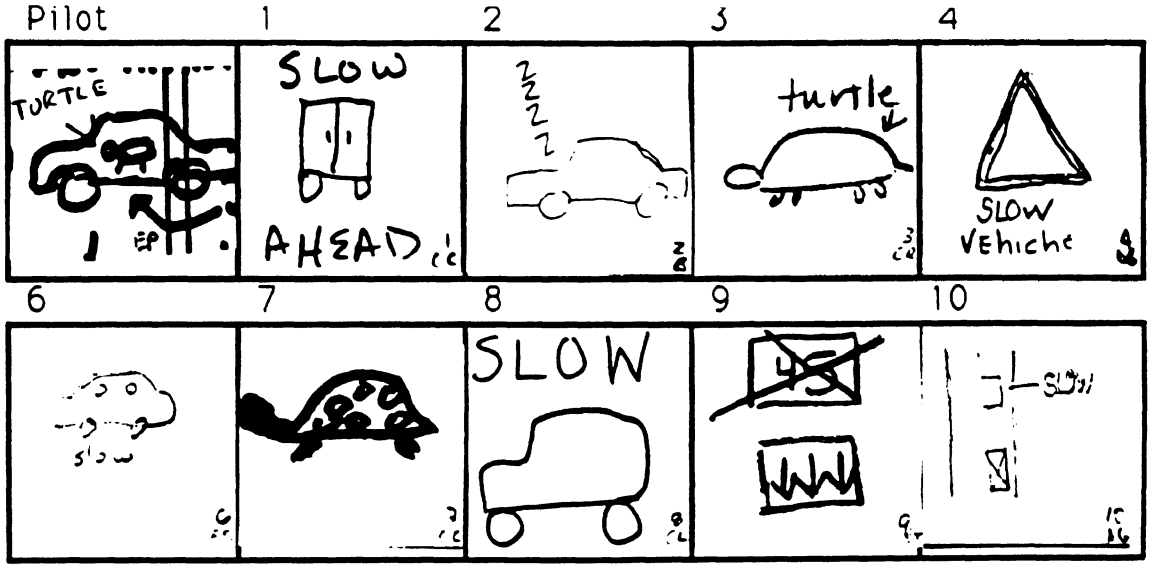


Figure 18. Participants' drawings for slow moving vehicle.

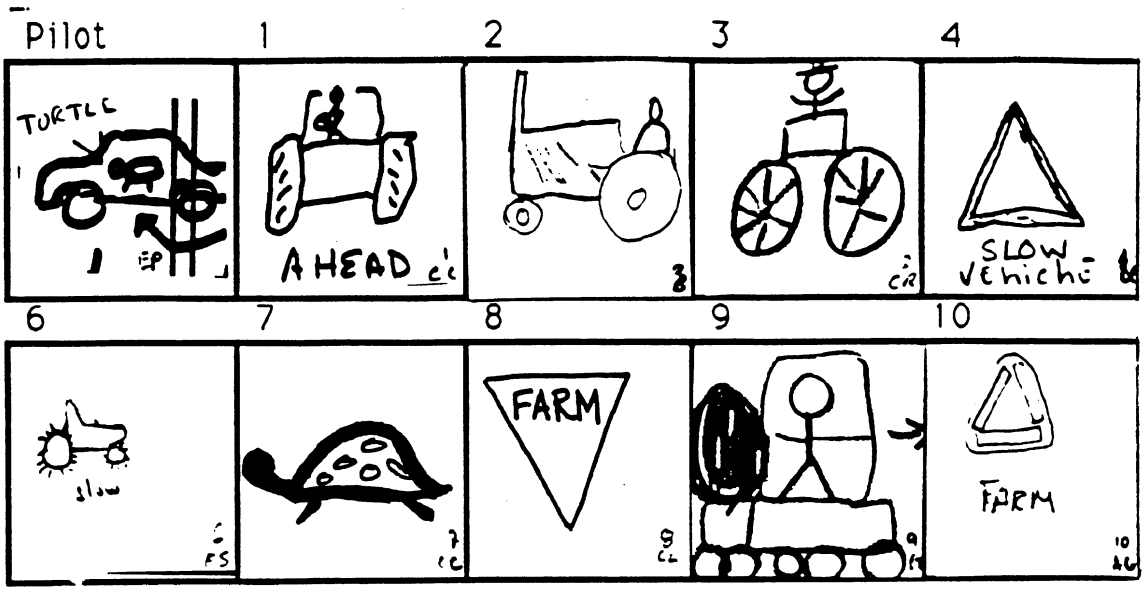


Figure 19. Participants' drawings for farm vehicle.

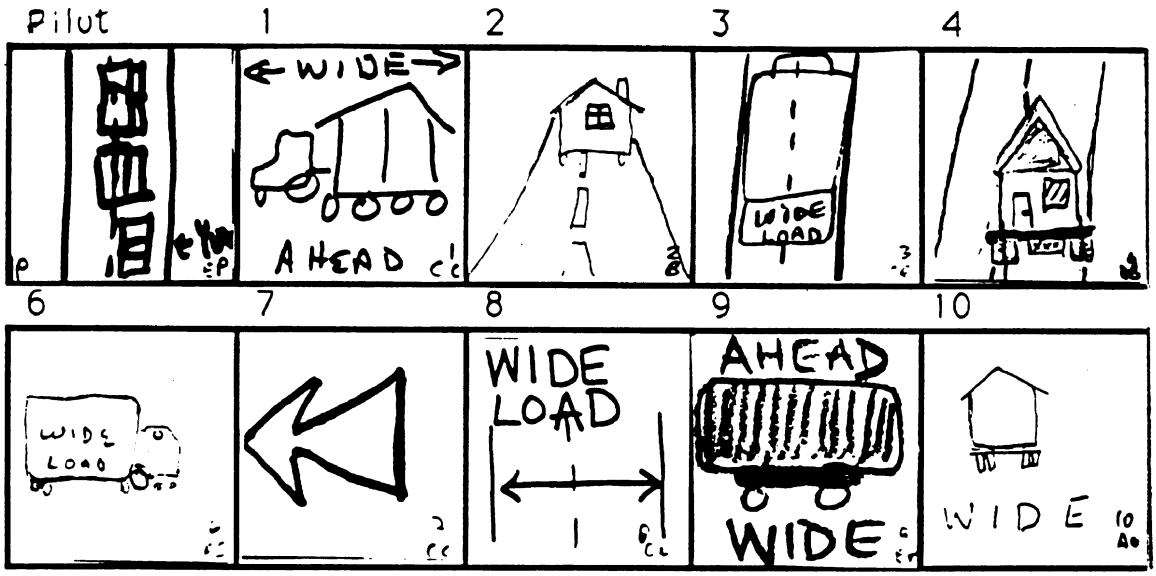


Figure 20. Participants' drawings for wide load.

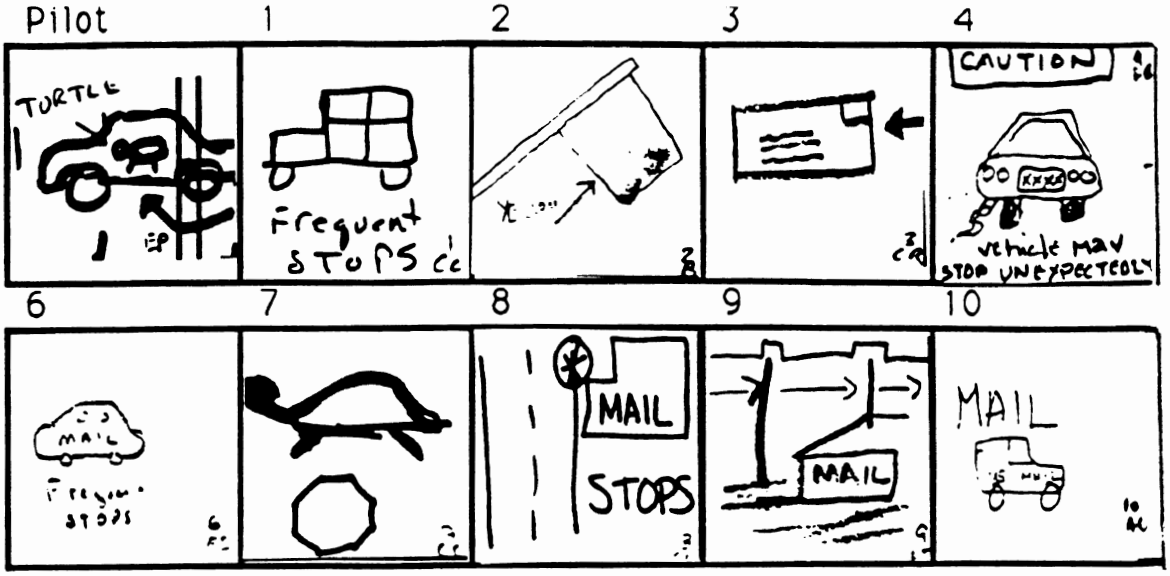


Figure 21. Participants' drawings for mail delivery truck.

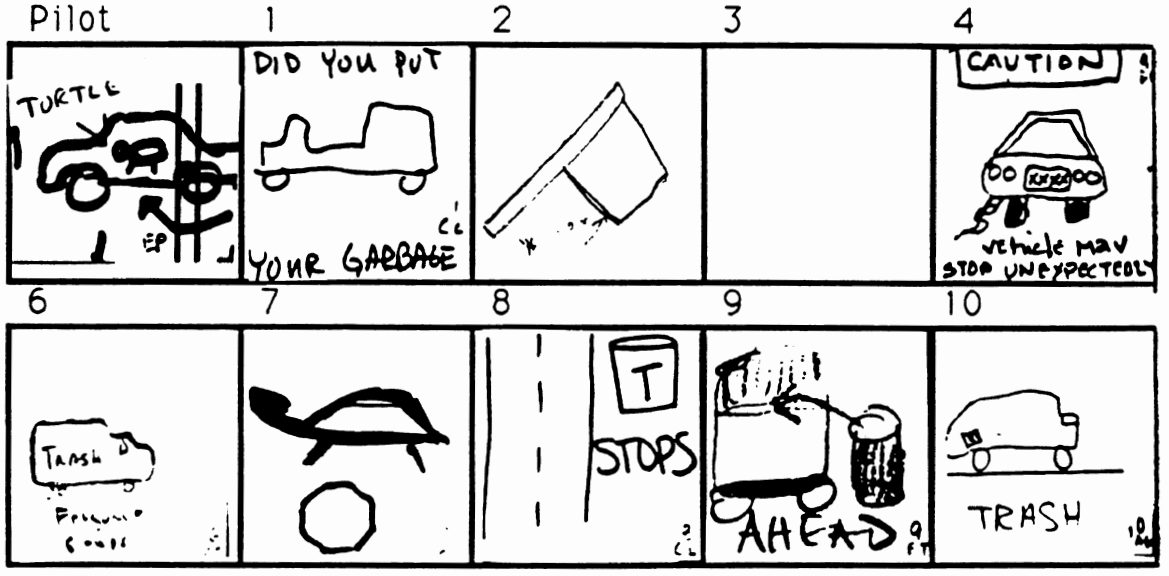


Figure 22. Participants' drawings for trash truck.

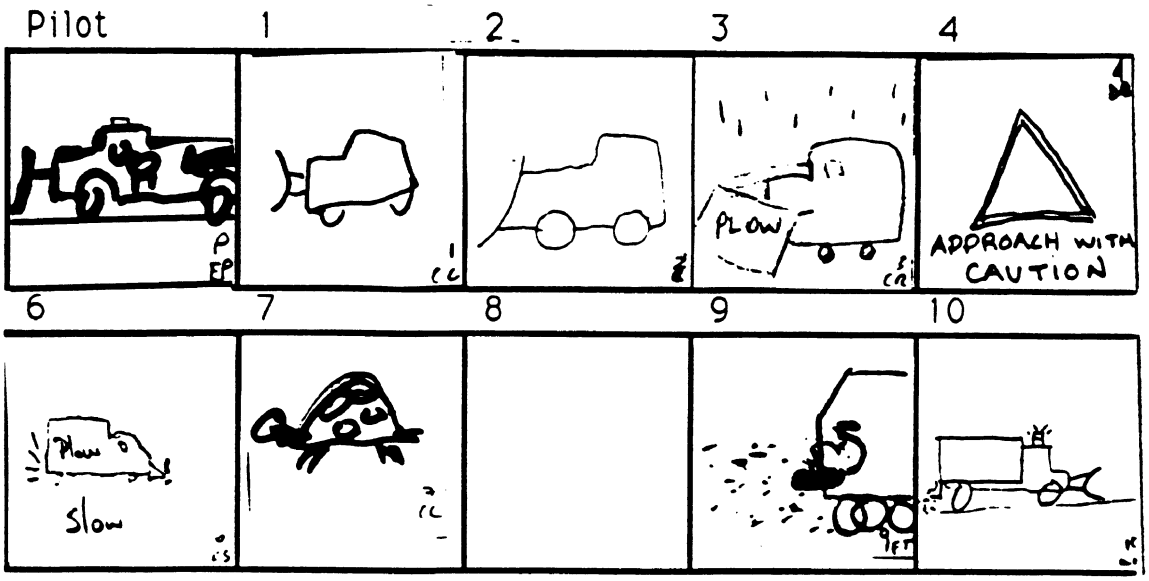


Figure 23. Participants' drawings for plow/gravel vehicle plowing or sanding.

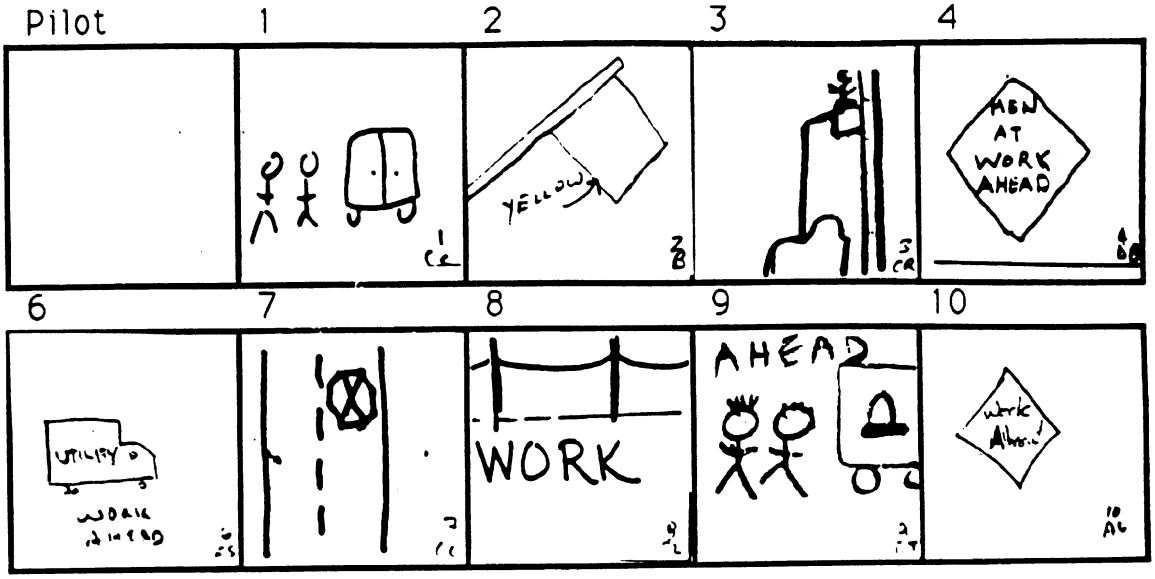


Figure 24. Participants' drawings for parked utility company vehicle.

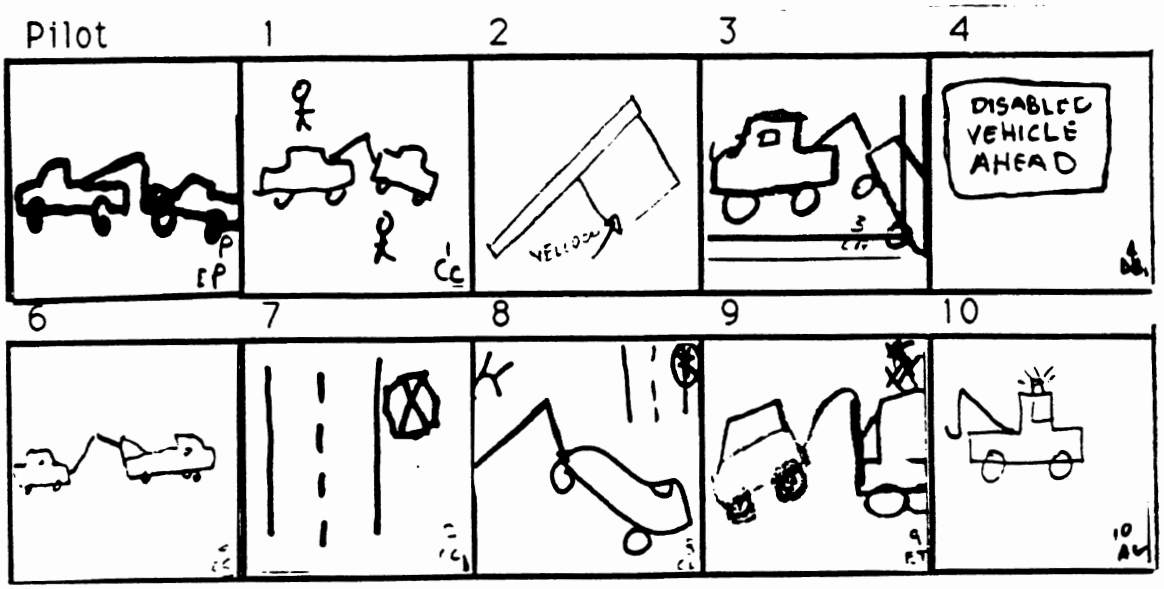


Figure 25. Participants' drawings for tow truck with flashers aiding a disabled vehicle.

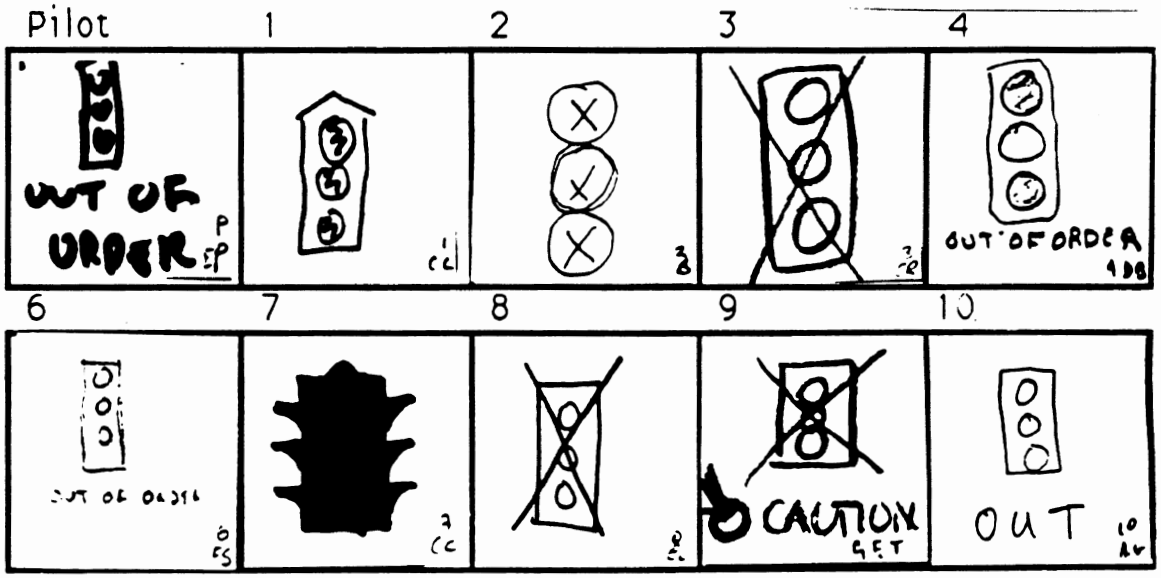


Figure 26. Participants' drawings for traffic light out of order.

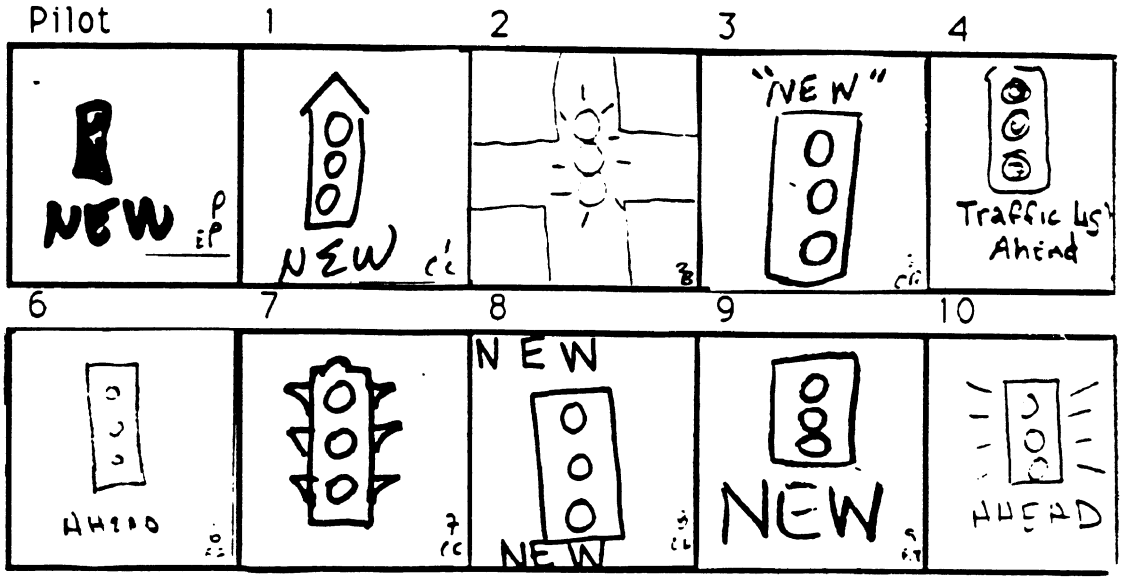


Figure 27. Participants' drawings for new traffic light.

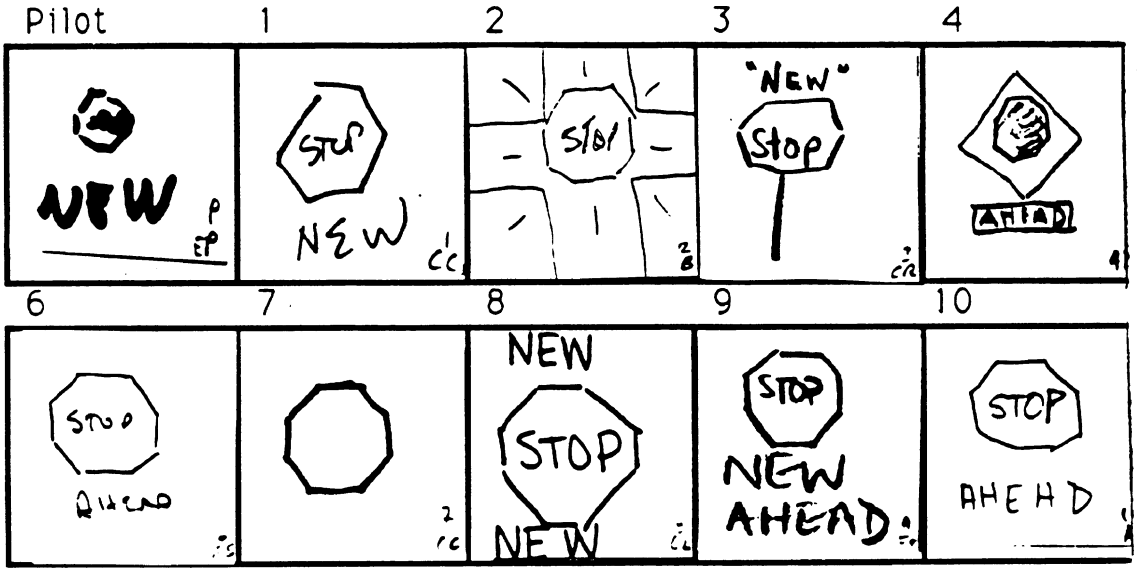


Figure 28. Participants' drawings for new stop sign.

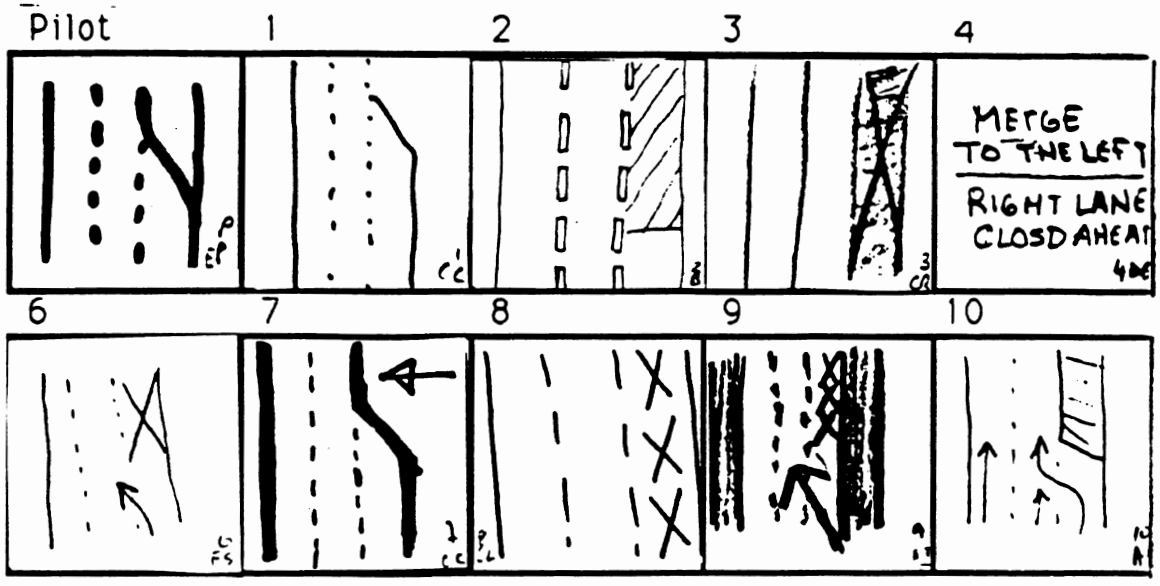


Figure 29. Participants' drawings for right lane closed, merge into left two lanes.

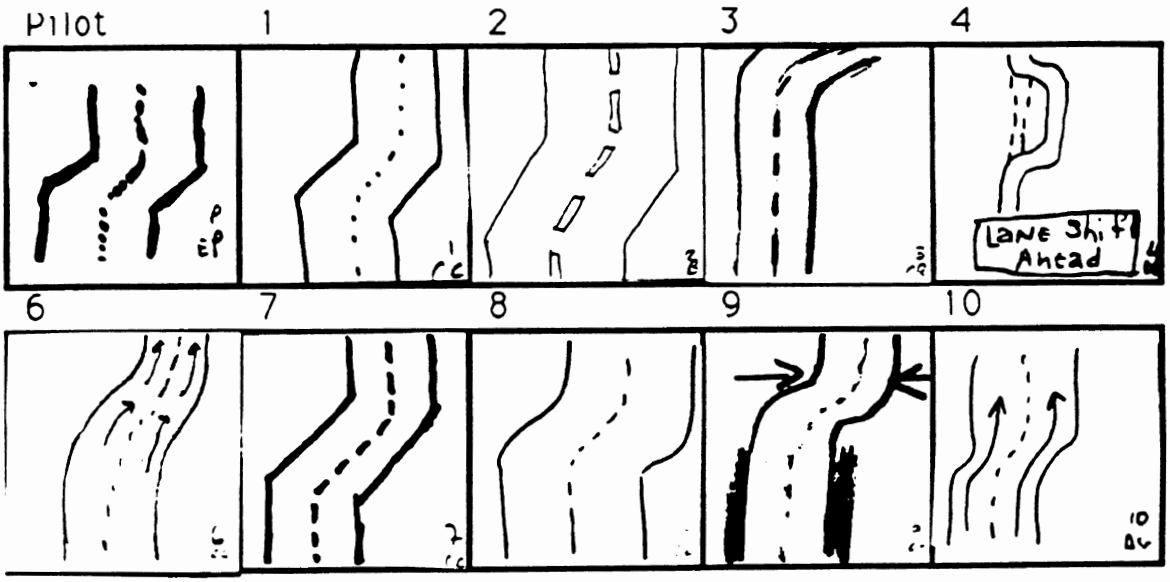


Figure 30. Participants' drawings for lanes shift/jog to the right.

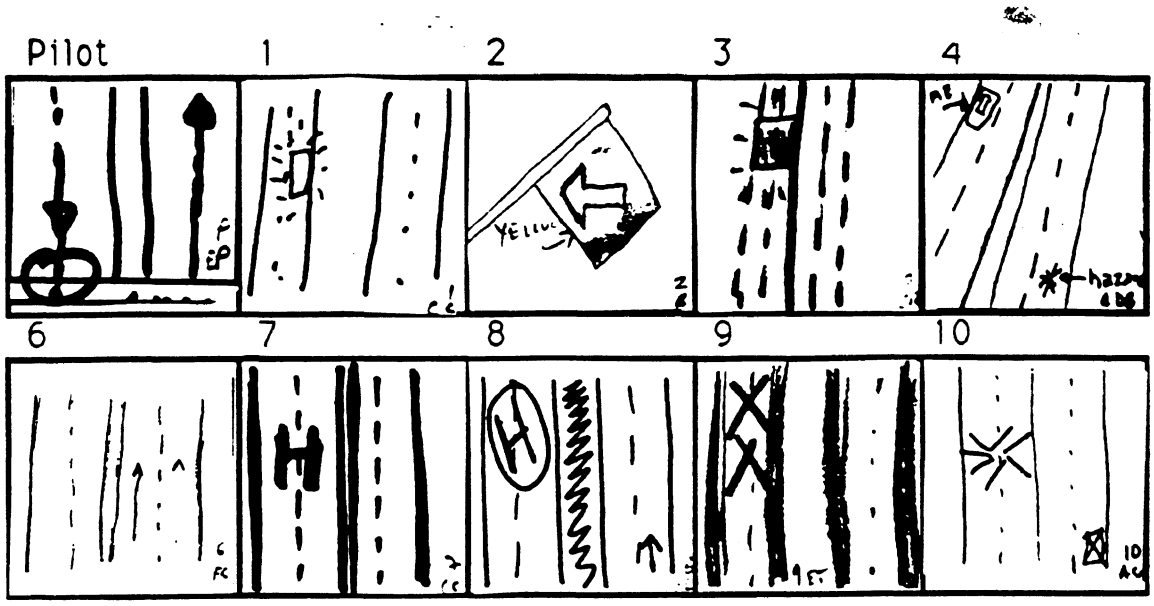


Figure 31. Participants' drawings for hazard approaching in opposite direction.

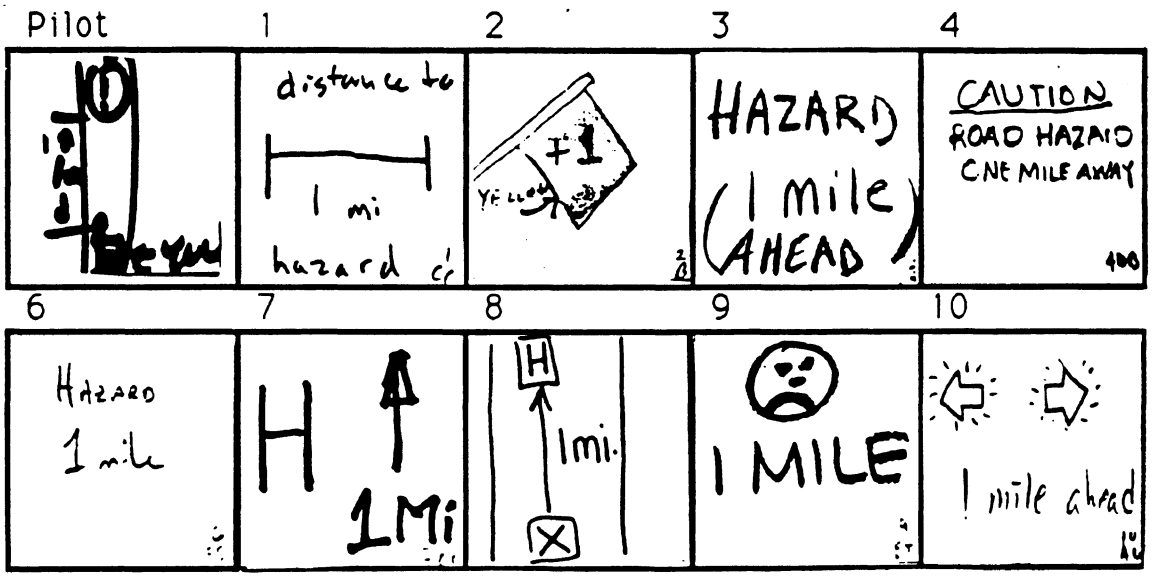


Figure 32. Participants' drawings for hazard 1 mile ahead.

The last question of the study addressed how to show the location and or motion of the hazard (see figure 33). The 10 drawings collected for this question highlighted the basic problem of directional conception, and emphasized that further testing was needed. Three people drew lone arrows: two of the arrows pointed in the direction of travel of the police car, and one pointed in the direction the driver would have to look

to see the approaching police car. (In other words, the arrows pointed in opposite directions.) Two other drawings contained both a police car and an arrow, the arrow indicating the police car's vector. One subject drew an intersection diagram indicating the relative locations of the driver's vehicle and of the police car, with the direction inherent in the vehicle icons.

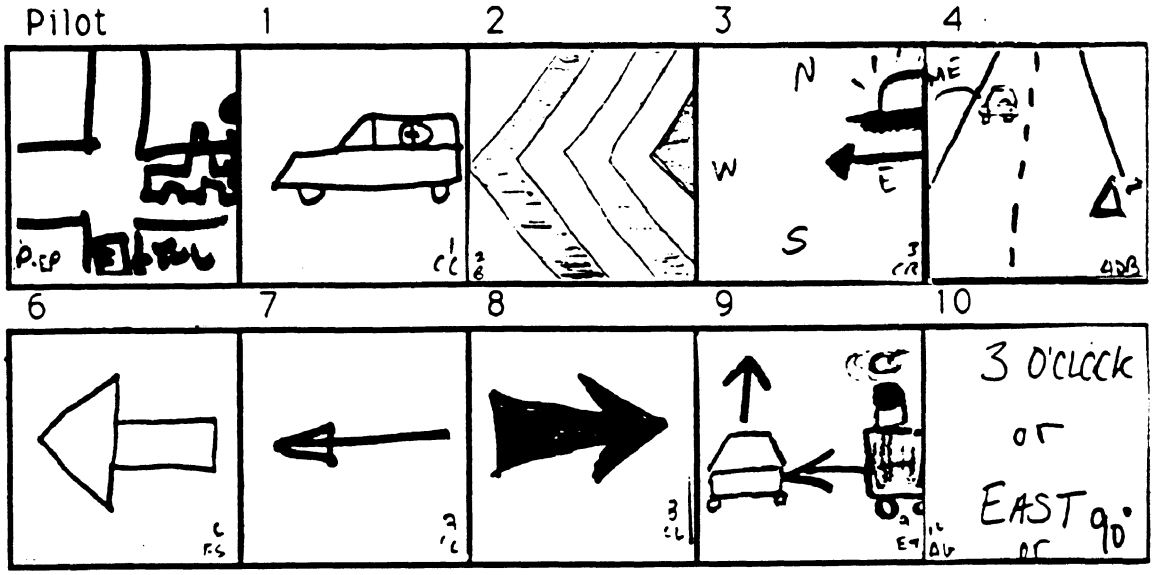


Figure 33. Participants' drawings for second icon indicating emergency vehicle's direction of approach.

Conclusions from Population Stereotype Method Study

There was a wide variety of responses, even for hazards for which there is a commonly used highway sign. For instance, for the road construction hazard, only three people drew a highway worker similar to one in the standard sign, including one who drew the worker with a jackhammer instead of a shovel. Similarly, for the railroad crossing hazard, only three people drew the indicative R's inside of the large X. Those who drew the RXR were a different set of people from those who drew the highway worker for construction.

While the population stereotype method was used on a limited number of participants here, it provided a quick way of discovering the some ideas people had for various symbols. As a result, many useful ideas generated here will be refined and expanded for use in the next study (part 2).

PART 2: IVSAWS TESTING AT DRIVER LICENSING OFFICE

Purpose

The purpose this experiment was to determine preferences for specific pictorial warnings from a varied population of drivers.

Method

The experimenters generated from three to nine candidate symbols for each hazard, based on the previous population stereotype method study and other sources. These symbol candidates were refined and then tested in a ranking preference study at the local driver licensing office. These were grouped and examined in three surveys: in-vehicle signs, slow moving and special vehicles, and emergency vehicles.

Test Participants

Experimenters recruited 3 sets of 25 drivers (42 men and 33 women) waiting in line at the local secretary of state (driver licensing) office in Pittsfield Township, MI. The drivers ranged in age from 17 to 81 years, with a mean age of 30.2. The 4 drivers over 55 years old were 59, 60, 67, and 81 years of age. Educational level was distributed as shown in table 4. Drivers were native English speakers, with the exception of four who spoke either Korean, Urdu, Malayan, or Sicilian, and four native speakers of Chinese. Two drivers owned cars with head-up displays (HUDs); six had driven a car with a HUD.

Table 4. Highest education level of subjects.

Education Level	some HS	HS degree	some trade/tech	trade/tech certificate	some college	college degree	some grad school	grad school degree	missing	
# subjects	3	8	3	2	28	6	7	8	1	75
% subjects	4%	11%	4%	3%	37%	21%	8%	11%	1%	100%

Test Materials and Equipment

Symbols were developed from the ideas gathered in the population stereotype method study described previously. Ideas were selected for further evaluation based on the number of respondents drawing the same basic idea, and on how easily the experimenters could understand the idea.

Also included in the set were existing highway signs, such as "sharp curve" and "construction," and modifications of existing signs, such as some of the "merge left" warnings, and the simplified "tractor" warning. The experimenters also referred to Easterby, Cox, and Hughes (1977) for ideas.[12]

Each warning had at least one text candidate that was either from a highway sign or written by the experimenters. Most warnings had two or three all-text candidates. The text message used the fewest words that the experimenters felt clearly conveyed the meaning. A common text variation was the basic description with and without the word "ahead." Text height ranged from 4 mm to 7 mm, depending on how the words fit in the display box.

Ideas for candidate symbols were hand drawn in a project team meeting, redrawn in MacDraw, and discussed in a second meeting. New symbol ideas and modifications emerged and were drawn. Since the symbols had to coexist as sets and subsets, the experimenters tried to make certain that, for each symbol, parallel candidates existed for ranking purposes. For example, within the subset of emergency vehicles there is a candidate version of each vehicle type in outline, in solid, in side view, and in front view. For the subset of the mail truck and trash truck, there is a version of each from side view, rear view while driving on the edge of the road, and rear view with an icon representing the vehicle's purpose (e.g., mailbox).

Due to time-per-participant constraints (participants were available for about 10 minutes each), the experiment was divided into three parts. The number of parts was determined by having a pilot subject rank the candidates for all 26 hazards and complete 5 extra questions. (This took 27 minutes total, or 55 seconds per hazard.)

The logical sections in which to divide the study were in-car signing (12 sets of rankings), atypical vehicles (9 sets of rankings), and emergency vehicles (7 sets of rankings). For the complete forms used, see appendix B. Twenty-five participants saw each part. Each part had instructions, an example, and sets of candidates for each symbol for ranking.

The candidates for each symbol were randomly arranged in a circle to reduce any location biases, with boxes next to each symbol for filling in the rank order. An example ranking form is presented in figure 34. Each candidate symbol was presented in a 36 mm box.

1. An ambulance is approaching you at high speed with its flashers on.

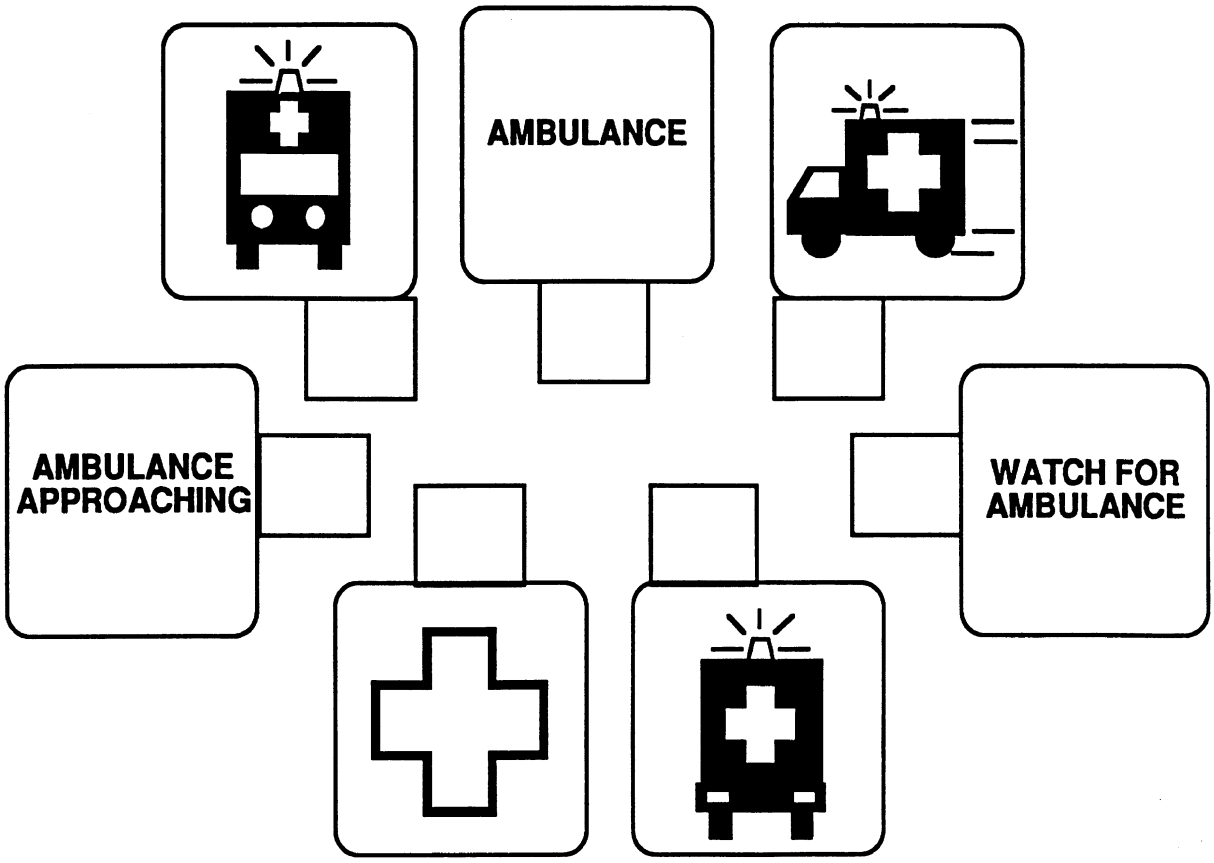


Figure 34. Example ranking form question.

Other materials included a biographical form requesting information, such as age, education, type of car driven, experience with advanced displays, etc. A copy of the biographical form is in appendix C. To help the participants visualize the operation of IVSAWS, they were shown a photograph of a person driving a car, modified to show a generic example of the system. Figure 35 is a black and white copy of the photo used.

Figure 35. Photo used at driver licensing office to help drivers understand IVSAWS.

Test Activities and Their Sequence

Upon arriving at the driver licensing office, the experimenter measured customer waiting times, to determine if there were 10 to 15 minutes for participants to complete the forms. Visits to the driver licensing office were scheduled to coincide with peak service times, usually around noon and from 3 to 5 PM.

After a person was seating and waiting for assistance, the experimenter introduced herself or himself, and explained the purpose of the study. Typically, people were willing to participate while waiting. The experimenter sat next to the subject while giving the instructions and completing the biographical form. The participant then read the instructions. An example question was provided to make sure the task was understood. Finally, the experimenter left the subject unattended to fill out the forms.

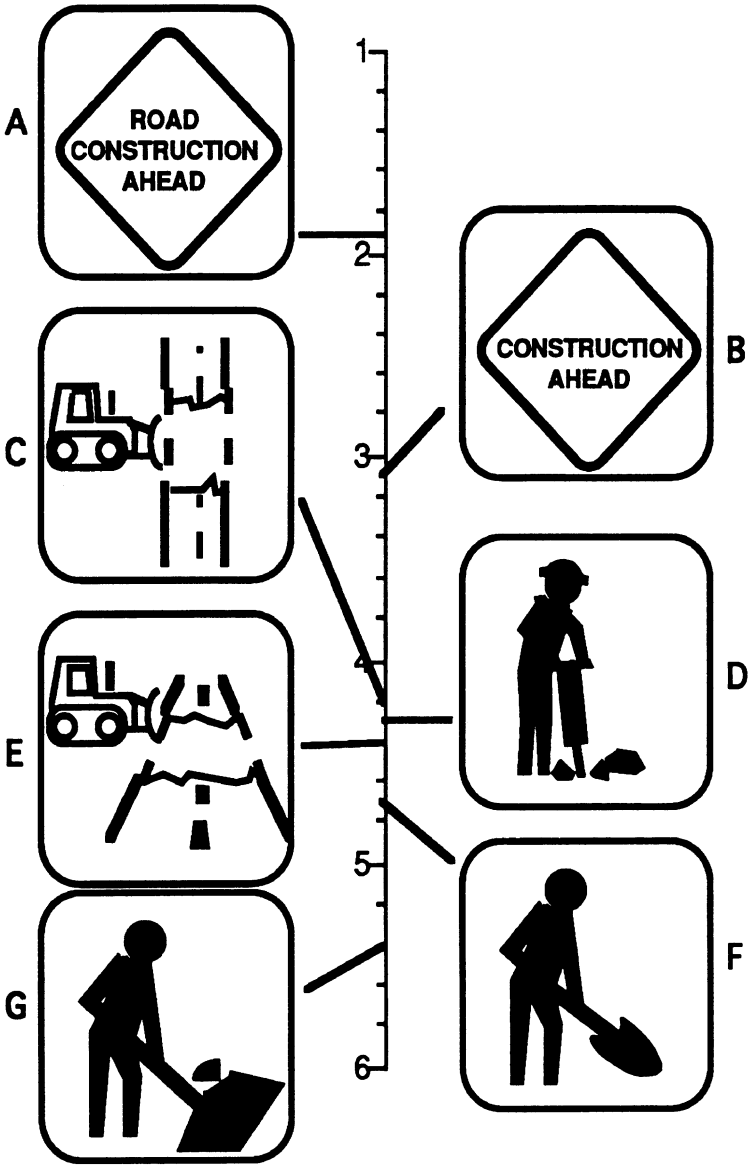
Participants ranked each set of candidate warnings from best (1) to worst (n). The experimenter then thanked them for their efforts and discretely checked the forms. In many cases participants had to modify forms that were not completed correctly. Typical errors involved ranking only the top two or three candidates for each symbol, or only using 1s and 2s for all candidates. Not all incomplete forms were caught for correction.

Results

The analysis of drivers' rankings of the warning candidates follows. Figures 36 through 63 summarize the results for parts 1, 2, and 3 (in-vehicle signs, atypical

vehicles, and emergency vehicles). For each symbol a scale is shown on which symbols are ordered from best to worst based on the mean ranking averaged over participants. A table of the ranking distribution follows each scale. For each symbol a Kruskal-Wallis (KW) test was performed and the H statistic for differences in the means is included above each table. The KW test is a non-parametric test for comparing independent groups, and is an analog to the Analysis of Variance (ANOVA).

Part 1 - In-vehicle signs



Of the three existing signs tested, the two text signs were ranked first and second, and the symbol was last. For this warning, text was always preferred over graphics, with the more detailed text message ranked highest. (The second text message "construction ahead" is more general and could also mean building construction.) Candidate "G" was ranked low partly because the work object is unclear. The modified shovel symbol, "F," ranked higher. The broken road was drawn by 3 of 10 of the subjects in the stereotype study.

In the case of text, "Road work ahead" should be considered for applicable situations, since it would be more legible.

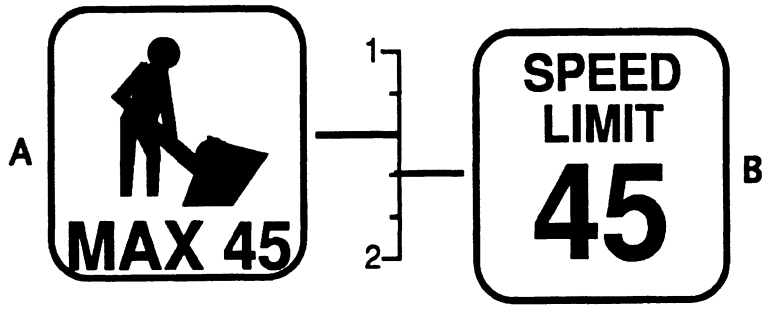
If the standard symbol of a worker is needed, a different implement should be considered.

Figure 36. Symbol 1: Approaching an area where there is road construction.

$H(6) = 49.5, p < 0.001$

	Best----------->Worst							
	1	2	3	4	5	6	7	Mean
A	16	4	1	2	1	0	1	1.9
B	3	12	1	2	4	1	2	3.1
C	1	3	8	4	2	2	5	4.2
D	0	4	6	1	9	2	3	4.3
E	2	0	5	8	1	6	3	4.4
F	2	1	1	5	6	9	1	4.7
G	1	1	3	3	2	5	10	5.4

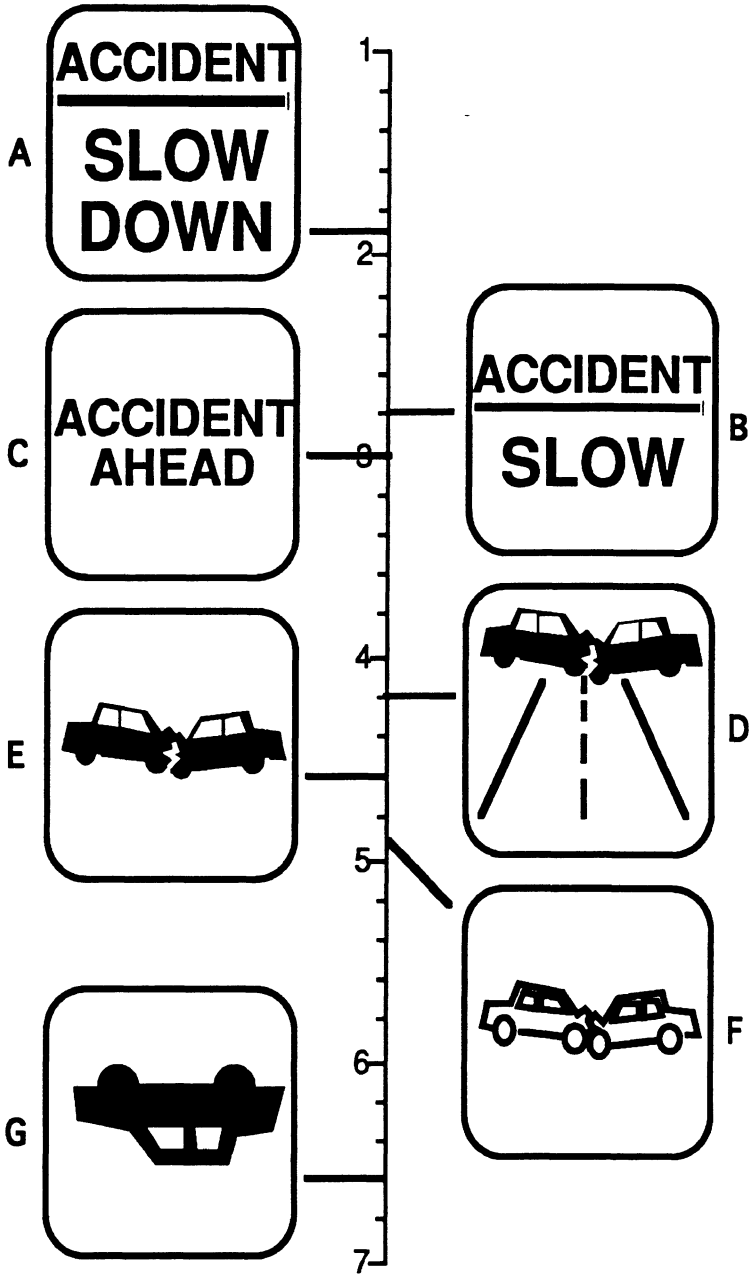
Figure 36. Symbol 1: Approaching an area where there is road construction (continued).



The combined text and graphic was preferred slightly over the standard text speed limit sign. Since the graphic used in the mixed symbol ranked lowest of all construction signs (see figure 36), it is possible another higher ranking graphic may have been more significantly preferred.

	Best---> Worst		
	1	2	Mean
A	14	11	1.4
B	11	14	1.6

Figure 37. Symbol 2: Approaching construction where the speed limit is a maximum of 45 miles per hour.

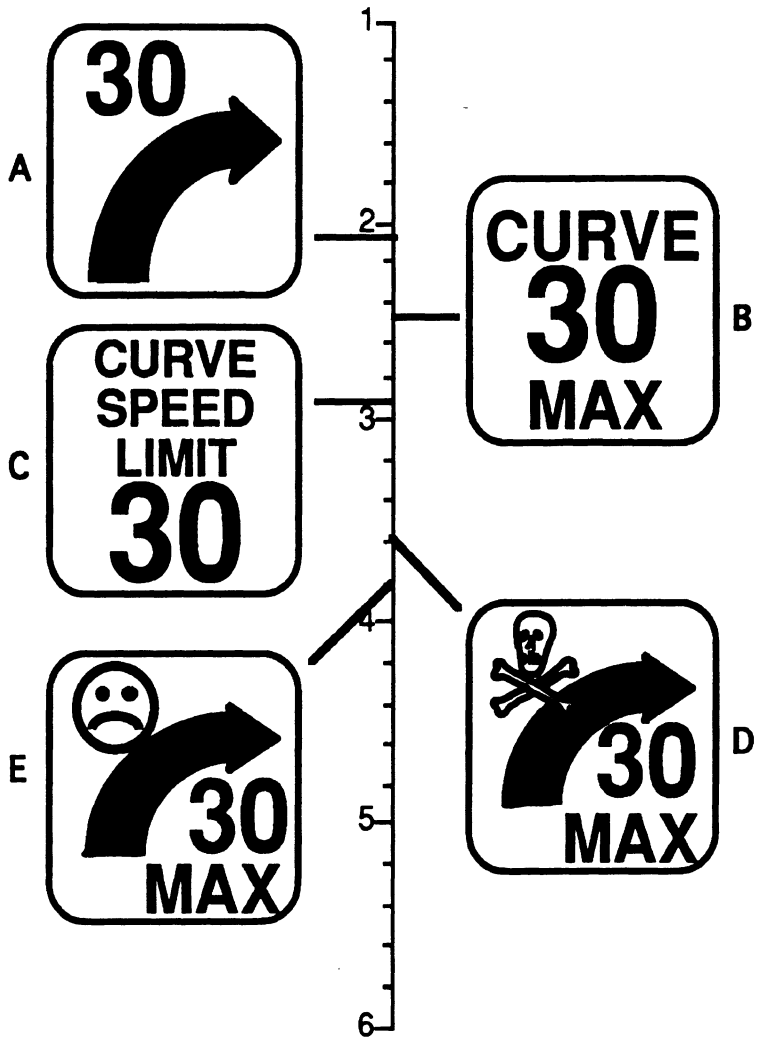


The choice of an appropriate warning for this hazard is an example of command-error problem. Should the message say what is wrong (the error), what to do (the command), or both? Drivers preferred the message that showed both. Further, there was a clear overall preference for text over symbols. The collided cars were drawn by 4 of 10 of the stereotype subjects. The upside-down car was drawn by 2 of 10 subjects, but ranked well at the bottom.

$H(6) = 93.4$, $p < 0.001$

	Best----------->Worst							
	1	2	3	4	5	6	7	Mean
A	14	4	5	1	0	1	0	1.9
B	2	13	3	3	3	0	1	2.8
C	6	6	6	2	1	3	1	3.0
D	1	1	5	8	5	4	1	4.2
E	1	1	3	6	8	4	2	4.6
F	1	0	2	5	8	8	1	4.9
G	0	0	1	0	0	5	19	6.6

Figure 38. Symbol 3: There is an accident ahead of you.



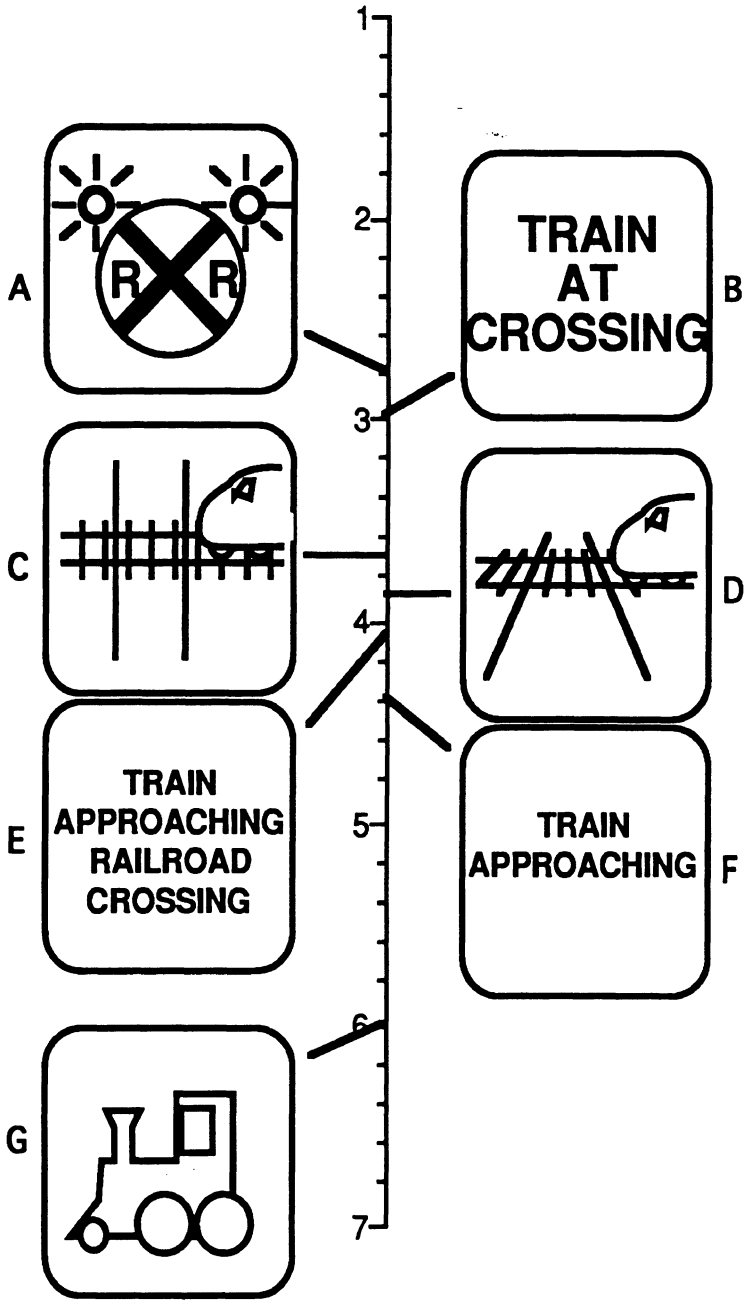
In this case, drivers wanted the simplest sign.

For use in further studies, a version that combines "A" and "B" could be used. The word "max" should be added to A beneath the curve.

$H(4) = 27.3$, $p < 0.001$

	Best----------->Worst					
	1	2	3	4	5	Mean
A	12	3	8	0	2	2.1
B	3	12	5	4	1	2.5
C	5	4	8	4	4	2.9
D	4	3	2	5	11	3.6
E	1	3	2	12	7	3.8

Figure 39. Symbol 4: There is a sharp curve ahead of you.



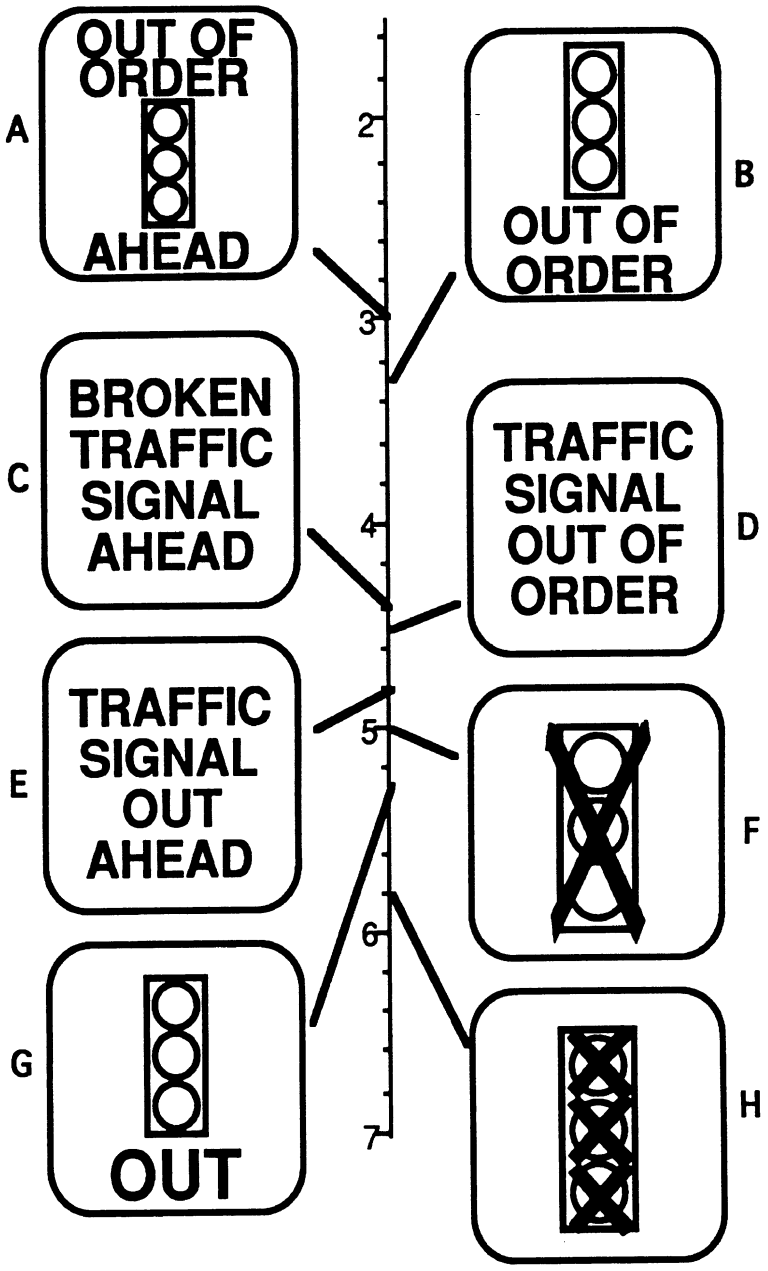
The top ranked symbol is similar to that in the MUTCD (Manual of Uniform Traffic Control Devices) sign set. The road with tracks and a train about to cross the intersection was drawn in some form by 6 of 10 subjects in the population stereotype method study. The RXR symbol was drawn by 3 of 10 subjects.

At crossings, drivers are likely to stop when a train is completely blocking the tracks; they are more likely to fail to stop when the train is not in sight. In the situation presented in "C" and "D," it is not the approaching train directly causing the driver to stop so much as the flashing lights and gate. Candidate "A" adds the warning sign missing from rural crossings.

$H(6) = 40.9, p < 0.001$

	Best----------->Worst							
	1	2	3	4	5	6	7	Mean
A	10	3	2	5	2	2	1	2.8
B	3	8	6	3	4	0	1	3.0
C	2	5	3	9	2	3	1	3.7
D	1	4	7	2	6	5	0	3.9
E	7	3	1	2	1	4	7	4.1
F	1	1	6	4	7	3	3	4.4
G	1	1	0	0	3	8	12	6.0

Figure 40. Symbol 5: Ahead of you is a railroad track with a train approaching.



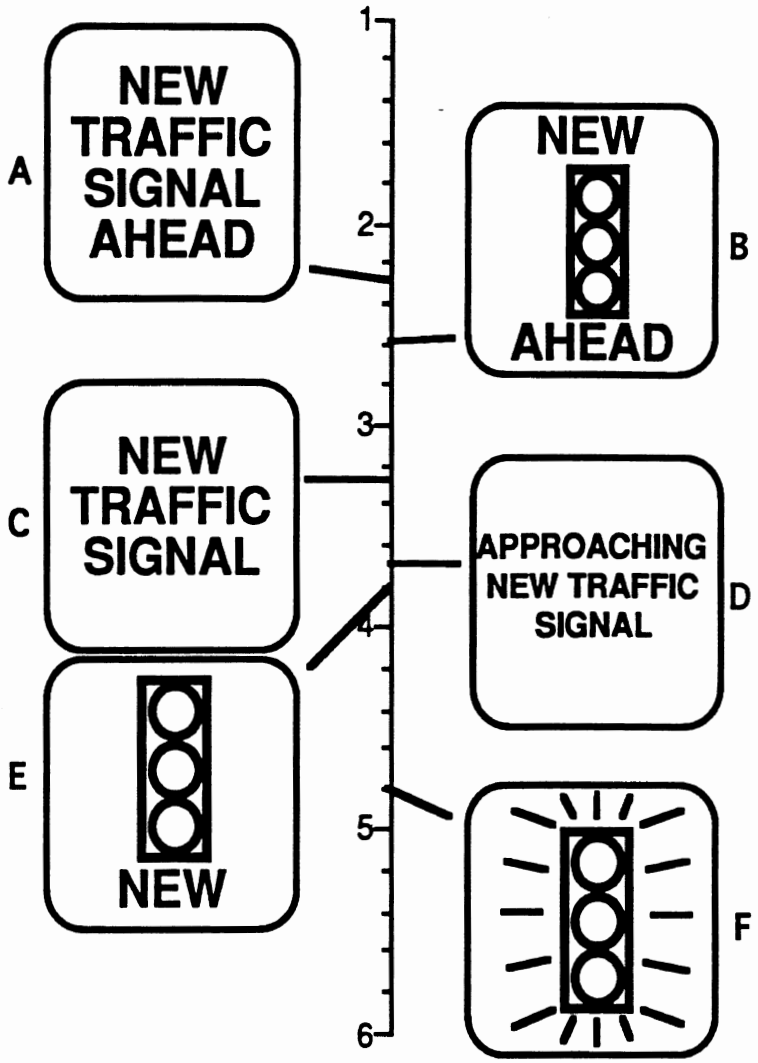
This is one of many cases where drivers preferred the word "ahead" in the message, despite the additional complexity. The outline of the light with "out of order" was drawn by 3 of 10 subjects in the stereotype study. Although the outline of the light with an "X" (as in candidate "F") was drawn by 4 of 10 subjects in the stereotype study, it ranked near the bottom.

The placement of the text in "A" could be debated. An alternative could be to place the text in a separate sign below the graphical figure, as in the case of the standard sign for "Signal Ahead."

$H(7) = 30.8, p < 0.001$

	Best→Worst								
	1	2	3	4	5	6	7	8	Mean
A	1	11	5	5	2	1	0	0	3.0
B	8	2	3	2	8	1	1	0	3.3
C	3	1	4	5	5	3	1	3	4.4
D	4	3	2	3	2	4	6	1	4.5
E	4	1	3	4	1	5	3	4	4.8
F	2	2	6	1	1	3	7	3	5.0
G	1	2	2	3	4	6	2	5	5.3
H	2	3	0	2	2	2	5	9	5.8

Figure 41. Symbol 6: You are approaching a traffic signal that is not functioning.



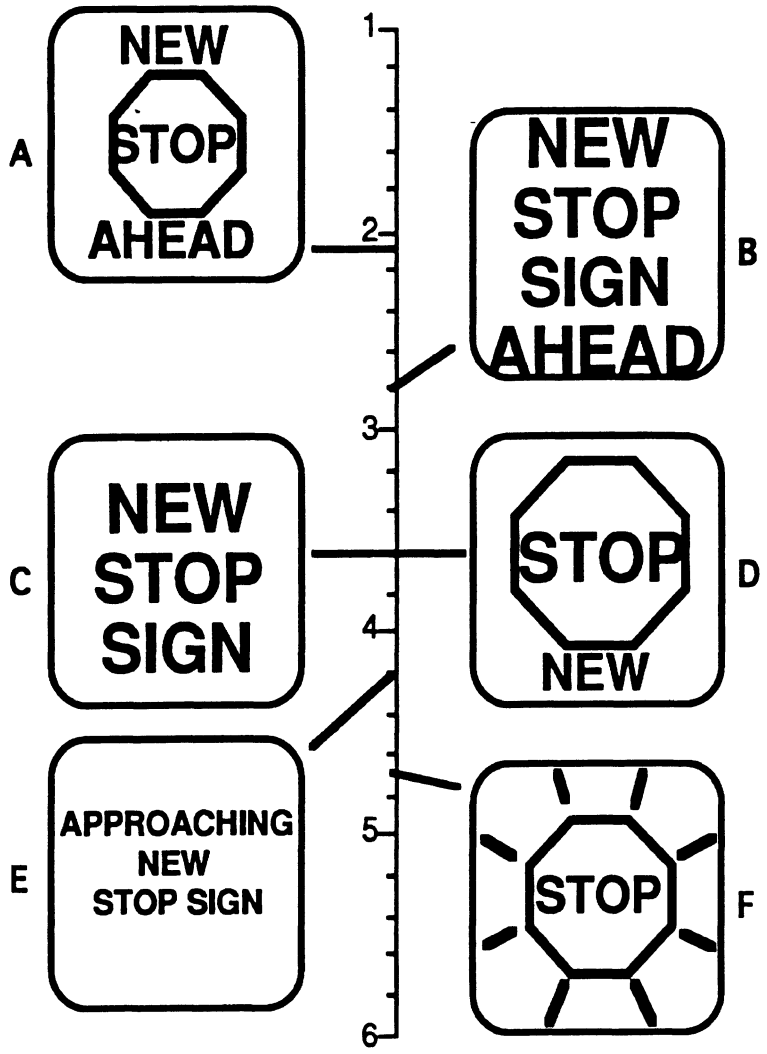
Again drivers preferred the word "ahead." The all text candidate was ranked slightly above the mixed candidate, but in the interest of consistency with the previous symbol and the next symbol, "new stop sign," the second symbol here will be selected for use.

In this set, the highest mixed text/graphics have the graphic inserted directly in place of the text equivalent. Candidate "B" (New traffic signal ahead) was preferred over "E" (Traffic signal new).

$H(5) = 35.4, p < 0.001$

	Best→Worst						
	1	2	3	4	5	6	Mean
A	8	8	3	4	2	0	2.4
B	5	7	7	4	1	1	2.7
C	2	3	10	5	4	1	3.4
D	4	4	2	5	3	7	3.8
E	3	3	1	5	12	1	3.9
F	3	0	2	2	3	15	4.9

Figure 42. Symbol 7: You are coming to a traffic signal you are not expecting because it was just installed.



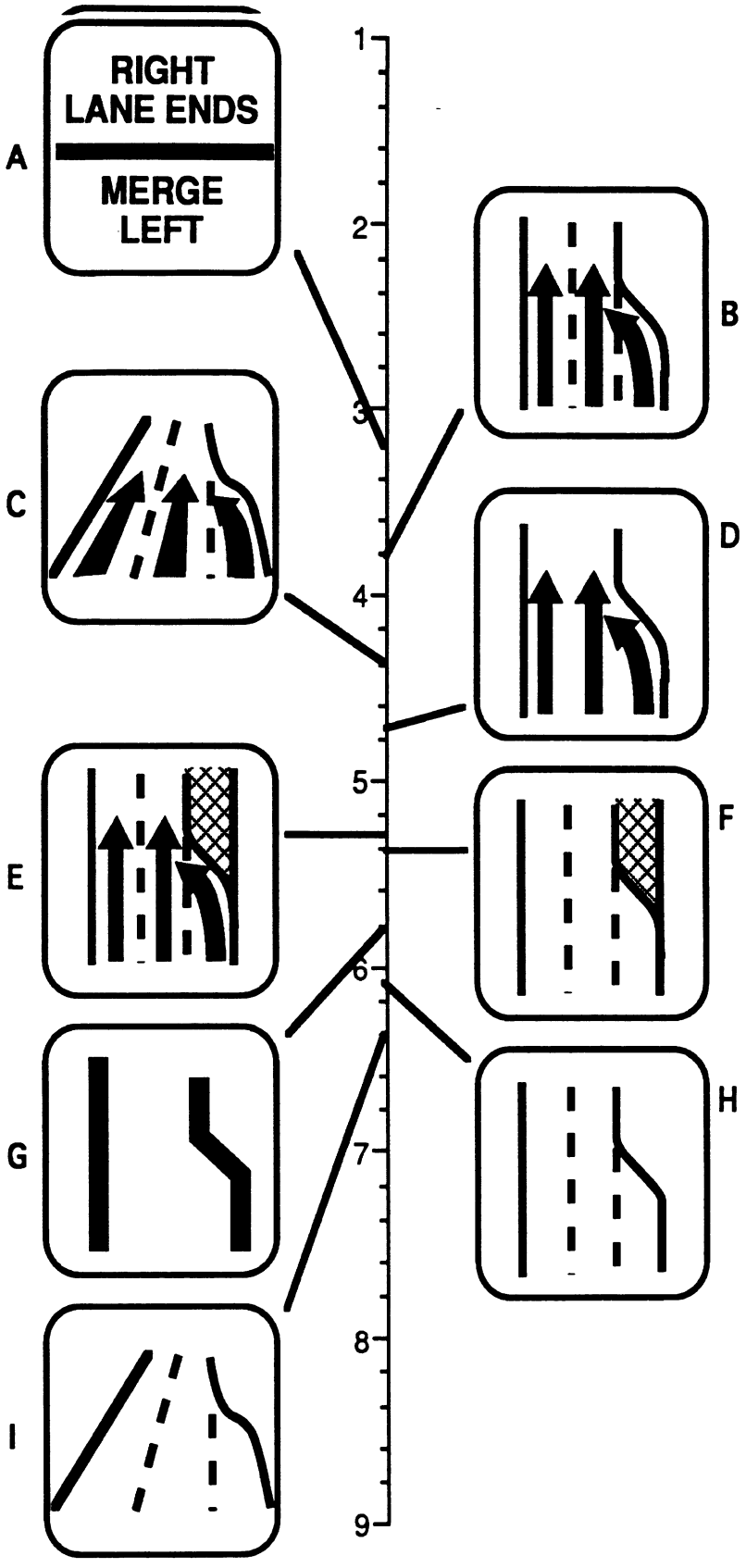
For this message drivers preferred the mixed candidate over the text only candidate, which contrasts with the traffic light version of this symbol. This may be because the graphic in this case contains text and is less ambiguous. Were the signal warning graphic in symbol 7, candidate "B," done in color, it may have been rated more like this one.

Again the word "ahead" was preferred over a larger stop sign symbol.

$H(5) = 36.6, p < 0.001$

	Best----------->Worst						
	1	2	3	4	5	6	Mean
A	10	8	2	4	1	0	2.1
B	6	6	5	4	3	1	2.8
C	1	2	10	6	6	0	3.6
D	2	6	2	5	9	1	3.6
E	2	3	4	4	3	9	4.2
F	4	0	2	2	3	14	4.7

Figure 43. Symbol 8: You are coming to a stop sign you are not expecting because it was just installed.



The all text version (both command and error) was preferred. Interesting was the preference of the lane delineations in the second ranked symbol, even though it complicates the image. The existing symbol, "G," ranked quite low. Even though six subjects thought it was the best, 11 subjects thought it was the worst. One subject commented that none of the pictures would be understandable if used without text.

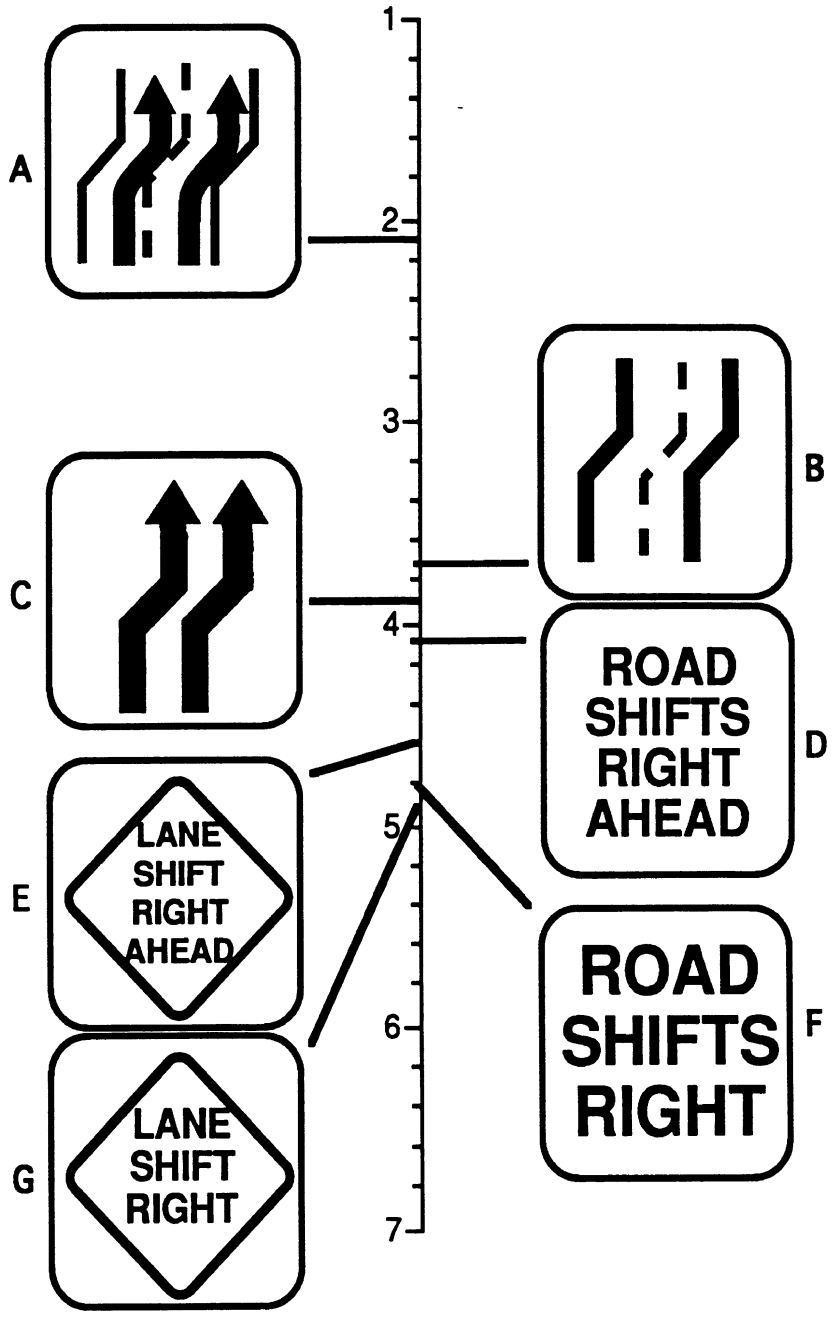
An exact duplicate of the existing merge sign graphic should also have been tested. The standard merge sign has a two-lane road narrowing to a one-lane road. The one included is identical in scale to the other experimenter-designed candidates.

Figure 44. Symbol 9: Ahead of you the right lane is going to merge into the center lane.

$H(8) = 34.9, p < 0.001$

	Best----------->Worst									
	1	2	3	4	5	6	7	8	9	Mean
A	11	3	1	3	2	1	2	1	1	3.2
B	1	6	4	5	5	4	0	0	0	3.8
C	1	3	6	3	3	6	2	1	0	4.4
D	1	3	4	3	6	1	5	2	0	4.7
E	2	3	2	5	2	1	1	5	4	5.3
F	0	3	5	0	2	7	4	3	1	5.4
G	6	2	0	1	0	3	2	0	11	5.8
H	2	0	3	2	2	1	5	7	3	6.1
I	1	2	0	3	3	1	4	6	5	6.4

Figure 44. Symbol 9: Ahead of you the right lane is going to merge into the center lane (continued).

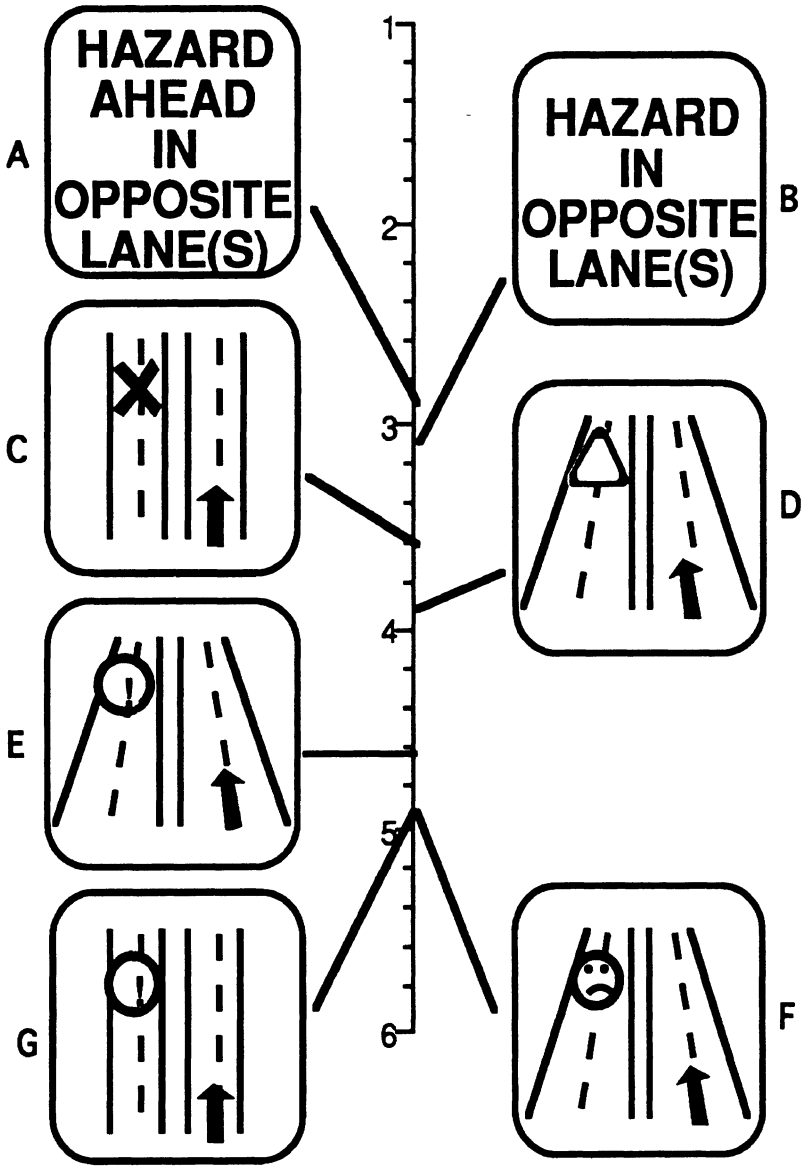


Graphic signs were preferred over text probably because drivers do not understand a "road shift" or "lane shift." The command-error combination symbol ranked highest, followed by the corresponding error (lane shift) and command (arrow) symbols alone.

$H(6) = 34.3, p < 0.001$

	Best----------->Worst							
	1	2	3	4	5	6	7	Mean
A	15	2	3	1	4	0	0	2.1
B	1	9	6	0	2	4	3	3.7
C	4	7	4	0	0	2	8	3.9
D	3	3	2	6	5	4	2	4.1
E	0	3	5	2	8	3	4	4.6
F	2	1	2	7	3	4	6	4.8
G	0	0	3	9	3	8	2	4.9

Figure 45. Symbol 10: Ahead of you both lanes will jog to the right.



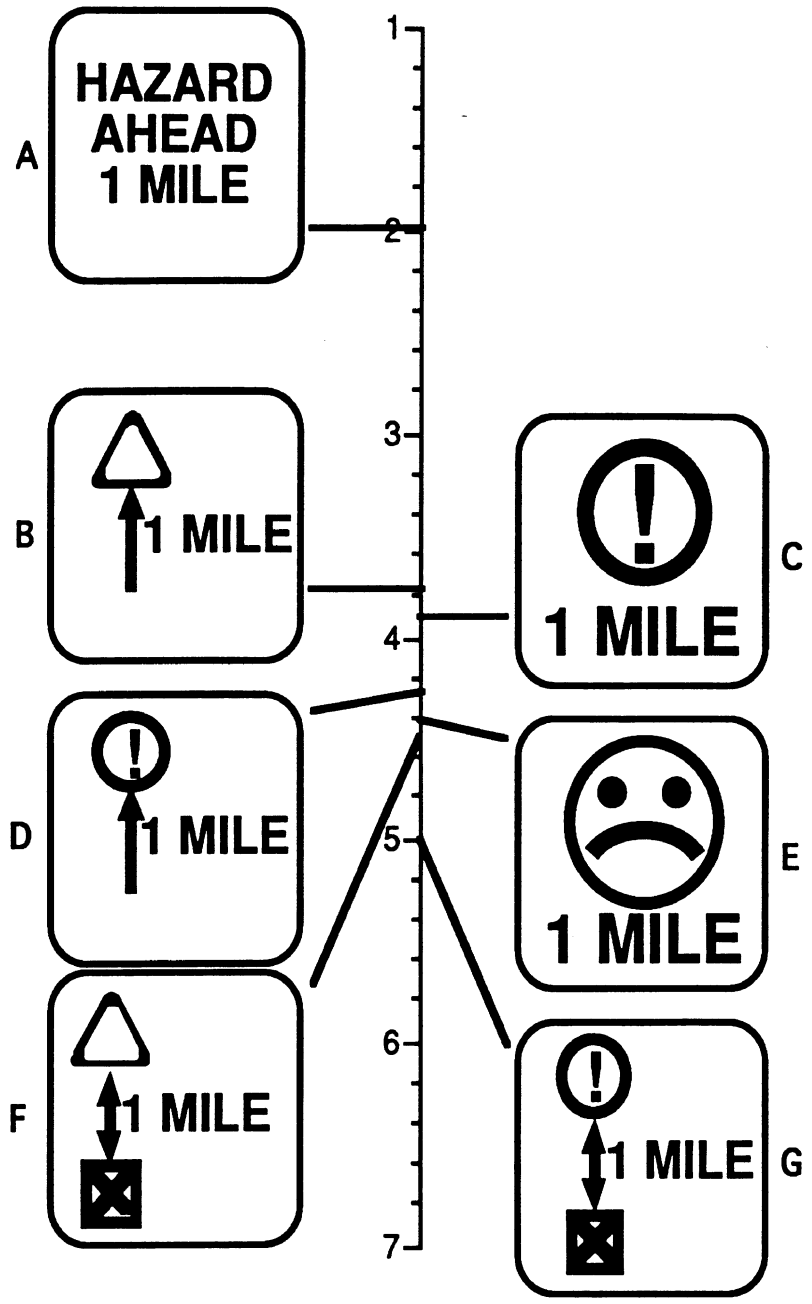
Both text signs were preferred over graphics alone, with the text containing "ahead" slightly preferred over the text without. Nine of 10 subjects, in the stereotype study, drew some kind of 4 lane highway/expressway, 8 of those drew it with some kind of icon indicating the hazard in the 2 left lanes.

The need for a symbol of this type depends upon the functionality of the final IVSAWS system. Two different signals would have to be transmitted in opposite directions to allow for presentation of this symbol. It also depends upon how much information the driver needs. It could be used as a second symbol to clarify the exact circumstances of a warning. It was included in this study for the sake of completeness.

$H(6) = 26.0, p < 0.001$

	Best----------->Worst							
	1	2	3	4	5	6	7	Mean
A	10	6	2	0	2	0	5	2.9
B	4	12	1	1	1	5	1	3.1
C	5	2	5	5	3	3	2	3.6
D	4	1	5	6	2	6	1	3.9
E	0	2	7	2	5	5	4	4.6
F	0	1	4	6	5	4	5	4.9
G	2	1	1	5	7	2	7	4.9

Figure 46. Symbol 11: There is a problem ahead of you, but it is only in the traffic lanes going the other way.



Text only was overwhelmingly preferred for the hazard distance symbol. Only 3 of 10 subjects in the stereotype study indicated text only, while 6 of 10 drew a graphic-with-text sign.

The use of this symbol depends on the functionality of the final IVSAWS system. The system would have to be capable of determining distance either as an inherent capability of the radio receiver, or, in the case of an accident, if the beacon was placed a measured distance before the scene.

This symbol was included for completeness since the functionality of the system had not yet been determined.

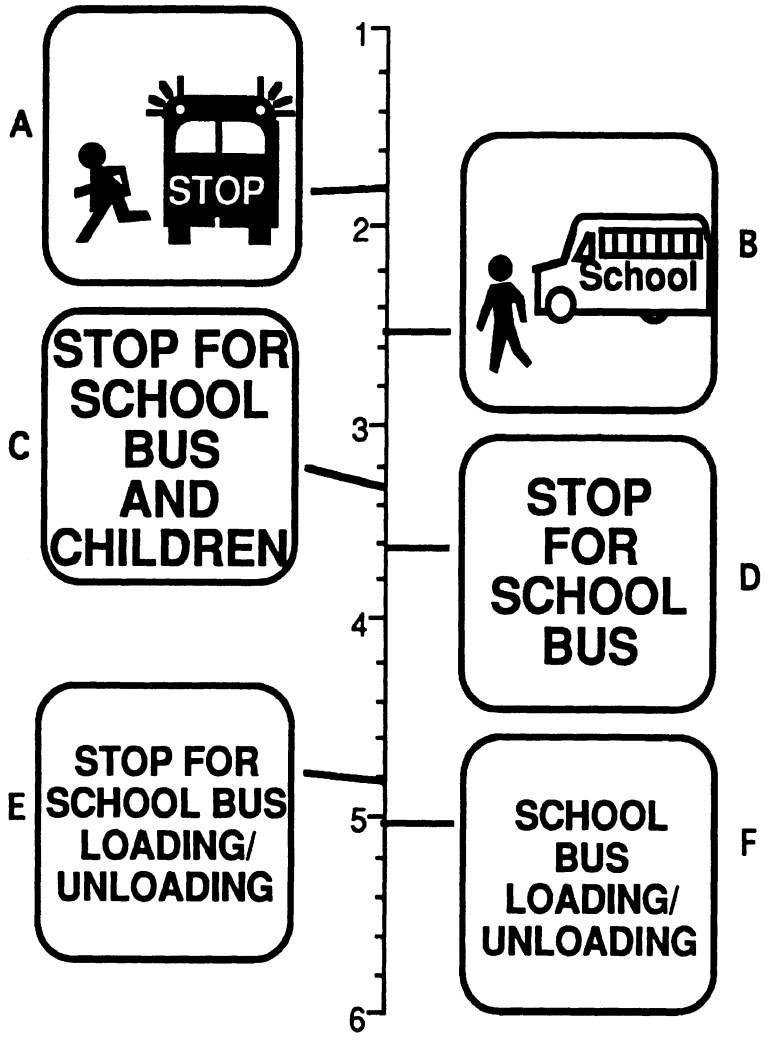
$H(6) = 34.7, p < 0.001$

	Best----------->Worst							
	1	2	3	4	5	6	7	Mean
A	17	3	1	0	2	0	2	2.0
B	2	6	3	5	4	3	2	3.8
C	1	5	5	5	2	7	0	3.9
D	0	4	6	3	5	5	2	4.3
E	3	6	2	1	1	1	11	4.5
F	1	1	4	6	6	5	2	4.5
G	1	0	4	5	5	4	6	5.0

Figure 47. Symbol 12: There is a problem on the road ahead exactly 1 mile away.

Part 2 - Atypical Vehicles

Figures 48 through 56 present the preference results for atypical vehicle warnings.

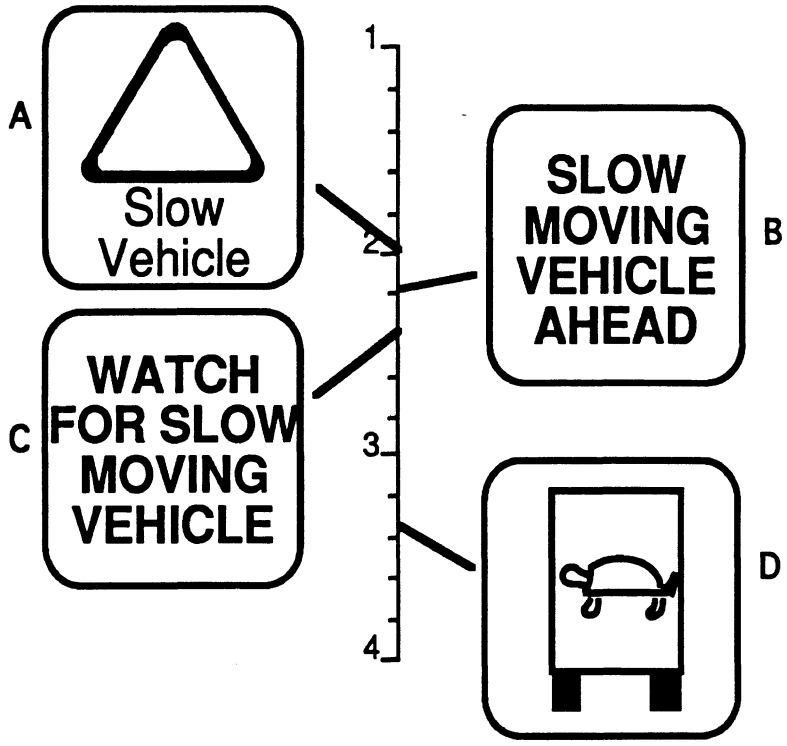


Graphics were preferred over text, which matches the results of the population stereotype method study. Four of 10 people drew a bus from the rear, and 5 of 10 drew a bus from the side.

$H(5) = 70.4, p < 0.001$

	Best ----------->Worst						
	1	2	3	4	5	6	Mean
A	18	2	2	1	0	2	1.8
B	3	16	1	1	4	0	2.5
C	1	4	9	9	1	1	3.3
D	1	2	10	9	0	3	3.6
E	2	0	3	1	8	11	4.8
F	0	1	0	4	12	8	5.0

Figure 48. Symbol 13: Ahead of you children are boarding or unboarding from a school bus.



The differences among the top three candidates are not significant, but the top two will probably be chosen as best graphic and best text, since the second ranked text is simpler than the third.

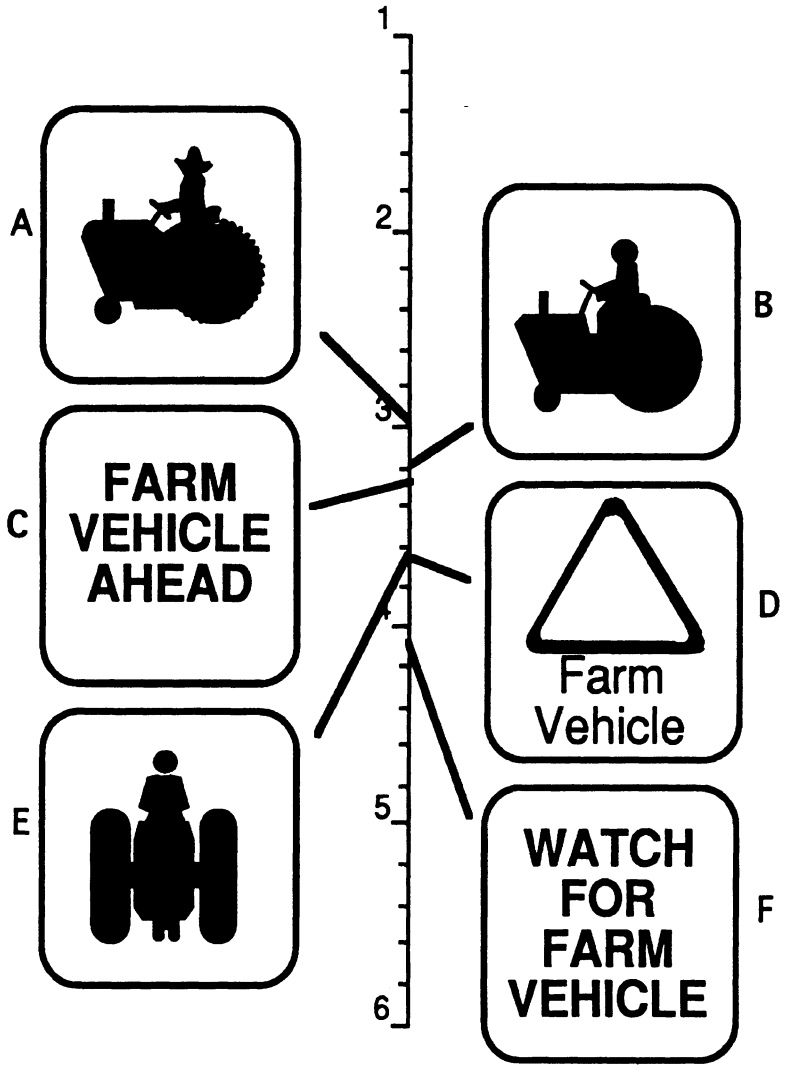
If a large percentage of slow vehicles are known to have the hazard triangle on the back, the matching symbol on the IVSAWS display would provide reinforcement for the warning.

A symbol containing a turtle was drawn by 3 of 10 subjects in the stereotype study; however, this symbol was ranked lowest.

$H(3) = 24.9, p < 0.001$

	Best-------->Worst				
	1	2	3	4	Mean
A	11	3	11	0	2.0
B	7	8	9	1	2.2
C	4	12	4	5	2.4
D	3	2	1	19	3.4

Figure 49. Symbol 14: You are approaching a slow moving vehicle.

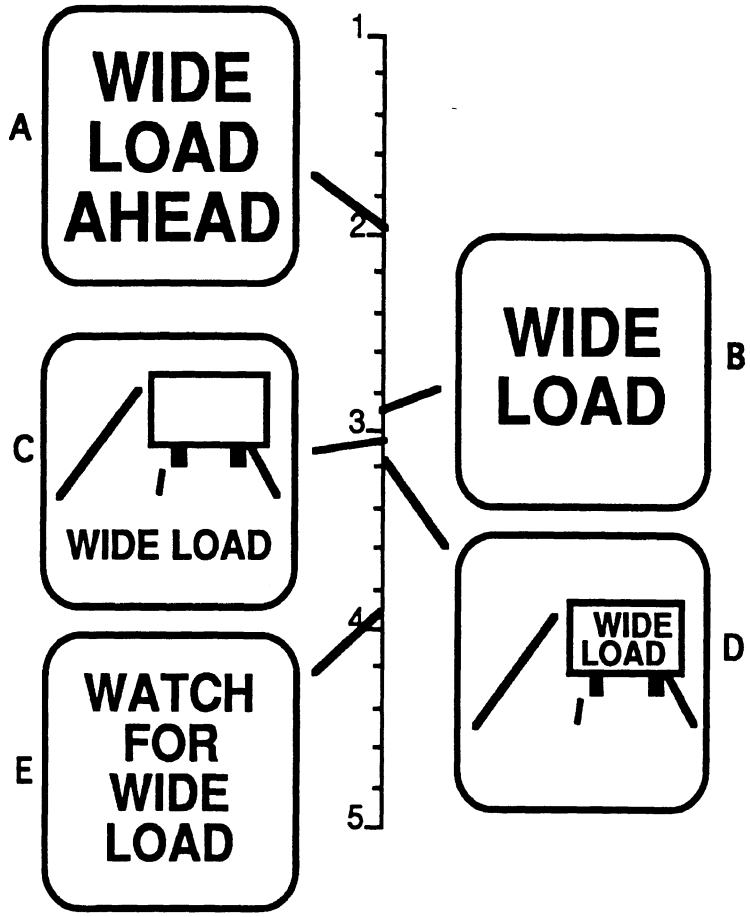


The top ranked candidate is the currently used symbol. It ranked insignificantly higher than the simplified version of the tractor. The text version "C" was probably helped by its close match with the written description.

H(5) = 6.6, p = 0.251

	Best----------->Worst						
	1	2	3	4	5	6	Mean
A	8	5	2	3	2	5	3.0
B	3	7	6	2	6	1	3.2
C	6	4	2	3	9	1	3.3
D	5	2	3	6	3	6	3.7
E	2	4	5	7	3	4	3.7
F	1	3	7	4	2	8	4.1

Figure 50. Symbol 15: You are approaching a farm vehicle.



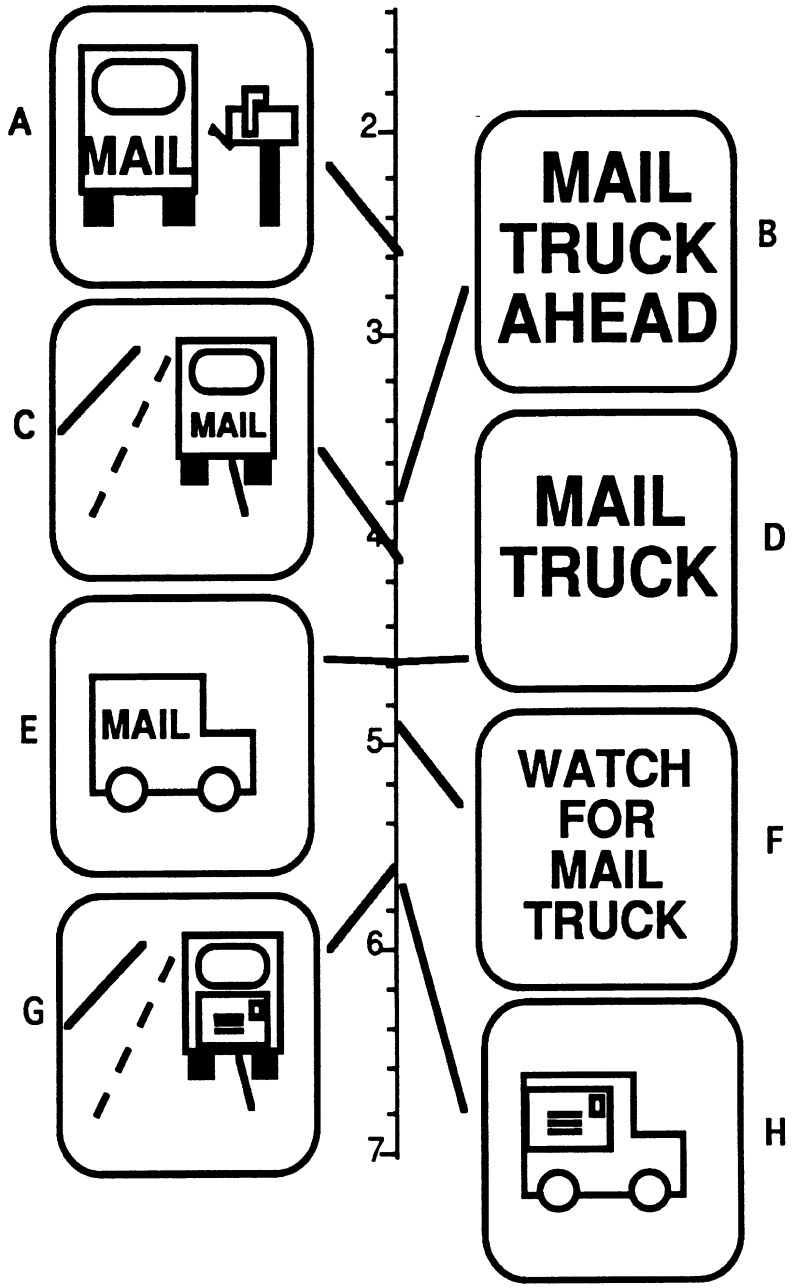
Text was preferred here, as was the globally preferred addition of the word "ahead."

The experimenters should have included a candidate version of the hazard triangle with the words "wide load." This warning belongs in the set with "Slow moving vehicle" and "Farm vehicle." More consideration should have been given to consistency.

$H(4) = 24.5, p < 0.001$

	Best----------->Worst					
	1	2	3	4	5	Mean
A	14	2	5	4	0	2.0
B	2	9	8	2	4	2.9
C	6	4	3	6	6	3.1
D	3	7	2	9	4	3.2
E	0	3	7	4	11	3.9

Figure 51. Symbol 16: You are approaching a wide vehicle in the road ahead.



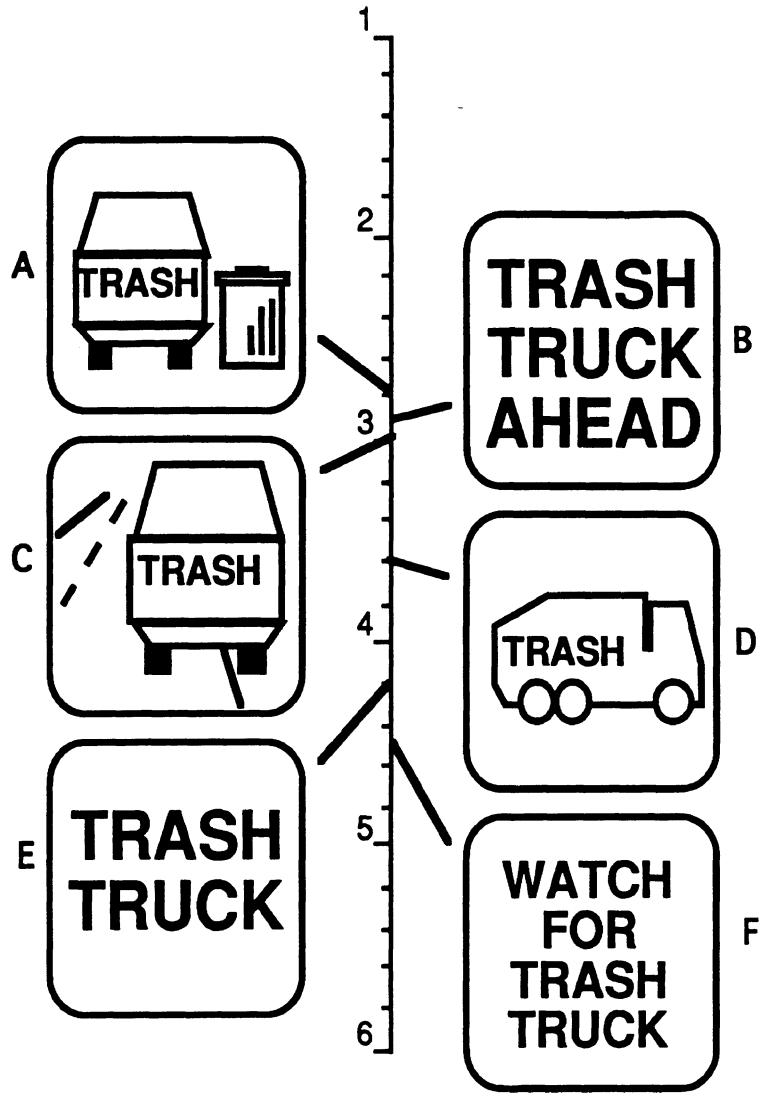
The graphic overwhelmingly preferred represents a driver's view upon approaching a stopped mail truck. Only 1 subject in the stereotype drew the rear view of a vehicle, while 6 of 10 subjects study drew a side view.

A version with aspects of "A" and "C" was considered for inclusion, but was too complicated.

$H(7) = 33.6, p < 0.001$

	Best----------->Worst								
	1	2	3	4	5	6	7	8	Mean
A	11	5	2	2	2	2	0	1	2.6
B	8	4	0	2	1	5	3	2	3.8
C	1	6	2	5	5	4	1	1	4.1
D	1	5	2	3	4	4	5	1	4.6
E	2	2	4	4	4	4	4	1	4.6
F	2	1	7	3	1	3	1	7	4.9
G	0	1	5	4	3	1	2	9	5.6
H	0	1	3	2	5	2	9	3	5.7

Figure 52. Symbol 17: You are approaching a mail delivery truck that may stop at any time.

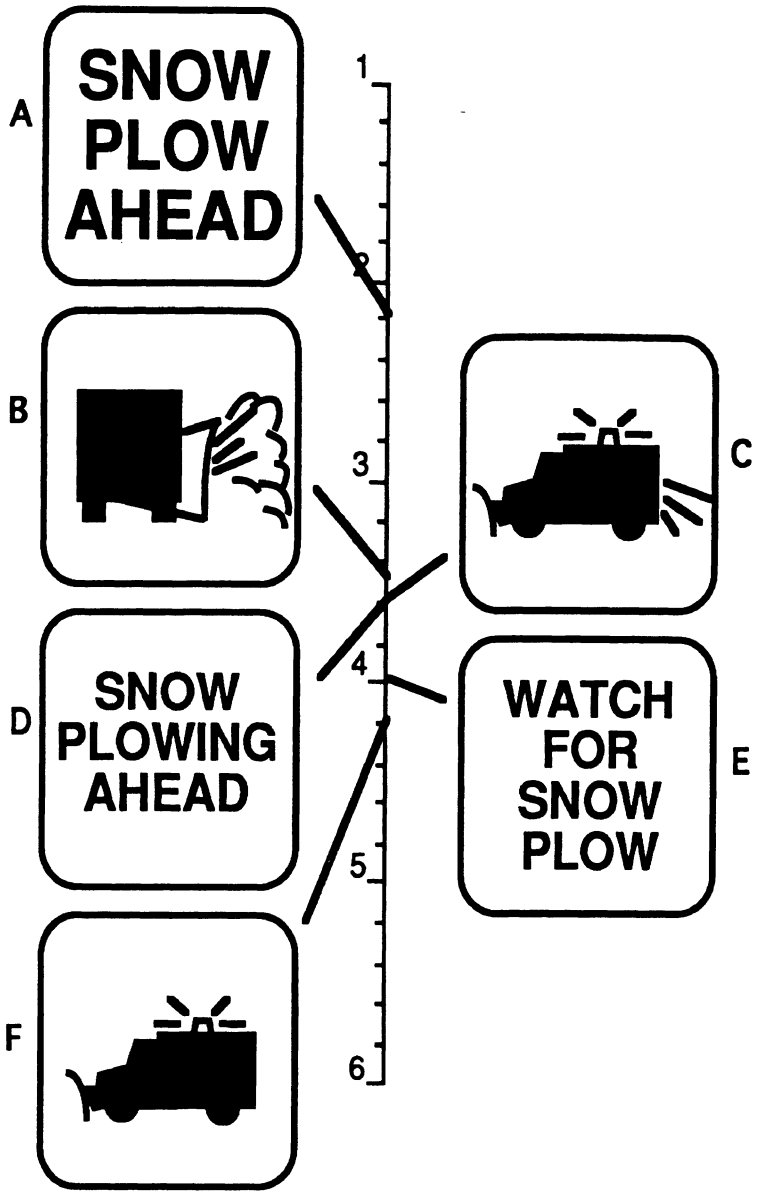


The top three preferred candidates here do not differ significantly, but in order to develop a consistent set with the mail truck, the corresponding symbol, "A," would be selected.

H(5) = 21.4, p = 0.001

	Best----------->Worst						
	1	2	3	4	5	6	Mean
A	9	3	5	3	3	2	2.8
B	8	4	2	4	7	0	2.9
C	3	7	6	5	3	1	3.0
D	3	5	6	1	4	6	3.6
E	1	3	4	6	5	6	4.2
F	1	3	2	6	3	10	4.5

Figure 53. Symbol 18: You are approaching a trash truck that may stop at any time.



The simplistic text was strongly preferred here, perhaps due in part to the difficulty of representing the plow image. Also, plows can be many different vehicle types.

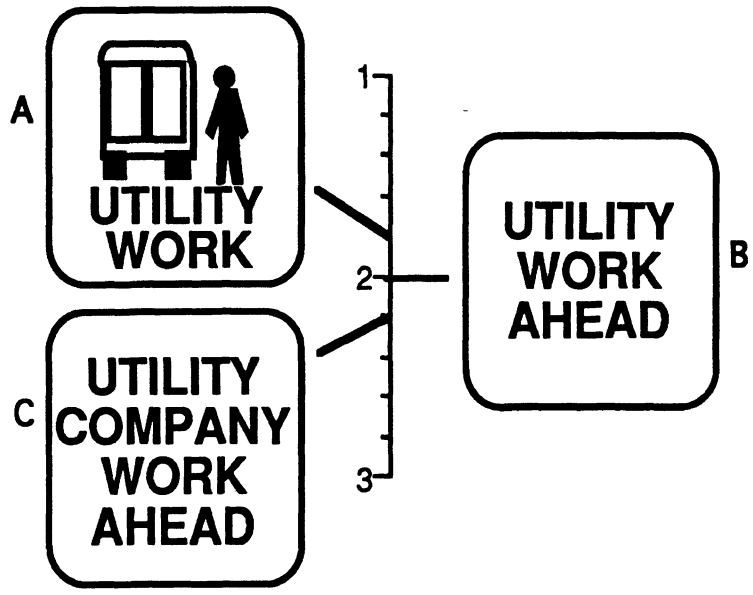
This warning is in a different class from the mail and trash truck warnings, so consistency with that subset is not necessary.

The experimenters should have included an outline version although it probably would not have had much effect since the solid vehicles ranked higher than the outline ones in the other rankings.

$H(5) = 21.4, p = 0.001$

	Best----------->Worst						
	1	2	3	4	5	6	Mean
A	12	5	1	6	1	0	2.2
B	5	2	5	5	4	4	3.5
C	4	3	5	6	1	6	3.6
D	3	5	4	3	8	2	3.6
E	0	5	8	3	1	8	4.0
F	1	5	2	2	10	5	4.2

Figure 54. Symbol 19: You are approaching a snow plow/salt truck that is plowing or salting the road ahead.



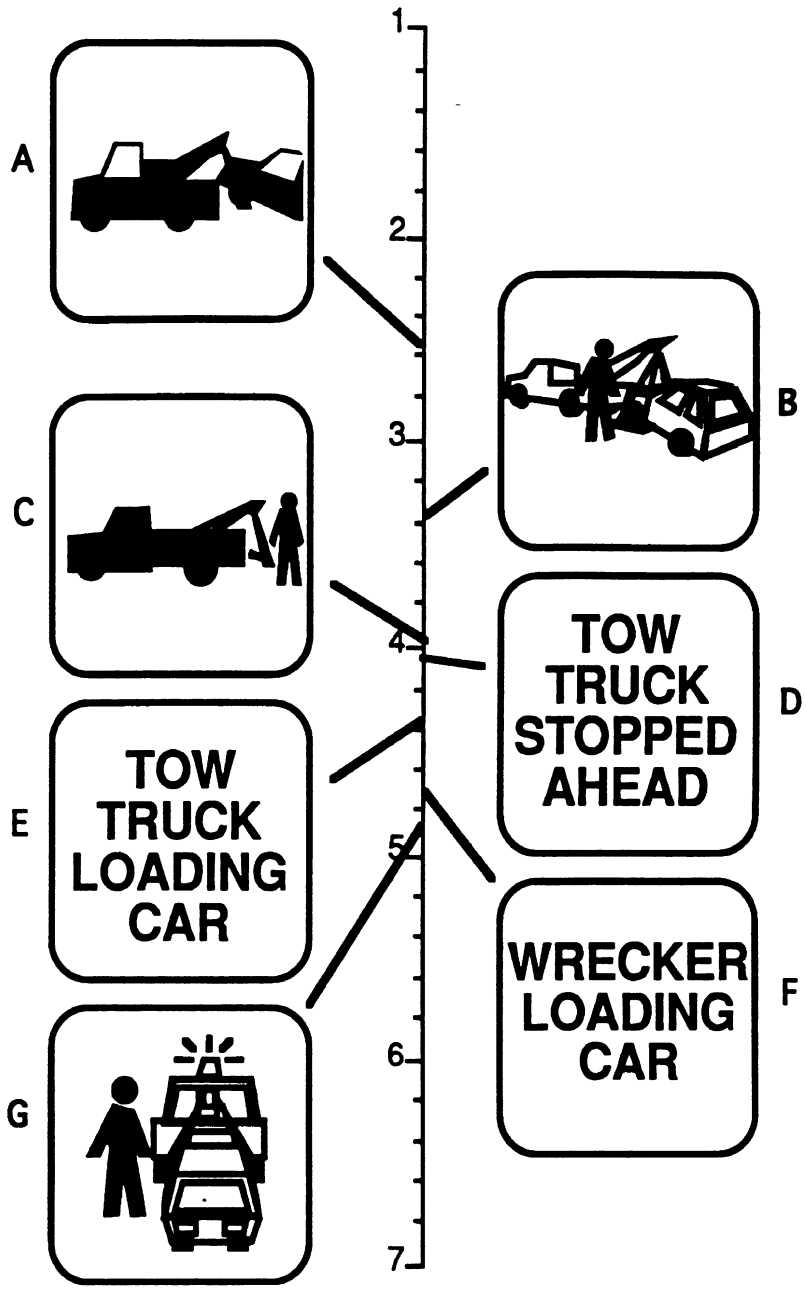
Preference ambiguity here may be partially due to the broad category represented, and to the limited number of candidates offered. The top candidate indicates the importance of the truck and vulnerable workers.

One approach to this problem of no clear preference for a general warning symbol, would be to generate specific separate symbols for each type of work (e.g. telephone or sewer and water). One risk to this is the problem of warning proliferation, which may lead to lower symbol comprehension and longer attentional demands.

$H(2) = 1.9, p = 0.388$

	Best->Worst			
	1	2	3	Mean
A	13	3	9	1.8
B	8	9	8	2.0
C	4	13	8	2.2

Figure 55. Symbol 20: Ahead of you a utility company (gas, electric, cable, etc.) is working near the road.



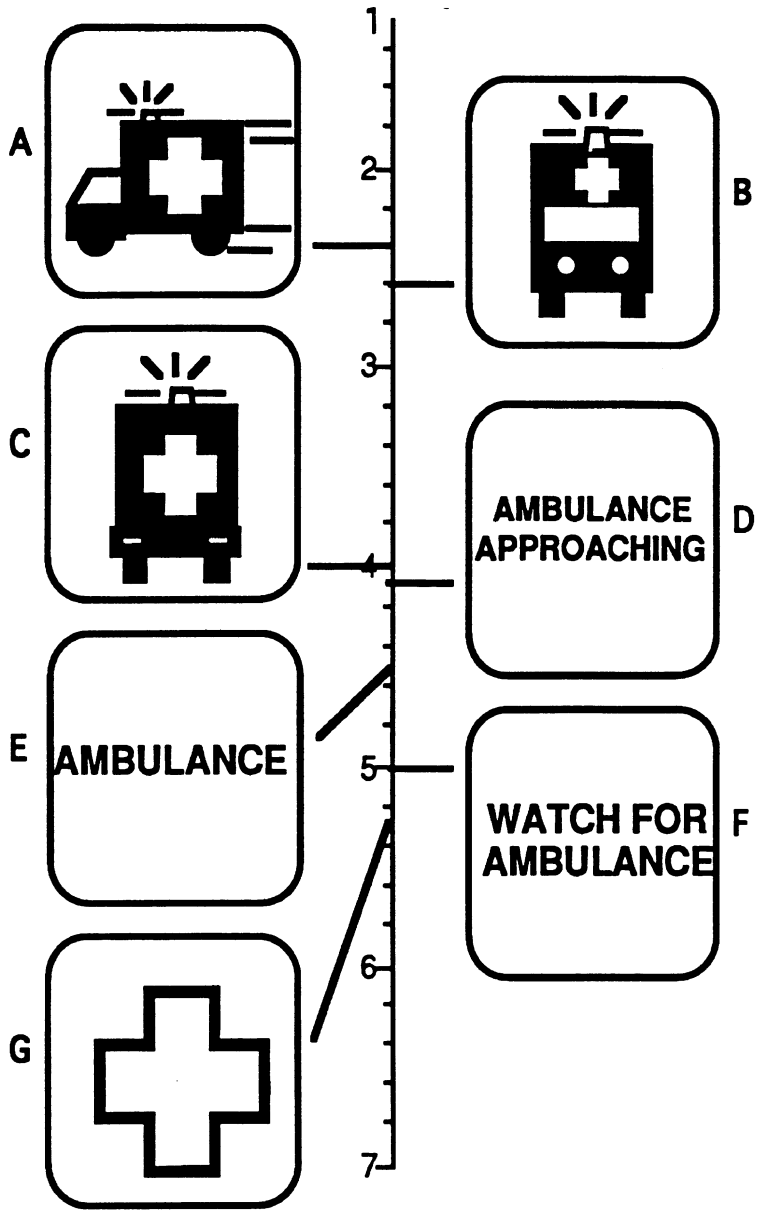
Graphics were strongly preferred for this warning. The preference here matches the population stereotype method where 6 of 10 subjects drew something very close to the top candidate. Interestingly, candidate "B," despite being extremely complicated, ranked second.

$H(6) = 22.3, p = 0.001$

	Best→Worst							
	1	2	3	4	5	6	7	Mean
A	8	9	2	1	2	1	2	2.6
B	6	4	4	3	3	3	2	3.4
C	2	3	4	8	3	3	2	4.0
D	4	4	2	5	1	4	5	4.1
E	3	2	4	3	4	5	4	4.4
F	2	2	2	1	10	5	3	4.7
G	0	1	7	4	2	4	7	4.9

Figure 56. Symbol 21: Ahead of you a tow truck is on the side of the road hooking up a disabled car.

Part 3 - Emergency Vehicles



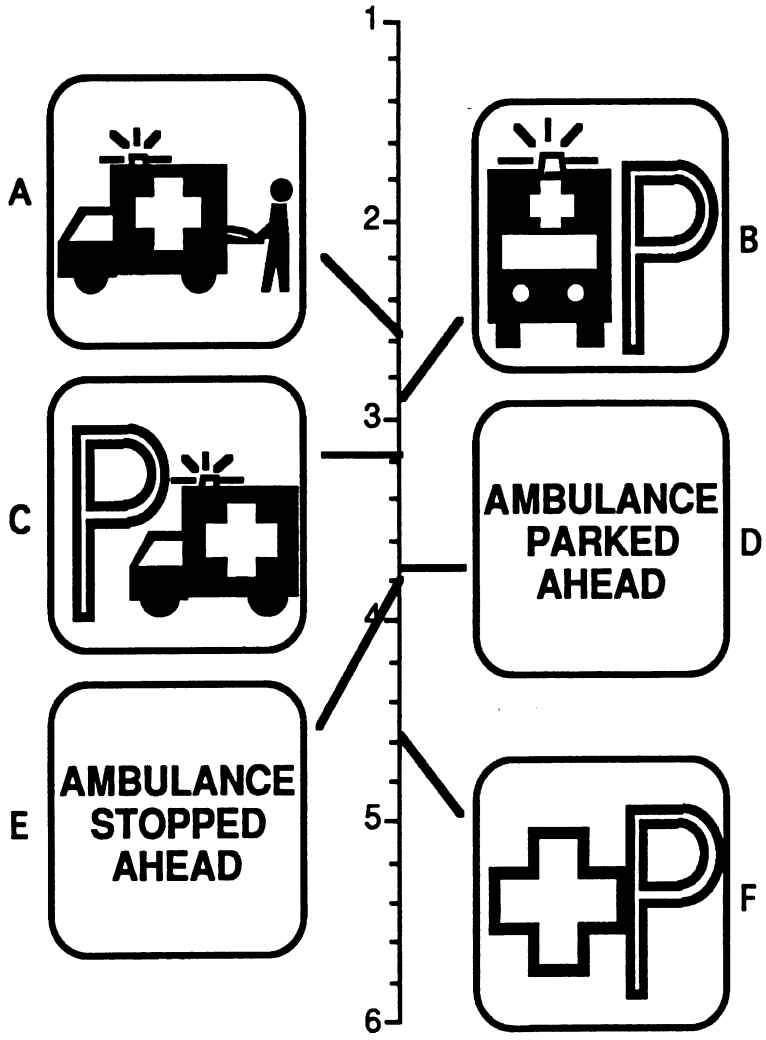
The issue of subset consistency is important for the emergency vehicles. The method of representing moving versus parked vehicles needs to be the same for all emergency vehicles. Graphics were preferred for all symbols here.

There was debate over the order of these symbols. Proper selection required that participants understand that they would have to distinguish between moving and parked vehicles. The experimenters decided upon putting the moving ambulance first since the moving ambulance is more hazardous than the parked one. Also, since the ambulance, police, and fire truck warnings all have to be consistent, the participants will understand later emergency vehicle symbol more easily.

$H(6) = 47.0, p < 0.001$

	Best----------->Worst							
	1	2	3	4	5	6	7	Mean
A	12	3	5	1	3	0	1	2.4
B	6	9	4	2	2	2	0	2.6
C	0	6	7	3	2	3	4	4.0
D	3	3	2	5	5	6	1	4.1
E	2	2	3	3	7	5	3	4.5
F	1	1	2	5	6	4	6	5.0
G	1	1	2	6	0	5	10	5.3

Figure 57. Symbol 22: An ambulance is approaching you at high speed with its flashers on.

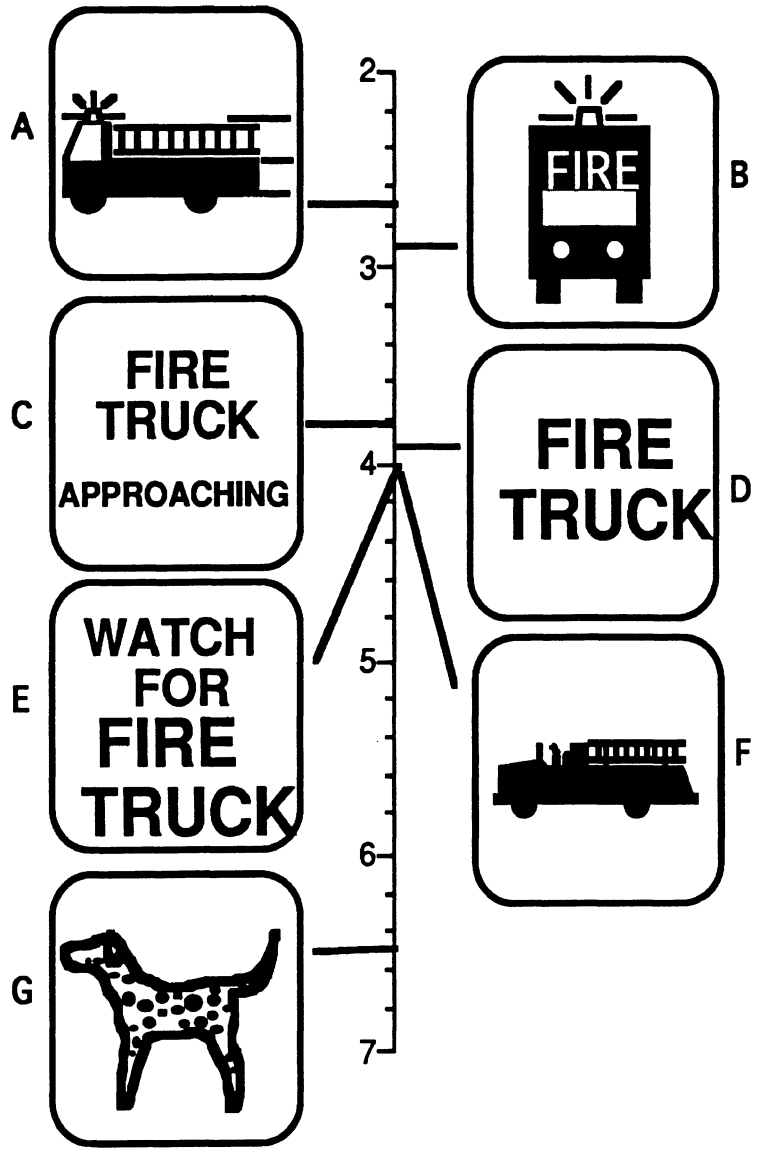


The graphic showing what this type of emergency vehicle would be doing on the side of the road, and the graphic with "P" added, were very closely preferred in this case. A "P" was drawn by only two subjects in the stereotype study.

$\underline{H}(5) = 30.0, \underline{p} = 0.001$

	Best----------->Worst						
	1	2	3	4	5	6	Mean
A	11	2	5	2	2	3	2.6
B	3	8	6	4	4	0	2.9
C	4	6	5	4	3	3	3.2
D	2	4	3	8	4	4	3.8
E	3	5	2	3	7	5	3.8
F	2	0	4	4	5	10	4.6

Figure 58. Symbol 23: An ambulance is by the side of the road ahead.



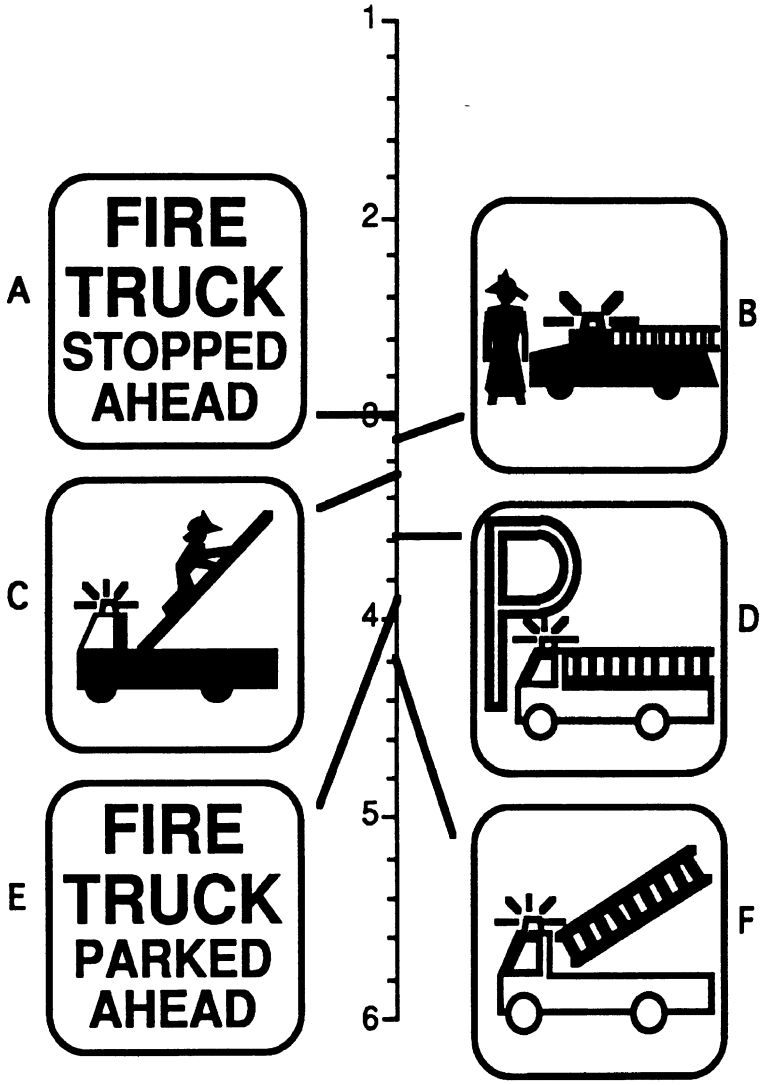
The top two preferred candidates for the fire truck match the top two from the moving ambulance ranking.

Candidate "F" is the currently used fire truck symbol from the fire station ahead road sign.

$\underline{H}(6) = 58.4, \underline{p} < 0.001$

	Best----------->Worst							
	1	2	3	4	5	6	7	Mean
A	8	8	2	0	5	2	0	2.7
B	9	3	4	6	0	0	3	2.9
C	5	2	2	4	7	5	0	3.8
D	1	6	5	2	5	5	1	3.9
E	2	2	4	7	6	3	1	4.0
F	0	4	7	4	2	8	0	4.1
G	0	0	1	2	0	2	20	6.5

Figure 59. Symbol 24: A fire truck is approaching you at high speed with its flashers on.



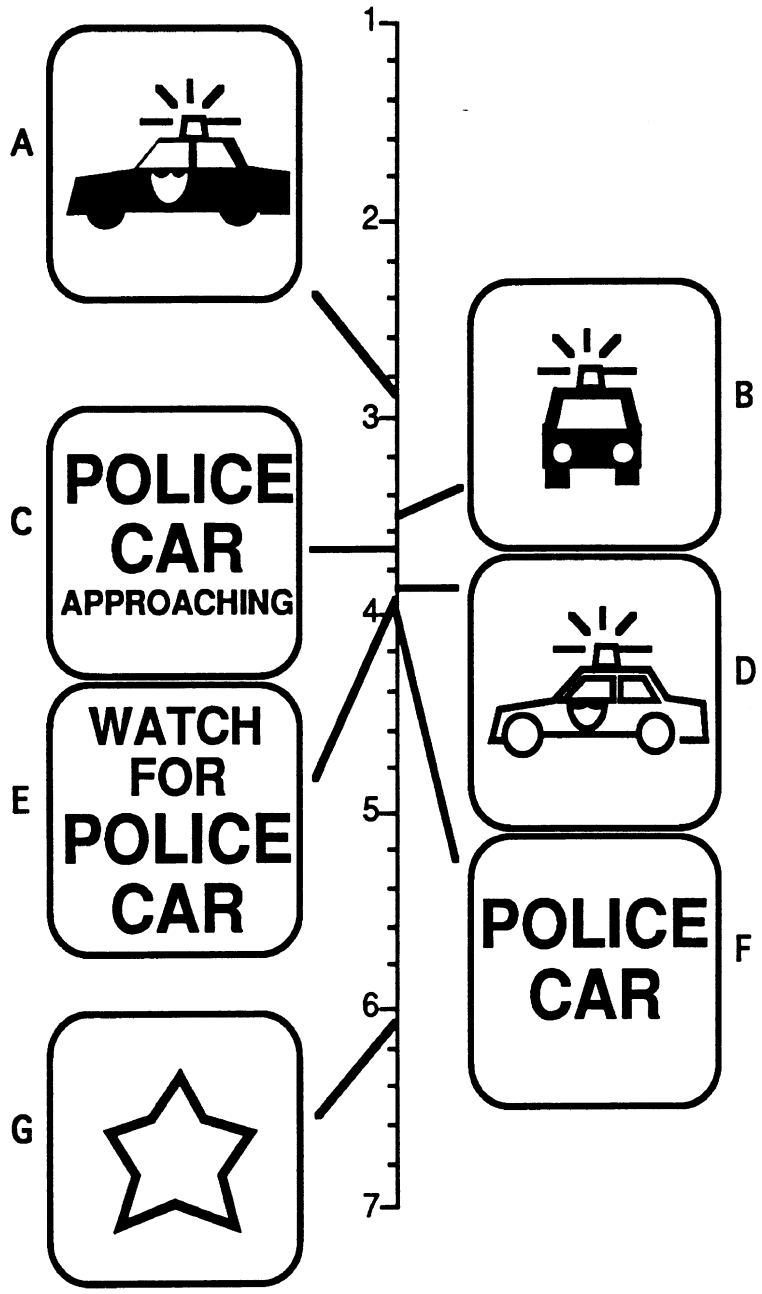
The top two candidates were not significantly different in preference. Either "B" or "C" would match the stopped ambulance with stretcher candidate, though "B" is a closer match since the human is on the same level as the vehicle. Text ranked low on the moving emergency vehicle rankings, so, for consistency sake, will probably not be used in this instance.

The experimenters should have included the more simplified version of the fire truck (as in "D") for "B." It is possible that design would have ranked higher, since a close version of the truck used in "B" ranked second to last in symbol 24.

$H(5) = 9.7, p = 0.084$

	Best----------->Worst						
	1	2	3	4	5	6	Mean
A	8	6	1	2	5	3	3.0
B	5	6	4	3	6	1	3.1
C	5	3	6	5	3	3	3.3
D	4	2	7	4	3	5	3.6
E	1	6	4	3	5	6	3.9
F	2	2	3	8	3	7	4.2

Figure 60. Symbol 25: A fire truck is by the side of the road ahead.

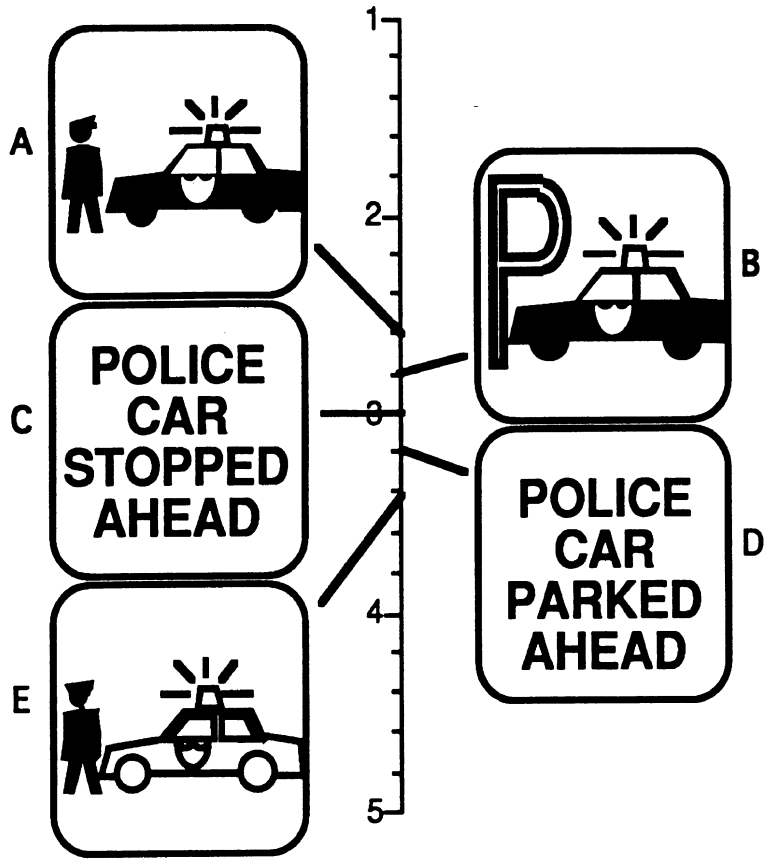


Candidate "A" ranked significantly higher than the rest of the candidates, and is consistent with the other top ranked moving emergency vehicle symbols. Candidate "A" should have had motion lines behind it, like those on the ambulance and fire truck. The motion lines will be added for the next stage of testing, to retain consistency.

$H(6) = 38.0, p < 0.001$

	Best----------->Worst							
	1	2	3	4	5	6	7	Mean
A	8	6	2	2	4	3	0	2.9
B	6	2	6	3	2	5	1	3.5
C	6	2	4	3	4	3	3	3.7
D	2	5	5	3	4	4	2	3.9
E	2	5	2	6	5	3	2	4.0
F	1	4	6	5	3	5	1	4.0
G	0	1	0	3	3	2	16	6.1

Figure 61. Symbol 26: A police car is approaching you at high speed with its flashers on.

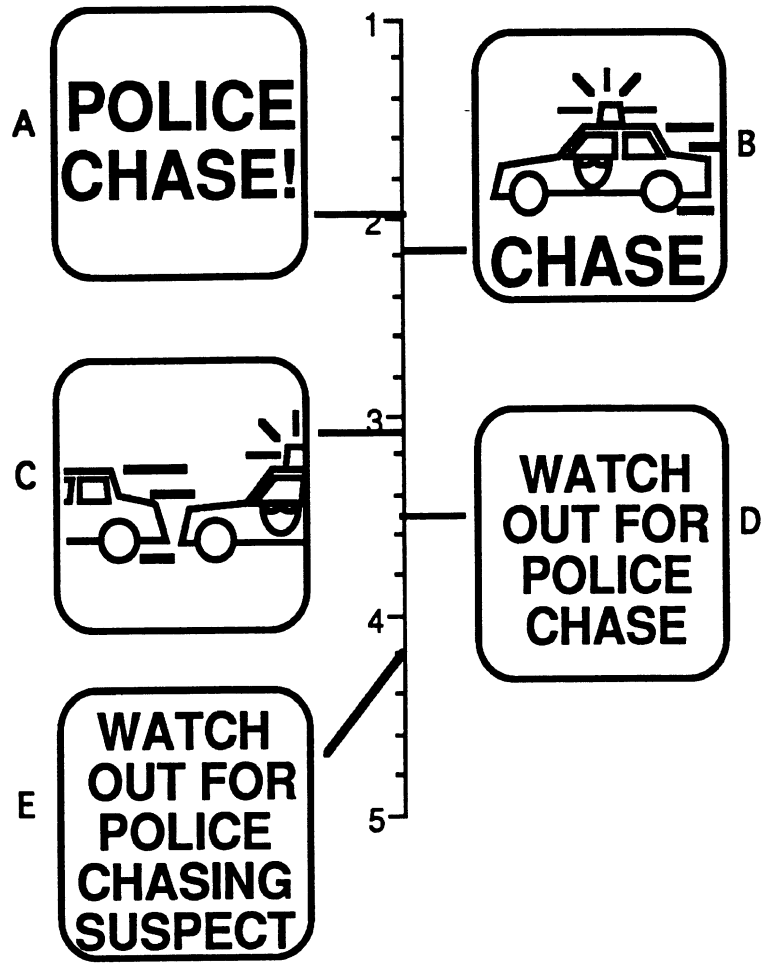


Candidate "A" is consistent with the stopped ambulance symbol, though preference differences were not significant.

H(4) = 4.8, p = 0.308

	Best----------->Worst					
	1	2	3	4	5	Mean
A	7	7	2	7	2	2.6
B	7	4	7	1	6	2.8
C	6	4	4	6	5	3.0
D	3	7	2	7	6	3.2
E	2	3	10	4	6	3.4

Figure 62. Symbol 27: A police car is by the side of the road ahead.



Candidate "B," in solid form, would be consistent with the other police symbols. It is possible the graphic candidate "B" would have ranked higher had it been solid, since that design was preferred in rankings for symbols 26 and 27.

H(4) = 43.8, p < 0.001

	Best----------->Worst					
	1	2	3	4	5	Mean
A	13	2	9	0	1	2.0
B	6	14	1	2	2	2.2
C	5	4	6	4	6	3.1
D	0	4	7	11	3	3.5
E	1	1	2	8	13	4.2

Figure 63. Symbol 28: A police car chasing another vehicle is approaching you at high speed with its flashers on.

Directionality Drawing Results

Appended to the end of the Emergency Vehicles ranking form were three pages addressing the display of hazard direction. Three situations were investigated: police car stopped by the side of the road ahead, police car approaching from the right, and police car coming from behind. To convey the idea of the situation without biasing the participants, driver views of the situations were drawn. (See appendix B.) A box with

two display sections, representing the IVSAWS system, was drawn on the dashboard with leader lines to a larger box in which participants could draw in their ideas.

Selected participant responses to the directionality questions (many participants left these blank) are reproduced in figures 64 to 69, along with the drawings used to represent the hazard situation.

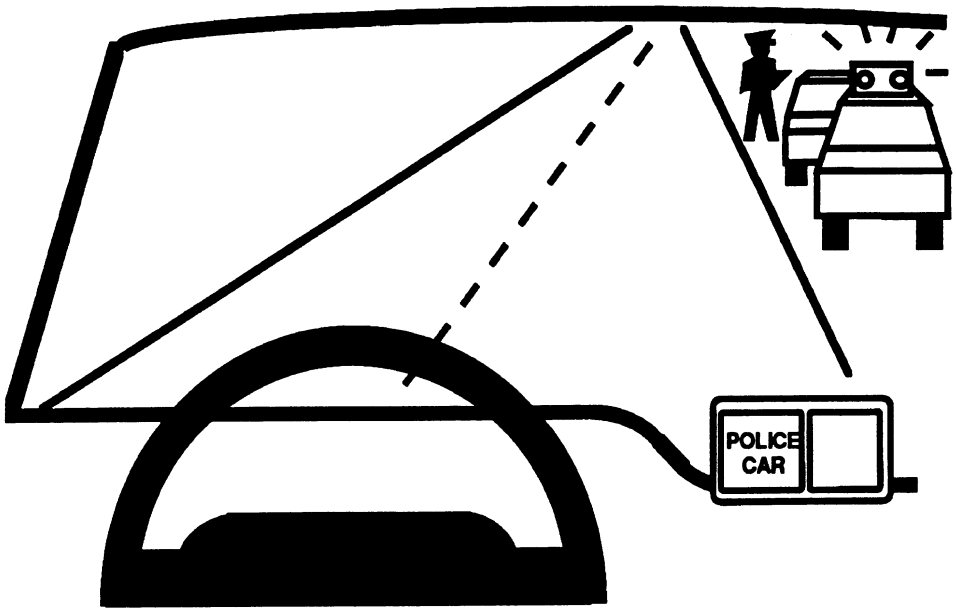


Figure 64. "Police car stopped ahead" situation graphic.

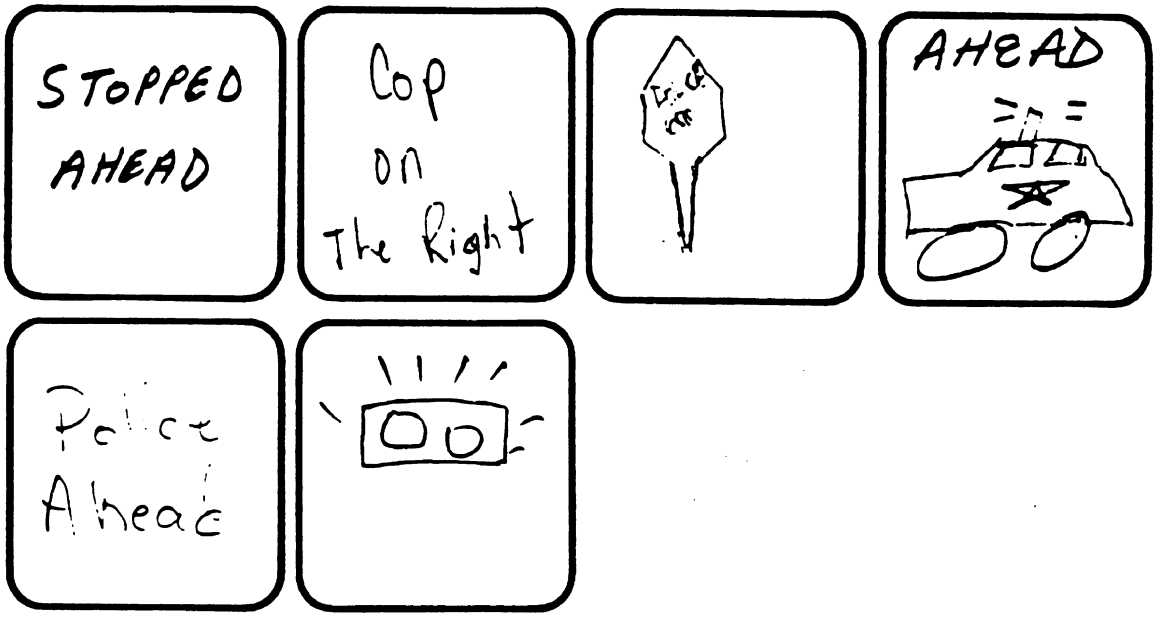


Figure 65. Select participant responses to "police car stopped ahead" situation.

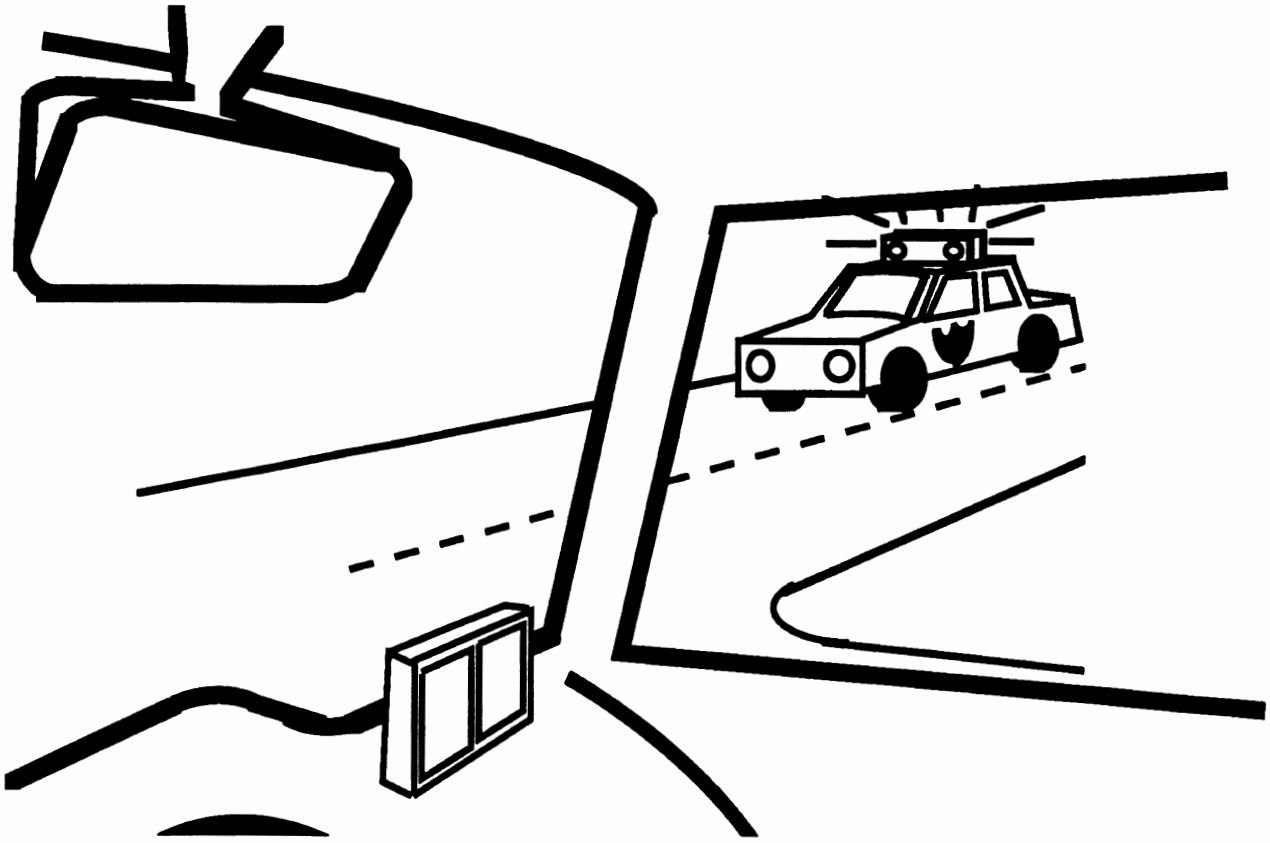


Figure 66. "Police car approaching from right" situation graphic.

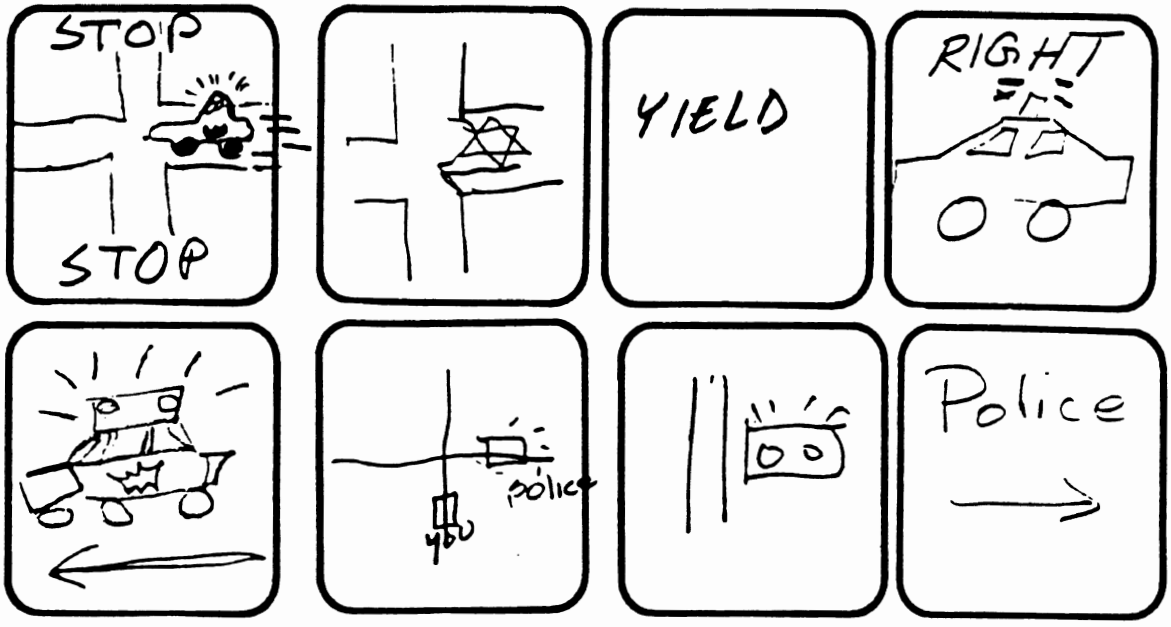


Figure 67. Select participant responses to "police car approaching from right" situation.

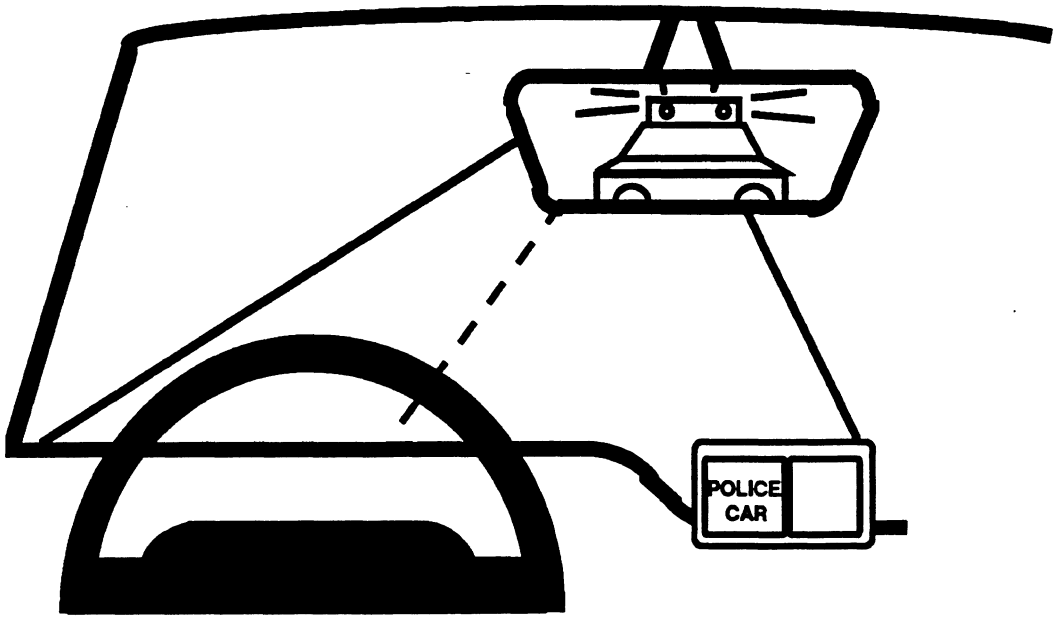


Figure 68. "Police car approaching from behind" situation graphic.

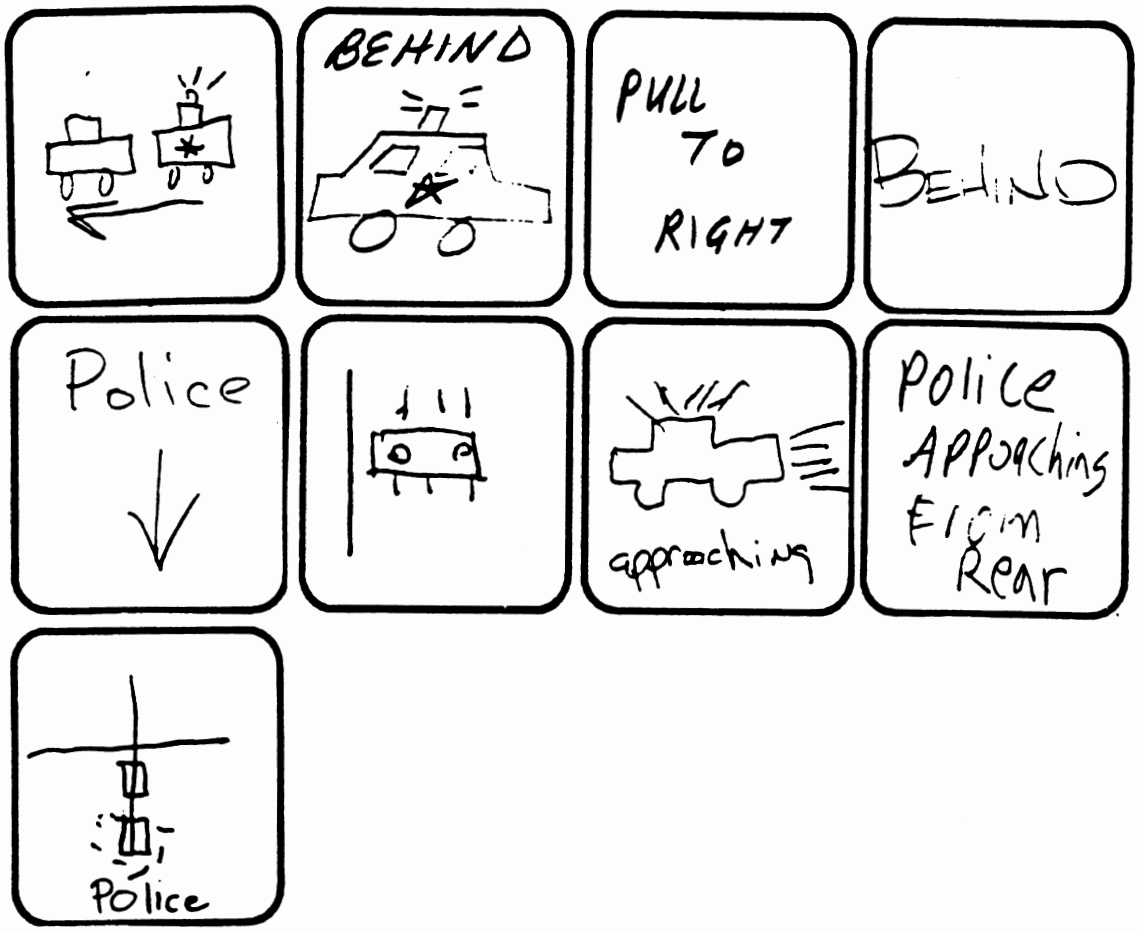


Figure 69. Select participant responses to "police car approaching from behind" situation.

Recommended Warnings

Based on the results of the ranking experiment and the principle of consistency, recommended warnings follow, grouped by warning type. For warnings with possible text and graphic versions, both sets are included below in table 5.

Table 5. Recommended warnings for in-vehicle signing of traffic control devices.

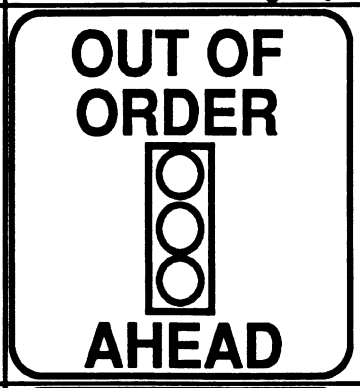
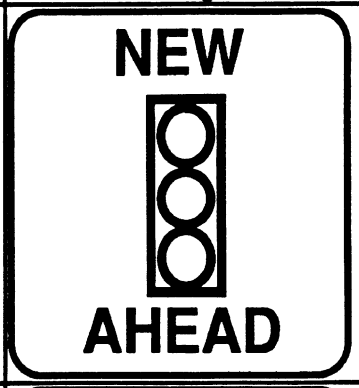
Format	Disabled traffic signal	New traffic signal	New stop sign
Mixed			
Text			

Table 6. Recommended warnings for in-vehicle signing of construction.

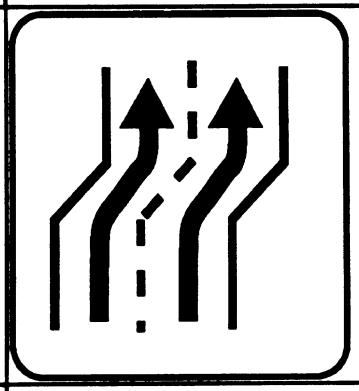
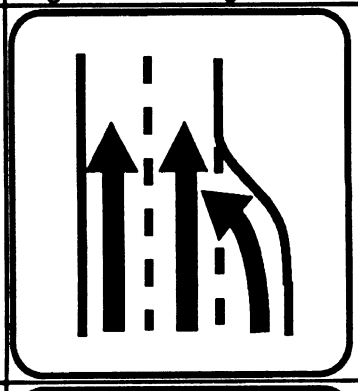
	Road construction	Lane shift	Right lane merges left
Graphic			
Text			

Table 7. Recommended warnings for in-vehicle signing of miscellaneous hazards (railroad crossing, curve speed limit, and accident ahead).

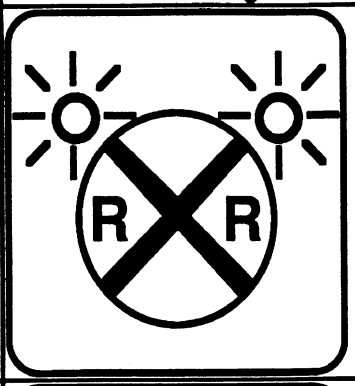
	Railroad crossing	Curve	Accident ahead
Mixed			
Text			

Table 8. Recommended warnings for moving emergency vehicles.

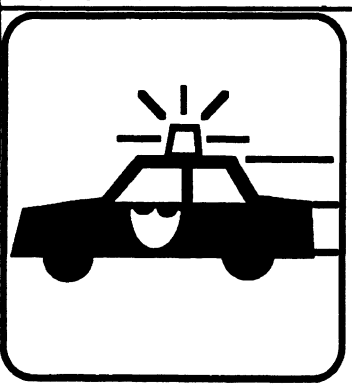
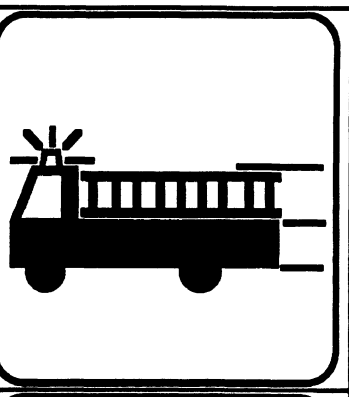
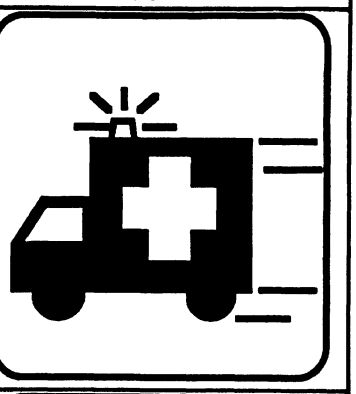
	Police car	Fire truck	Ambulance
Graphic			
Text	POLICE CAR APPROACHING	FIRE TRUCK APPROACHING	AMBU-LANCE APPROACHING
	Police in chase		
Mixed	 CHASE		
Text	POLICE CHASE!		
	Note: Missing from the text warnings is the impression of the emergency vehicle with its flashers on. The text warnings could be mistaken to apply to emergency vehicles driving as part of normal traffic.		

Table 9. Recommended warnings for stopped emergency vehicles.

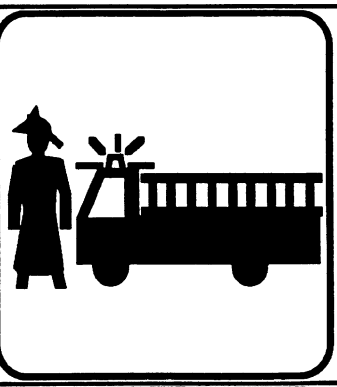
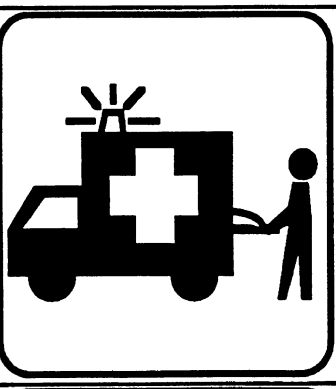
	Police car	Fire truck	Ambulance
Graphic			
Text	POLICE CAR STOPPED AHEAD	FIRE TRUCK STOPPED AHEAD	AMBU-LANCE STOPPED AHEAD

Table 10. Recommended warnings for atypical vehicles that make frequent stops.

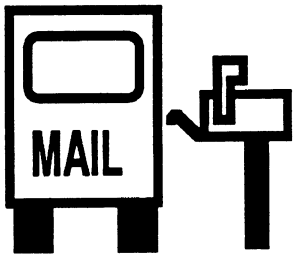
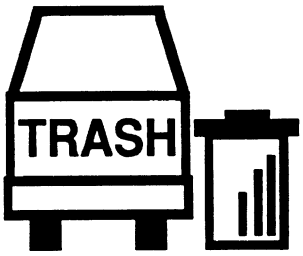
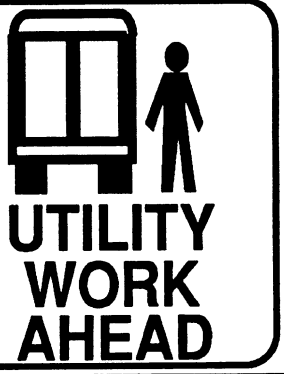
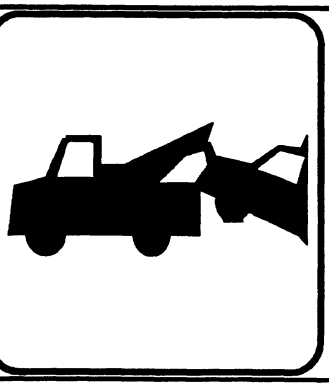
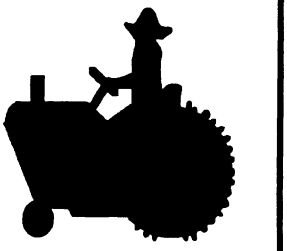
	Mail delivery vehicle	Trash truck	Utility work
Mixed			
Text	MAIL TRUCK AHEAD	TRASH TRUCK AHEAD	

Table 11. Recommended warnings for atypical vehicles that are slow moving.

	Generic slow moving vehicle	Wide load	Snow plow
Mixed			
Text	SLOW MOVING VEHICLE AHEAD	WIDE LOAD AHEAD	SNOW PLOW AHEAD

Table 12. Recommended warnings for other atypical vehicles (school bus and tow truck).

	School bus	Tow truck	
Graphic & Mixed			
	Farm vehicle		
Graphic			
Text	**FARM VEHICLE AHEAD**		

Conclusions from Testing at Driver Licensing Office

The previous experiment provided considerable insight concerning driver preferences for in-vehicle warnings. These results should be viewed with some caution, as they need to be verified in driver performance experiments. Specific recommendations are given in the previous section, though for some of the warnings (e.g., slow moving vehicle, utility vehicle) none was clearly preferred.

In general, drivers showed no clear preference for text versus graphic warning messages, although some specific rankings showed a clear preference. Hazards

where there was no clear preference for text versus graphic (e.g., school bus, mail truck) were sufficiently numerous that testing of alternatives is required in each case. It is unknown what the effect will be of mixing formats across warnings, though the consistency principle would argue against this. There were a few cases in which drivers preferred part of the message as text and part in a graphic format (e.g., the "traffic light out of order ahead" symbol). Given no uniform preference for format, there is a temptation to present redundant warnings (for example, to spell out "traffic signal" and to include the graphic). That is not recommended since performance with both is likely to be slower than with either format. In many cases, both formats need to be processed, not just one.

In developing the recommended warnings in the previous sections, the authors believed it was most important to have a consistent format within each warning category. Standardization of graphics adds the advantage of predictability in comprehending these warnings, potentially minimizing interpretation time. Hence, the same general format (text vs. symbols) and placement rules were followed in each category (slow moving vehicles, status of signs and traffic signals, etc.), but not necessarily across categories.

In presenting warnings, a major question is whether the problem (the error) or what to do about it (the command) should be shown. Results from the "accident ahead" and "lane shift" warnings suggest there are circumstances where both might be shown. However, the majority of the warnings depict the problem (e.g., mail truck).

For symbols, the major question was the orientation of graphics, specifically which direction vehicles should face. In this experiment drivers preferred showing vehicles moving from right to left in every case, so this orientation is tentatively recommended. It is unclear how that orientation will work in real vehicles since the orientation drivers will see (rear view) may not match the display. That may not be critical, since the purpose of the warning is to alert the driver to the nature of the hazard, but not necessarily to a specific image.

Another orientation issue was the depiction of the relative location of the hazard. If the hazard was ahead, there was a clear preference for including that word in the warning, even for messages that were symbolic.

A particular problem with graphics was clearly distinguishing parked from moving vehicles. Showing a "P" next to the vehicle graphic was often awkward, but it is not apparent how obvious the horizontal motion lines were to drivers.

It is important that warnings should be consistent with existing sign practice (MUTCD). While some graphics and text are well understood (e.g., railroad crossing), there were others where parts of the messages could be improved (e.g., the shovel in the road construction sign). The enhanced understanding of those minor deviations should exceed the loss due to a lack of consistency with current practice. There were numerous cases where drivers clearly preferred nonstandard warnings, and they should be considered for use.

This experiment by no means addresses all of the issues concerning the design of IVSAWS warning messages. Driver performance data are needed, and issues relating to the prioritization of multiple warnings and the number of warnings to be shown at a given time need to be addressed.

PART 3: IVSAWS FIELD EXPERIMENT ON HAZARD AND HAZARD LOCATION UNDERSTANDABILITY

Purpose

The purpose of this field study was to assess the understandability of select hazard warning symbols and symbols that identify the location of the hazard relative to the driver's vehicle.

Method

This experiment was conducted in three parts. In part 1 of this experiment, participants stated the meaning of 10 hazard symbols that were presented to them while driving. In part 2, participants stated the meaning of one hazard symbol with a location symbol. In part 3, while parked at an intersection, participants identified hazards and their location from 40 messages that contained both a hazard and a location symbol.

Test Participants

Twenty licensed drivers participated in this experiment, 10 young (21 to 29 years old, mean = 23), and 10 older (59 to 73, mean = 65). Equal numbers of men and women were drawn from each age group. They were recruited from lists of previous and new participants inexperienced with advanced in-vehicle systems. The mean reported annual mileage for all participants was 12,850 miles (ranging from 2,000 to 25,000). Seventeen participants wore corrective lenses, with their corrected visual acuity ranging from 20/40 to 20/13 and reported their education levels ranged from "high school degree" to "graduate school degree." Each participant was paid $15 for a one hour test session.

Test Materials and Equipment

A 1991 Ford Taurus station wagon, with automatic transmission, was used for the experiment. A posterboard card holder, used to hold the simulated IVSAWS displays, was mounted to the right of the steering wheel, on the upper part of the instrument panel. It did not obscure the exterior view. Two of the test sessions were audiotaped.

The IVSAWS messages were laserprinted in black on white paper and mounted onto 4x6 inch index cards with a dark border. The size selected (five inch diagonal) was identical to the monitor likely to be used for a subsequent experiment. A full size example of one of these messages appears in figure 70.

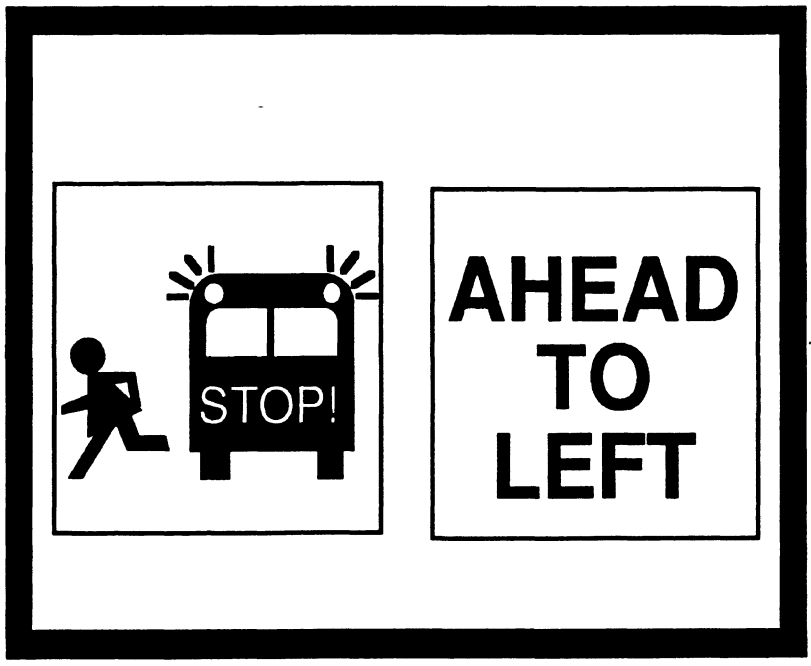


Figure 70. Example of IVSAWS message, shown actual size.

The biographical form used was a simplified version of the one used in the previous driver licensing office study. Copies of the consent form, the biographical form, and payment form are in appendix D.

The 10 IVSAWS hazard warnings were selected from a list of 30 previously tested within the categories of slow moving or stopped vehicle, in-car signs (both existing and new), and moving emergency vehicles. The hazards represented by these symbols were common (Streff, et al., 1991)[10], could result in fatal accidents, not shown to be clearly understood (from the first part of this study), and were applicable to the test route. The following hazards were selected:

Slow moving or stopped vehicle:
- Un/loading school bus--Stop.
- Accident--Slow down.

In-car signs (replacing existing road-side signs):
- Road construction.
- Train at crossing (two versions).
- New stop sign ahead.
- Traffic light out of order.

Moving emergency vehicles (with flashing lights on):
- Moving ambulance (with flashers).
- Moving police car (with flashers).
- Stopped police car (with flashers).

Three warning formats were examined: graphic, text, and mixed. The 10 warnings, grouped by format, are shown in figure 71.

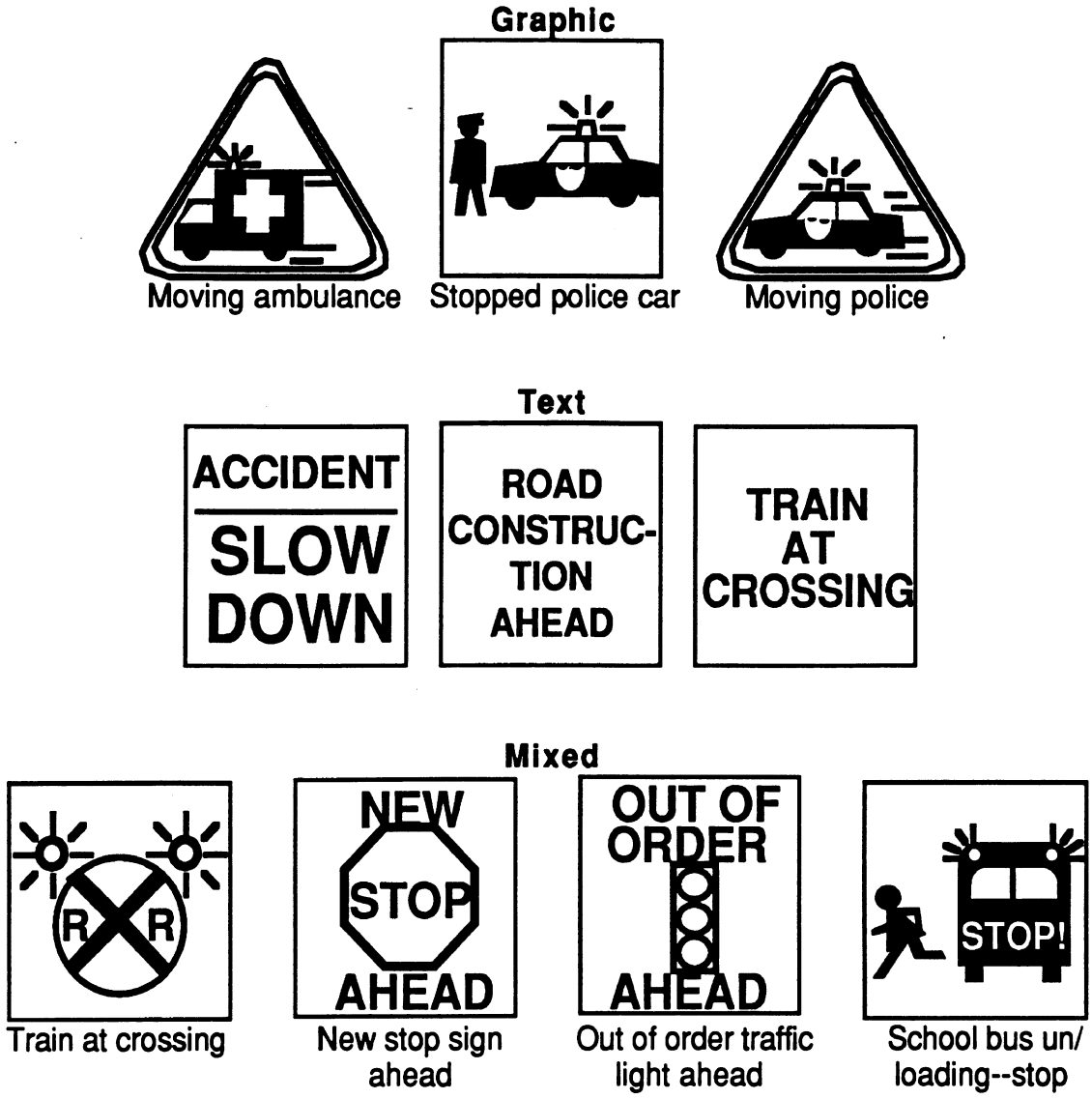


Figure 71. The 10 IVSAWS warnings, shown by format.

The moving police car and ambulance were framed with a triangular hazard symbol to distinguish a moving hazard from a stationary one. All other symbols were framed with a square. The triangular frame is consistent with Erlichman (1992).[11] The "hazard identification" symbols appeared to the left side of the "hazard location" message. Where identification and location where combined in a single graphic, such as the "new traffic light ahead," the message appeared in one box on the left side of the screen.

The authors believe that providing information about the location of a hazard is useful to drivers. However, providing the additional direction information outweighs the cost of searching the road for the hazard. Directional information was investigated as associated with moving emergency vehicles only. All the other symbols shown, with the exception of the school bus, would be displayed only to drivers approaching the hazard along the road they are on, that is, straight ahead. The direction data for the other hazards may be used by the system to determine whether the hazard is

applicable to the system's vehicle, but it would not be displayed to the driver. Many of the nonemergency vehicle warnings already incorporate the text direction message "ahead" as a result of driver preference.

The hazard location information was intended to tell drivers where the hazard was in relation to their cars. It was not intended to provide other vector information, such as the direction of travel of the hazard (e.g., approaching, passing, etc.). This criteria put certain restrictions on possible designs.

Originally, more than 20 location cue designs were considered for this part of the study. The emergency vehicle portion of the second part of this study (IVSAWS testing at driver licensing office) contained three free-response symbol questions concerning the display of hazard location. Some ideas were taken from this study and additional ones were created by the experimenters.

Some possible design schemes for presenting location information were:

- Inside-out (the scene when looking out of the car).
- Outside-in (outside the car looking in).
- Aerial view (low flying airplane view).
- Arrows or pointers or hand pointing to the hazard.
- Instruction to direct gaze (eyeballs looking in direction of hazard).
- Location integrated in hazard symbol (display hazard icon in various angles).
- Absolute and relative bearings (270 degrees, 90 degrees left).
- Grid or graph.
- Text (left).
- Nautical terms (starboard).
- Clock (3 o'clock).

There were various complicating factors related to the design of these schemes, since the system was meant to convey only relative location information, not to convey (unintentionally or erroneously) direction of travel information.

Multiple versions of each scheme evolved from group discussion. Considerations included clarity, simplicity, legibility, quick comprehension, ease of symbol generation, and distinctiveness. Four final formats emerged for testing: arrows/pointers, overviews, text, and inside-out. See figure 72.

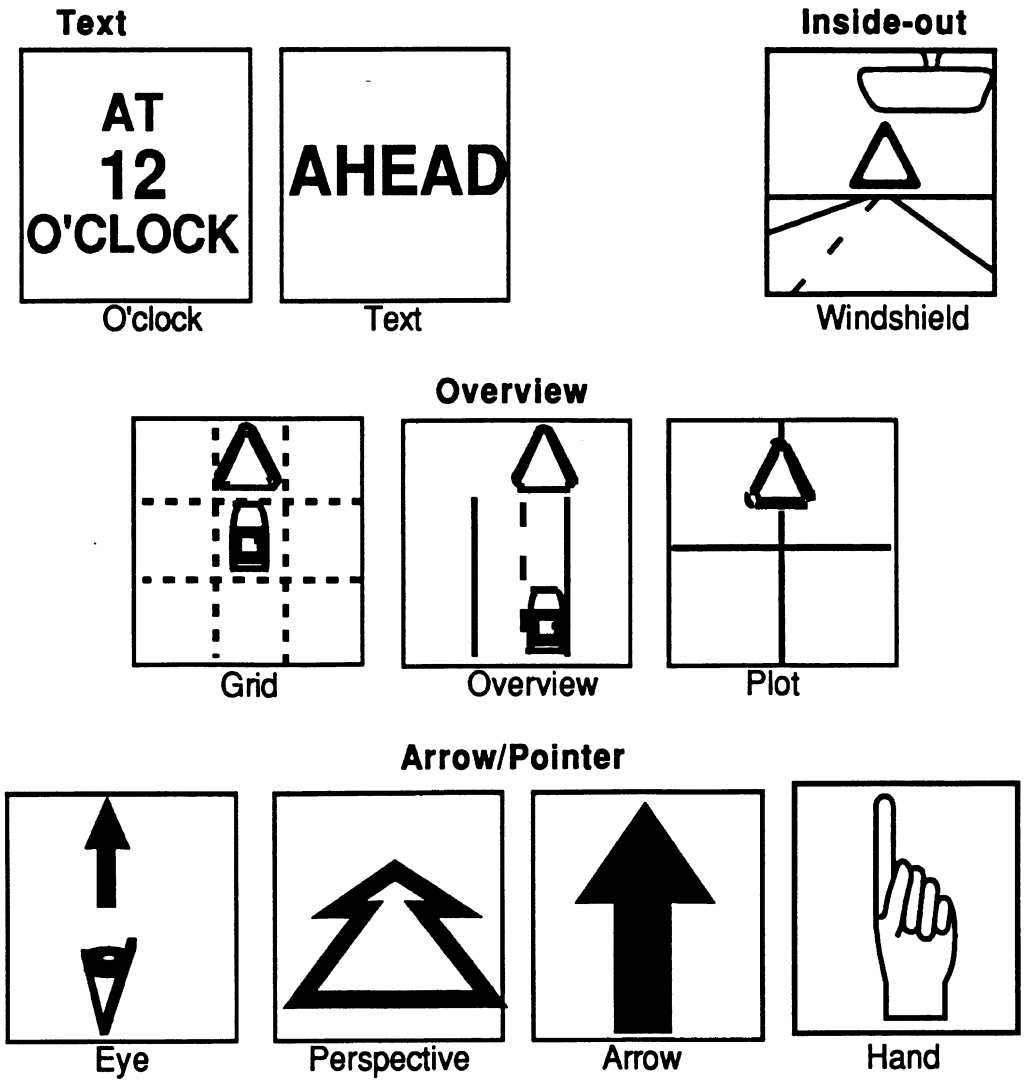


Figure 72. The 10 hazard location design symbols, grouped by the four formats, for the straight ahead location.

In the overview group, triangles were used to represent the location of the hazard. The triangle in the overview format corresponded with the triangle framing the hazard symbol. The triangle is a simple, distinctive symbol that already exists as a warning symbol, although for slow or stopped hazards. This inconsistency should have been avoided. In addition, it is easier to generate a triangle than multiple icons of the hazard, and does not have a confounding directionality (of movement) associated with it.

Six relative locations of hazards (from the driver's perspective) were considered important for investigation:

- Straight ahead.
- Cardinal right.
- Cardinal left
- Diagonal right (ahead).
- Diagonal left (ahead).
- Behind.

These locations are compatible with various intersections and road geometries (4-way intersections, Ys, Ts, etc.). Locations that are ahead of the driver mean that the driver is approaching and may encounter it (unless the emergency vehicle is traveling away from the driver's vehicle, or either vehicle makes a turn). Only one "global" behind message was used because, while the driver might be aware of the hazard, it is likely that it would not be visible unless it was straight behind the driver. In addition, it is easier and less distracting for a driver to look out the front windshield to locate something ahead than to use the mirrors (or turn around) to locate something to the rear.

This study was run in a neighborhood where the streets were orthogonal. It did not address how to describe a hazard that the driver would encounter beyond a curve in the road. For example, it is unclear if this situation should be considered "ahead," or "ahead to left." Depending on the functionality of the system, it may not be possible to distinguish between the two.

Test Activities and Their Sequence

In part 1, the 10 hazard identification symbols used for testing were randomized and numbered as follows:

1. Moving police car with flashers on.
2. Out of order traffic light ahead.
3. Road construction ahead.
4. Un/loading school bus--Stop.
5. Moving ambulance with flashers on.
6. Train at crossing (Text version).
7. Stopped police car with flashers on.
8. New stop sign ahead.
9. Accident--Slow down.
10. Train at crossing (Graphic version).

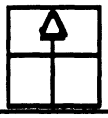
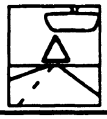
In part 2, all subjects were presented with one example of a hazard symbol (a moving police car in all cases) with a hazard location symbol. This was to test the drivers' understanding of the concept of hazard location cues. To counterbalance the bias, each of the 10 location symbols was shown to 2 of the subjects.

In part 3, hazard location designs were assigned numbers as follows:

1. Arrow.
2. Overview.
3. Perspective arrows.
4. Inside-out.
5. Text.
6. Eye.
7. Plot.
8. Hand.
9. Grid.
10. O'clock.

In the part 3 test sequence, subjects saw 40 flash cards (10 location coding schemes times 4 locations). They were adjacent to either of two of the hazards--the moving ambulance or the moving police car. Only 4 of the 6 location cues were examined for each format because 1 cardinal pair (left and right) and 1 diagonal pair (ahead to the right and ahead to the left) were considered similar. Subject to those constraints, the four chosen varied from format to format. For each block (format), the four directions were randomly ordered within each block. Formats were ordered so that two designs of the same format (arrow/pointer, overview, inside-out, text) were not presented consecutively. The order is shown in table 13:

Table 13. Presentation order of the hazard location symbols.

Design # & Icon	Card #	Format	Design	Location
1 	1 2 3 4	TEXT	o'clock	right ahead left ahead behind
2 	1 2 3 4	OVERVIEW	grid	left behind ahead ahead left
3 	1 2 3 4	ARROW/POINTER	hand	ahead left left behind ahead
4 	1 2 3 4	OVERVIEW	plot	right ahead ahead right behind
5 	1 2 3 4	ARROW/POINTER	eye	right ahead right ahead behind
6 	1 2 3 4	TEXT	text	behind ahead left right ahead
7 	1 2 3 4	INSIDE - OUT	inside-out	ahead left ahead left behind
8 	1 2 3 4	ARROW/POINTER	perspective arrow	left ahead behind ahead right
9 	1 2 3 4	OVERVIEW	overview	ahead right behind ahead left
10 	1 2 3 4	ARROW/POINTER	arrow	ahead behind ahead left left

Subjects 1 through 10 were presented with the cards in the above order, but each had a different starting point in order to eliminate order effects. (Subject 1 started at design

1, card 1; subject 2 started at design 2, etc., until each had seen all 40 cards.) The order was reversed for subjects 11 through 20 so that design 10 was shown first, design 9 shown second, etc. In addition, the order of the 4 locations was changed, so that the first and second cards (that subjects 1 through 10 had seen) were switched, and the third and fourth cards were switched. That is, subjects 10 through 20 saw the cards within each design in the order of card 2, card 1, card 4, card 3.

Test Route

The test route (figure 73) was in a residential neighborhood. The route was chosen because of its proximity, light traffic, and parallel streets. These features made it easy to follow a specific route, and allowed for a suitable spot to park with an intersection immediately in front of the test vehicle, and cross streets in view further ahead and behind the vehicle. This was necessary to allow for the possibility of appropriate ahead, behind, and right or left location-of-hazard responses. After driving the test route for parts 1 and 2, for part 3 drivers made a U-turn and parked the car near an intersection, shown in figure 74.

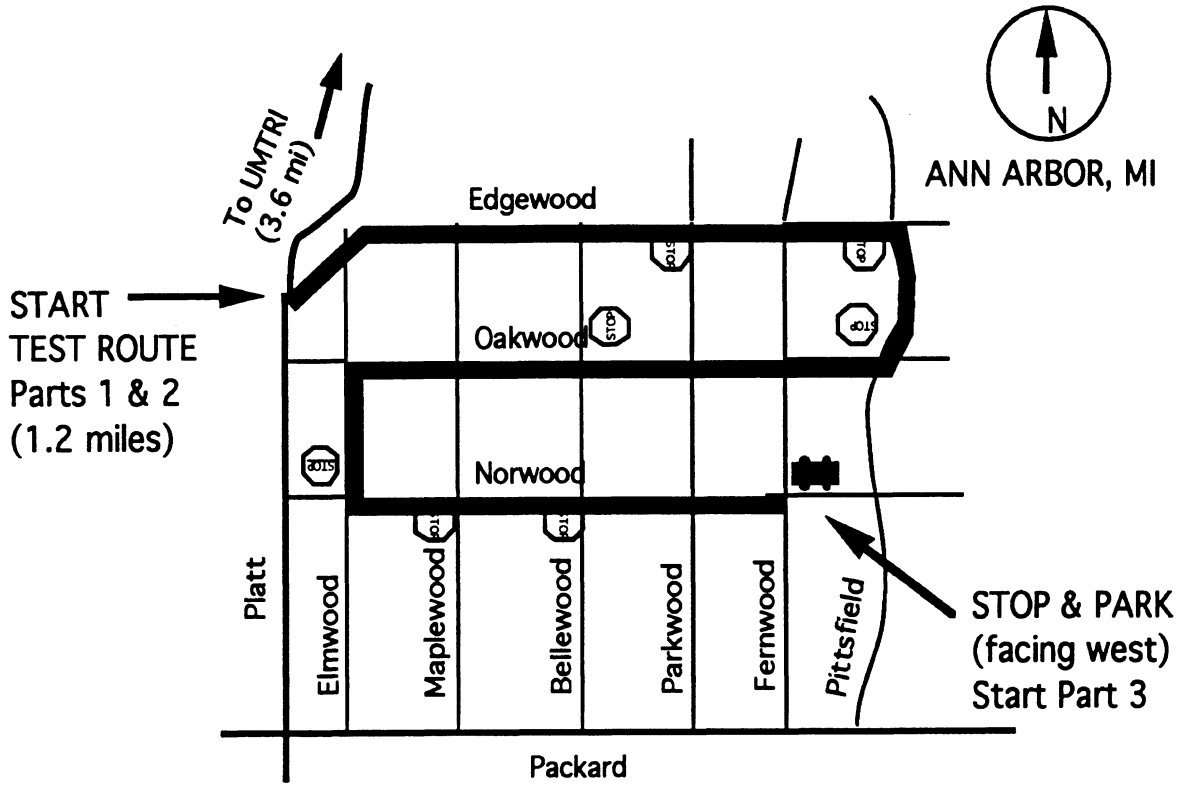


Figure 73. Test route.

Figure 74. Location of vehicle at intersection of Fernwood and Norwood during part 3.

Test Procedure

At UMTRI, the purpose of the study was explained to the participant. (The complete experimental procedure is in appendix E.) Participants read and signed the consent form, and completed the biographical form, both of which appear in the appendix. Following a vision test (using a Titmus vision tester) and confirmation of possession of a valid driver's license, the experimenter and participant proceeded to the test vehicle.

Participants adjusted the mirrors, seat, and steering wheel, and became familiar with the interior of the vehicle. Participants were told that the symbols would be presented on cards. (Since the focus was on symbol understandability, a more costly computer simulation of IVSAWS would have likely led to similar results.) The experimenter explained the test route and instructed the driver to obey the speed limit.

Participants drove to the test area and were verbally guided through the test route. While driving the first part of the route drivers saw 10 IVSAWS warnings (hazard type only) and answered the question "What does this mean to you?" for each of the cards. The experimenter wrote down all responses.

Part 2 of the experiment involved presenting a moving police car hazard card, which also contained a location cue (showing where that hazard was located). (The 10 previous cards in part 1 depicted only a hazard, whereas this one showed a hazard and its location, ahead). Participants again stated what they thought that message meant. (A transcript from one participant appears in appendix F.)

For part 3, the car was parked on the right shoulder of the road. Participants imagined they were driving when the messages appeared. On the left side of each of the 40 cards was a hazard, on the right side was the location cue. Drivers considered each message independently. The participant was instructed to identify the hazard, state its location, and point to its location relative to their current position. Figure 75 illustrates a participant's response for part 3.

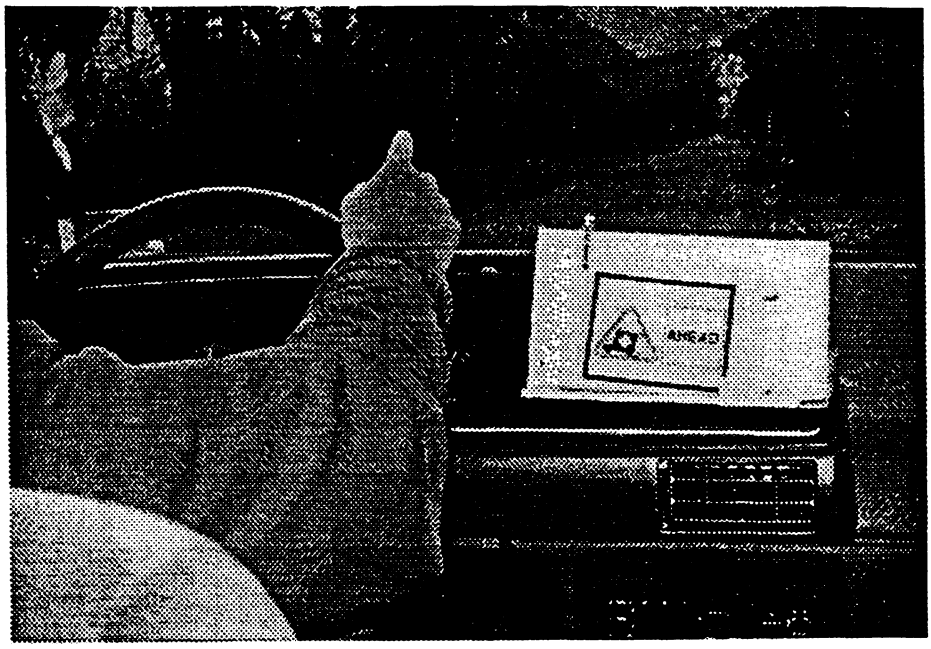


Figure 75. Participant identifying the hazard, stating its location, and pointing to it.

Finally, participants were asked what the triangles on the cards meant. Participants also ranked their preferences for the systems based on ease of use. (Prior to ranking, participants were not informed of the correct responses to the cards, so preference could later be compared to performance.) Examples from each of the 10 designs of location cues (printed on cards) were stacked with the worst on the bottom and the best on top. Following the test session, participants were then directed back to UMTRI.

Results

Part 1 - Responses to Hazard Symbols

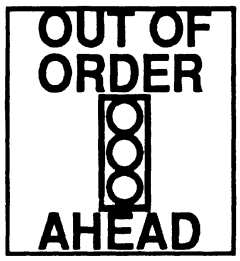
Answers for this free-response segment ("What does this meant to you?") were categorized after the experiment. Categories were based on the level of understanding and detail. Typically up to four categories emerged for each symbol. Listed below, in figures 76 through 85, for each hazard symbol, are descriptions of the response categories and the number of subjects whose response fell within that category. A brief discussion of the participants' understanding of the symbol follows each.

All understood the moving police car warning referred to the police, but some missed the idea that the police car had its flashing lights on and was moving fast. See figure 76. Those who said to yield to the police can be assumed to realize it was moving quickly. Drivers need to know this symbol is more than just a "radar detector" or "police car detector," but rather a "speeding police detector."

Count	Response Category
12	Police car moving, with its lights on, or yield to the police.
3	Police car in area or ahead.
5	Police car only.

Figure 76. Response categorizations for moving police (with flashers).

Subjects have a clear understanding of the out of order traffic light symbol, as shown in figure 77. A few subjects mentioned the intersection would become a four-way stop, a response that should be understood by licensed drivers. It may be safe to assume that those who did not mention the signal was ahead, did read it, but did not mention it because it was "understood" or obvious.



Count	Response Category
20	Stop light or signal lamp was not working, or broken. (Most also mentioned it was ahead.)

Figure 77. Response categorizations for out of order traffic light ahead.

The road construction warning was clearly understood by all subjects, probably due to having seen this sign previously. See figure 78. A few also mentioned they would be cautious or there would be delays.

Count	Response Category
20	Construction or road construction or someone working on the road ahead.

Figure 78. Response categorizations for road construction ahead.

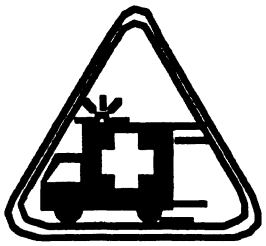
Everyone understood that the school bus loading or unloading symbol represented a school bus; however, there was diversity of responses regarding the activity of the bus. See figure 79. Participants seemed to interpret the word "stop!" very differently. Some understood it to mean they should stop, and others interpreted it as the bus was stopped or stopping (none said both). Also, the concept of the lights flashing on the bus (and that children were either loading or unloading) was not universally grasped. Drivers need to realize this warning symbolizes more than a bus stop, or that a bus is stopping, but that they must legally stop for a bus with its flashing lights on because it is unloading or loading children. Perhaps this would be conveyed better with a color message, thus highlighting the red lights.

Count	Response Category
3	School bus [only].
4	Stopped school bus.
6	School bus was unloading, children getting off or near the bus. [Three also said to stop.]
7	School bus [no mention of its activity] **and** said to stop.

Figure 79. Response categorizations for school bus un/loading--stop!

Everyone understood the vehicle was an ambulance or some type of emergency vehicle in the moving ambulance warning. See figure 80. It is not apparent, however, if those who simply mentioned "ambulance" realized the ambulance is moving fast, with its lights on (possibly transporting a passenger to a medical center). It may be safe to assume that people understood the ambulance was moving at high speed as the function of ambulances is to transport people quickly. In contrast, while police

vehicles sometimes need to drive fast, they also are seen cruising on patrol, or stopped on the side of the road checking speeds. Ambulances are less rarely seen, and, when they are, it is likely they are transporting a patient.



Count	Response Category
5	Ambulance [only].
8	Ambulance in the area, such as one coming or approaching them, or a place where ambulances cross [near a hospital].
7	Ambulance had its lights on and was transporting, or implied the ambulance was moving fast, because they would yield to the ambulance, or pull over or stop.

Figure 80. Response categorizations for moving ambulance (with flashers on).

The text version of the train at crossing hazard seems to more clearly convey the message of an actual train crossing the road at the railroad crossing then the graphic version (see below). It is assumed people who read the text verbatim understood what it meant. See figure 81. Most subjects understood this message meant more than just a marker for the railroad crossing, but that it also indicated a train was at the crossing. Everyone, except one, explicitly stated a train was at or approaching the crossing ahead. Some also commented to stop, be cautious, or be prepared to wait.

Count	Response Category
19	Train at the railroad crossing, or one coming.
1	A train (railroad) crossing (where the tracks crossed the road).

Figure 81. Response categorizations for train at crossing [text].

Everyone understood the stopped police car warning involved a police car. Beyond that however, there was a variety of reactions. See figure 82. Only six people understood the police car was stopped ahead. Only a few people mentioned the

flashing lights, indicating the officer was attending to an incident. Many people seemed to be confused about the activity of the police car/officer, if it were moving (and therefore they should yield), or if the officer wanted them to stop. This symbol is similar to the stopped bus unloading or loading children. In that instance, people did not have an overwhelmingly clear understanding that there were people in the area around a stopped vehicle. This concept may be better understood by using a color symbol, highlighting the flashing light.

Count	Response Category
7	Police car [only].
6	Police car, and also said they would stop, slow down, pull over, or be careful about their own behavior [e.g., check their speed].
6	Activity associated with the police car, such as the vehicle was stopped, an officer was attending to an accident, or had pulled someone over.
1	Police car's lights were flashing and the officer wanted the driver [subject] to pull over.

Figure 82. Response categorizations for stopped police car (with flashers on).

The majority of participants understood the meaning of the symbol: a new stop sign is ahead. (A few people mentioned there would be flags on the sign.) See figure 83. Even the one person who said they did not understand the message, read it correctly. All the subjects did mention the stop sign ahead, so it may be safe to assume they would also stop, regardless of when the sign was posted at that location. Previous encounters with this type of signing, and the direct text message, may be the reason for the clarity.

Count	Response Category
17	New stop sign posted or created ahead.
1	Read the text of the symbol but added they didn't understand it.
2	A stop sign ahead [only].

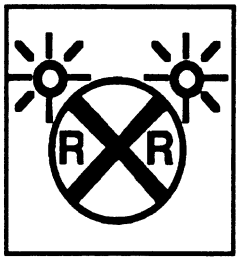
Figure 83. Response categorizations for new stop sign ahead.

Everyone understood the accident message: there is an accident and drivers should slow down. Since this was an all text message, on the whole the participants read the message verbatim, as shown in figure 84. Since no one mentioned otherwise, therefore, it is safe to assume they understood the meaning.

Count	Response Category
20	Either mentioned an accident, or to slow down, or both.

Figure 84. Response categorizations for accident--slow down.

Everyone understood there was a railroad crossing; however, only about half stated that a train was at the crossing or approaching it. See figure 85. There is much more uncertainty for this mixed version of the "train at crossing" hazard. For example, one subject commented this version was "the same as the other one," while another said this one was "not at effective as the other one." Effectiveness could be increased by adding "train" beneath the graphic, indicating that a train was present. Perhaps also the addition of color would aid this symbol. If language is not an issue, the text version is more widely understood, although this symbol is more compatible with an actual railroad crossing.



Count	Response Category
9	Train at the crossing, or a train coming, and some also mentioned the flashing lights at the crossing.
10	A railroad crossing ahead [with no mention of a train at the crossing or a train approaching the crossing].
1	Uncertain if it meant just a railroad crossing, or if a train was coming. [Could not understand the symbol for the lights, the lines around where the circles indicating the flashers.]

Figure 85. Response categorizations for train at railroad crossing [graphic].

Overall, the symbols for stationary hazards (new stop sign ahead, out of order traffic signal ahead, road construction, and accident ahead) were most clearly understood, perhaps because of drivers' experience with signs. The symbols representing emergency vehicles (stopped police car, moving police car, moving ambulance, and school bus un/loading) produced a range of responses concerning the vehicles' specific activity. The vehicles themselves were all recognized, however. A clearer understanding of the activity of the emergency vehicle (stopped police car versus moving police car) would likely result if the driver associated the appearance of the hazard warning symbol with the actual (visible) hazard. Of the two "train at crossing" hazard symbols, the text message was most widely understood. Again, associating the actual hazard with the symbol might have elicited different results.

Part 2 - Responses to Hazard and Location Symbols

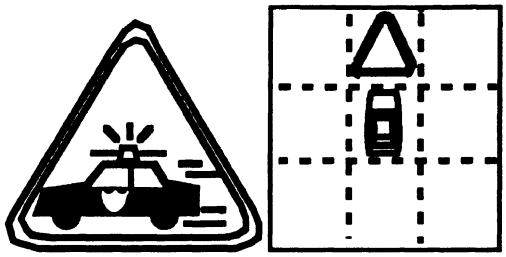
Figures 86 through 95 show all responses to the question "What does this mean to you?" for the case where one example location cue is provided. Each design was shown to only two subjects (S#).

The o'clock design was understood by both who saw it (12 o'clock representing ahead). Both subjects said a police car was ahead, as shown in figure 86.

S #	Response
5	Police car up ahead at 12 o'clock.
15	Police car moving straight ahead.

Figure 86. Responses to the "o'clock" location design.

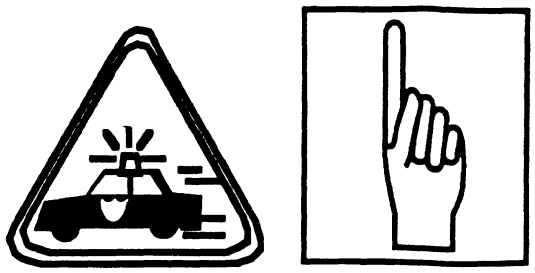
The grid design was taken literally, as one subject thought it represented an upcoming intersection, where another thought the police were in a chase. The car in the location hazard was intended to represent the driver's vehicle, but some ambiguity resulted. It was unclear to one subject if the car shown was the police car or her own car. See figure 87.



S #	Response
1	Police car at next intersection ahead.
11	Police car in pursuit, chasing.

Figure 87. Responses to the "grid" location design.

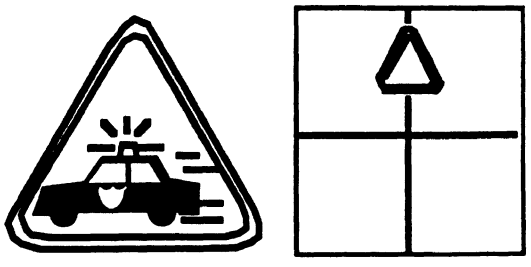
The hand design was understood to be a command from the police for drivers to stop. See figure 88. It seems likely that if the hazard were different, the response would also have differed, since it is not uncommon for police to direct traffic or to gesture for a driver to pull over.



S #	Response
8	[I'd] better stop for police car.
18	Police car--caution! I don't know what the hand is--Stop??

Figure 88. Responses to the "hand" location design.

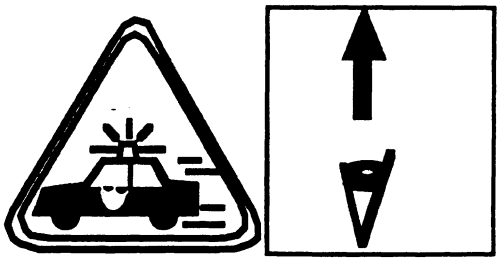
The response to the plot design was similar to that of the grid. One subject thought it meant a police car was beyond the intersection ahead, but was not sure. The other was equally uncertain, but the response implied that the driver expected to encounter a police car. See figure 89.



S #	Response
10	Be prepared for police--I guess it is a school zone.
20	Police car--I don't know what this is--I bet it meant ahead of next intersection.

Figure 89. Responses to the "plot" design.

The eye design proved to be the most perplexing, with both subjects making comments to that effect. See figure 90. One conjectured that an emergency vehicle was approaching from the rear, while the other did not mention location at all. By far, this one generated the most confusion.



S #	Response
2	Egad! Police vehicle. I don't understand.
12	Confusing. Emergency vehicle approaching--maybe from rear. That's strange.

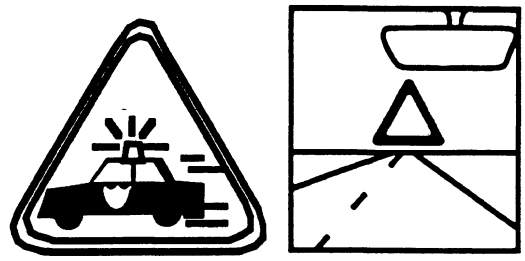
Figure 90. Responses to the "eyes" location design.

The text design was clearly understood by both who saw it. They gave the shortest and simplest responses, as shown in figure 91.

S #	Response
6	Police ahead.
16	Police car ahead.

Figure 91. Responses to the "text" location design.

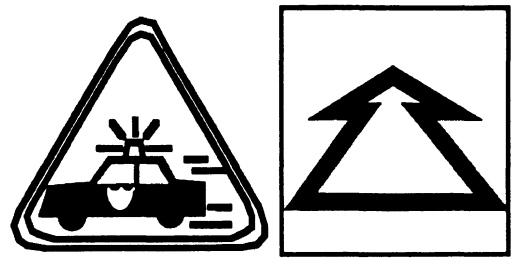
The responses to the windshield design were consistent, yet the opposite of the intended meaning, as shown in figure 92. It seems that the presence of the rearview mirror caused the drivers to believe the hazard was behind them, although the hazard did not "appear" in the mirror.



S #	Response
9	Watch for police coming from behind.
19	Slow down, a cop coming behind me.

Figure 92. Responses to the "inside-out" location design.

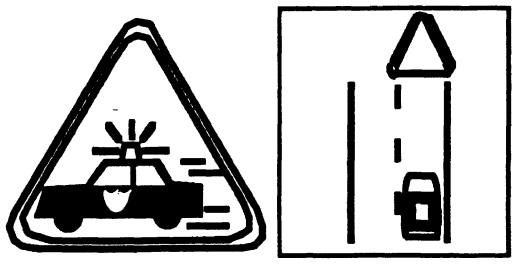
The perspective arrow design generated conflicting responses that tend to occur from arrow designs. See figure 93. One assumption is that the arrow is a command to the driver, while another assumption concerns the location or movement of the hazard. Here, one subject thought the arrow was directing them to continue straight ahead. The other subject (correctly) said that the police car was straight ahead, also noting its speed.



S #	Response
3	Yield to cops--[I should] go straight.
13	Hmmm. Police car straight ahead, cruising along.

Figure 93. Responses to the "perspective arrow" location design.

The overview design caused some confusion regarding the vehicle in the location cue. See figure 94. One of the subjects correctly stated that it meant a speeding police car ahead, but added that he did not understand it. The other hesitated before saying to yield because there was an emergency vehicle and an accident. The second subject seemed to interpret the vehicle as the police car (instead of his own vehicle), and the triangle as an accident.



S #	Response
7	Speeding police car ahead of me. I don't understand.
17	Hmmm. Kind of weird. [I should] pull over to side. Emergency vehicle. There's an accident.

Figure 94. Responses to the "overview" location design.

The regular arrow design evoked the conflicting responses typical to arrow cues, as shown in figure 95. One person thought that he should continue driving straight. The other person hinted at the idea that the vehicle was ahead, but going to cross her path, presumably at the upcoming intersection.

S #	Response
4	Emergency vehicle is crossing. I'd yield for the flashing car, if there was one.
14	Police car with flashing lights--[I should] continue straight ahead.

Figure 95. Responses to the "arrow" location design.

Overall, the designs from the text category (o'clock and text) were most clearly understood. The "at 12 o'clock" design and "ahead" text messages were unambiguous to those subjects who saw them. The overview designs (plot, grid, overview) proved to be confusing, with the vehicle shown in the location symbol being too ambiguous. In addition, the lines marking relative quadrants around the vehicle were interpreted too literally. For example, drivers thought the grid design represented an intersection. There were a number of problems surrounding two of the arrow designs (perspective and regular arrow). Some subjects interpreted the arrow as a command for them to move in that direction, rather than the arrow indicating the location of the hazard. Some subjects also said the arrow indicated a vector, either the direction of movement of the vehicle or its speed.

Perhaps some of the overall confusion in this part of the study resulted from the use of the moving police car as the hazard. If a stationary (or a less anxiety producing) hazard were used, it is possible that the results would have differed.

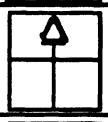
Part 3 - Hazard Location Accuracy

In determining if responses were correct for this part of the experiment, responses that included a side component were combined. For example, "to the left" and "ahead to the left" were considered equivalent because of the difficulty in distinguishing these locations for coding. Subjects might say the hazard was "to the left," yet point in a direction that was "ahead to the left," perhaps because the intersection was slightly ahead (yet also to the side) of the vehicle. Figure 96 demonstrates the ambiguity between a verbal and gestured response for "to the left."

Figure 96. Subject's response to a hazard located "on the left," illustrating a coding ambiguity that led to combining responses for "to the left [right]" and "ahead to left [right]".

Percent correct responses to hazard location cues for each design appear in table 14. Table 14 also shows the percent of responses in which subjects implied a direction of motion of the hazard. (The location cues were intended to provide only the location of the hazard relative to the driver's vehicle; however some subjects' free response included comments on motion.) Also in this table is the percentage of infeasible locations described by subjects, responses where subjects failed to stay within the possibilities allowed by the streets and intersections of the test area. Responses included reporting the hazard to be "...On the grass on my right," "...Under me, if on a bridge," or "...Coming from the house."

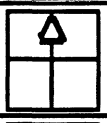
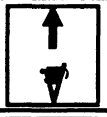
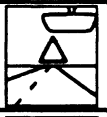
Table 14. Location cue designs listed in order of percent correct, with the corresponding percentage of responses involving movement and inapplicability.

Design Icon	Design # & Design name	Format	% of responses with correct hazard location	% of responses that included direction of movement of hazard	% of responses incorporating infeasible or inapplicable situations
	(6) Text	Text	100.0	25.0	5.0
	(1) O'clock	Text	93.8	23.8	8.8
	(4) Plot	Overview	92.5	31.3	18.8
	(9) Overview	Overview	83.8	32.5	23.8
	(2) Grid	Overview	82.5	35.0	32.5
	(7) Windshield	Inside-out	77.5	30.0	20.0
	(3) Hand	Arrow	75.0	30.0	18.8
	(5) Eye	Arrow	67.5	30.0	20.0
	(8) Perspective	Arrow	66.3	43.8	13.8
	(10) Arrow	Arrow	58.8	43.8	13.8

Overall, the two designs within the text format (text and o'clock) were superior. These two designs produced the highest percentage of correct responses, and also the lowest percentage of both movement and inapplicable responses. Of the two, the text design clearly was the best, with the highest percentage of correct hazard location responses (100 percent), and the lowest percent of infeasible responses (5 percent). It also produced the second lowest percentage of responses implying movement of the hazard (25 percent). Interestingly, the results of percent correct, as arranged from best to worst, also are grouped by format. The 2 text designs were best, followed by the 4 overview designs, the inside-out design, and lastly the 3 arrow designs.

The percentage of correct responses for each of the six hazard locations was tabulated for each of the designs. These totals are presented in table 15. Because the side locations were randomly selected for each design (for example, either to the right, or to the left), an unequal number of systems were tested for right and left locations. This makes a comparison of response accuracy among the locations difficult.

Table 15. Percent correct responses by hazard location relative to driver's vehicle.

Design Icon	Design	Hazard location					
		Behind	Ahead	To the Left	To the Right	Ahead to Left	Ahead to Right
	(1) O'clock	90	90	n/a	95	100	n/a
	(2) Grid	75	90	75	n/a	90	n/a
	(3) Hand	65	70	75	n/a	90	n/a
	(4) Plot†	90	95	n/a	90	n/a	95
	(5) Eye	55	65	n/a	70	n/a	80
	(6) Ahead	100	100	n/a	100	100	n/a
	(7) Windshield	90	60	95	n/a	65	n/a
	(8) Perspective	50	80	65	n/a	n/a	70
	(9) Overview	89†	84††	n/a	70	95	n/a
	(10) Arrow	60	55	55	n/a	65	n/a

n/a = not applicable (this location was not shown for this design)

† Within this location design, 11 subjects saw "ahead" twice instead of "behind." "Behind" was seen by only nine subjects.

†† "Ahead" was seen twice by 11 subjects.

In the ANOVA of the correct responses to the hazard location cues (table 16), the effects of driver age (younger or older), driver sex, design, and all combinations of these were examined. Age, sex, and design differences were all highly statistically significant. Young subjects did better than older subjects (89 percent versus 71 percent), and men did somewhat better than women (84 percent versus 76 percent). See table 17.

Table 16. ANOVA of correct responses to hazard location cues.

Factor	Degrees of Freedom	Sum of Squares	Mean Square	F value	p
Age	1	6.125	6.125	39.715	0.000*
Sex	1	1.445	1.445	9.026	0.003*
Design	9	12.745	1.416	9.607	0.000*
Age*Sex	1	3.125	3.125	20.992	0.000*
Age*Design	9	1.375	0.153	1.094	0.365
Sex*Design	9	1.755	0.195	1.343	0.211
Age*Sex*Design	9	1.925	0.214	1.614	0.107

* Effect is statistically significant at $p<0.05$

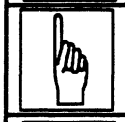
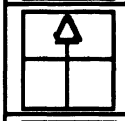
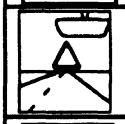
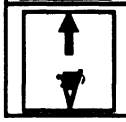
Table 17. Percent correct location responses overall, by sex and age. (n=20)

		Sex		
		Males	Females	Mean by age
Age	Younger	86.5	90.5	88.5
	Older	81.5	60.5	71.0
	Mean by Sex	84.0	75.5	

Differences among designs were highly statistically significant at the $p<0.001$ level. The percentage of correct hazard location responses ranged from 58.8 percent to 100 percent. The text design, with perfect results, clearly was the best.

In the preference rankings, the text design was preferred, though preference varied considerably across individuals, as shown in table 18. A Kruskal-Wallis analysis shows that there was no statistical significance among the designs based on rank. The text design received the most number one rankings (seven), and the best overall mean rank (3.3).

Table 18. Number of design preference rankings 1st to 10th (best to worst) received by each design, shown in order of preference.

H(9)=16.7, p=0.0543		Count of Rankings Best ----------> Worst										
Icon	Design # & Name	1	2	3	4	5	6	7	8	9	10	Mean
	(6) Text	7	2	1	4	3	1	1	1	0	0	3.30
	(10) Arrow	5	5	1	2	1	4	1	1	0	0	3.50
	(9) Overview	2	2	2	3	4	1	4	1	1	0	4.75
	(3) Hand	2	3	3	3	1	3	1	0	4	0	4.75
	(2) Grid	1	2	2	2	2	3	2	4	2	0	5.55
	(8) Perspective	1	2	3	2	2	2	3	1	2	2	5.55
	(4) Plot	0	1	2	2	4	2	2	3	1	3	6.25
	(1) O'clock	2	0	4	0	2	1	1	2	3	5	6.50
	(7) Windshield	0	2	1	1	1	1	3	4	6	1	6.95
	(5) Eye	0	1	1	1	0	2	2	3	1	9	7.90

Responses to Meaning of Triangle

Some subjects gave more than one response to "what did the triangle mean to you," and therefore the total number of responses is more than 20. All responses are shown in table 19.

Table 19. Responses to the meaning of the triangle.

Count	Response
10	Indicated a hazard.
8	Yield to hazard, slow down, or caution.
5	Similar to existing signs (yield sign, upside-down yield sign, or reflective triangle on rear of slow-moving vehicle).
1	Position or location indicator for hazard on location symbol.

The responses to triangles suggested that it was ambiguous to some subjects. A few mentioned that an existing sign, as an indicator of slow moving vehicles, was inconsistent with its association here with a speeding emergency vehicle. For those who understood it to be a position indicator on the location cue, this was also a problem. Within part 3, some subjects did not correctly interpret the triangle to be the hazard location marker in the overview designs, and instead interpreted it as a separate incident, for example, an accident that the emergency vehicle was attending.

Conclusions from Field Experiment

Overall, the hazard symbols were understood adequately. Perhaps the specific activity of the emergency vehicle would be better conveyed if a color symbol were used, or if drivers saw an actual hazard and its symbol together. Where two versions were tested for the "train at crossing" hazard, the text version was clearly understood by more drivers. The text message, therefore, is recommended over its graphic counterpart.

Of the location designs examined, the text design (left, right, ahead, behind, ahead to the left, ahead to the right) led to the best performance (no errors) and was preferred by drivers, though the differences in preferences were not significant. Text for indicating relative hazard location is therefore recommended. Following were overview, inside-out, and arrow designs, in that order. In several cases for the poorer designs, the interpretation given by drivers was exactly the opposite of that intended. Interestingly, preferences were not consistent with performance. Specifically, while the arrow design received the second best mean preference rank, it produced the most performance errors.

A general sense of the triangle as a hazard warning was conveyed, yet the additional inconsistency of associating a "slow moving vehicle" sign with a high speed vehicle led to some confusion. As a result, the triangle should not be used as a frame around moving emergency vehicles.

Appendix A - IVSAWS Population Stereotype Method Study Survey Form

Development of Symbols for a Road Hazard Advanced Warning System

Paper Interview by:
Marie Williams
Paul Green

INSTRUCTIONS

A system is under development which will alert drivers about potentially hazardous situations ahead. This system may be in future cars that you will drive. The symbols for warnings will appear on a display mounted on top of the instrument panel.

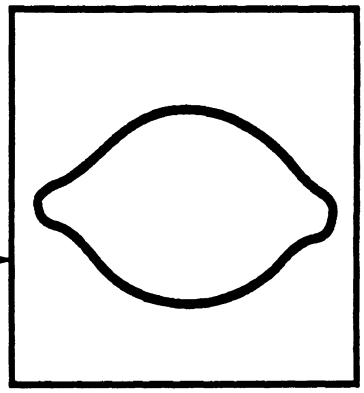
Following are descriptions of potentially hazardous circumstances for which symbols are needed. In each box, draw what you feel the warning symbol should look like. Keep the drawings as simple as possible. Don't be concerned about the drawing quality as it is the concept we are interested in.

Please complete the symbols in the order given.

Example

You are driving on a highway approaching a Yugo.

The symbol should be →



Situation: Driving on an Expressway - Road Construction

1. You are approaching an area where there is road construction.

The symbol should be →

2. You are approaching construction where the speed limit is a maximum of 45 miles per hour.

The symbol should be →

Situation: Dangerous Curve

3. You are approaching a curve; if you drive faster than 30 miles per hour you may lose control of your car and go off the road.

The symbol should be →

Situation: Accident Ahead

4. You are driving on a highway, there is an accident ahead of you.

The symbol should be →

Situation: Emergency Vehicles

5. An ambulance is approaching you at high speed with its siren and flashers on.

The symbol should be →

6. Ahead of you an ambulance is parked with its flashers on.

The symbol should be →

7. A fire truck is approaching you at high speed with its siren and flashers on.

The symbol should be →

8. Ahead of you a fire truck is parked with its flashers on.

The symbol should be →

9. A police car is approaching you at high speed with its siren and flashers on.

The symbol should be →

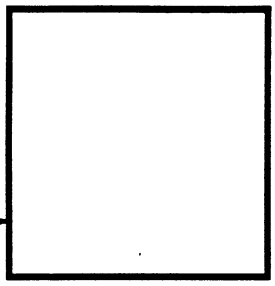
10. Ahead of you a police car is parked with its flashers on.

The symbol should be →

Situation: Emergency Vehicles continued

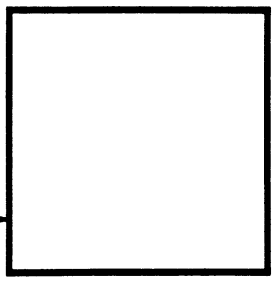
11. A police car chasing a fleeing suspect at high speed is approaching you with its siren and flashers on.

The symbol should be →



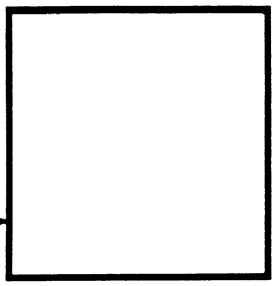
12. A police car is approaching you <u>from the right</u> at high speed with its siren and flashers on.

The symbol should be →



13. A police car is approaching you <u>from behind</u> at high speed with its siren and flashers on.

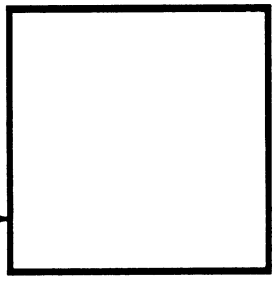
The symbol should be →



Situation: Railroad crossings

14. Ahead of you is a railroad track with a train approaching.

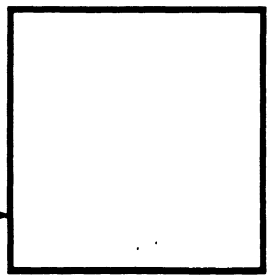
The symbol should be →



Situation: Special Vehicles

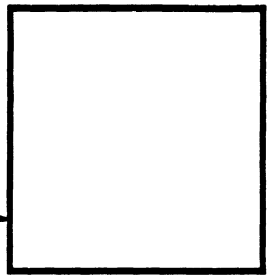
15. You are approaching a school bus loading or unloading children.

The symbol should be →



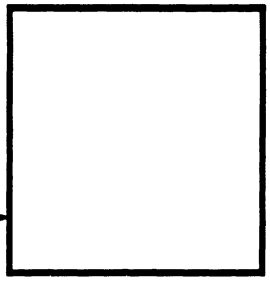
16. You are approaching a slow moving vehicle driving much slower than you are.

The symbol should be →



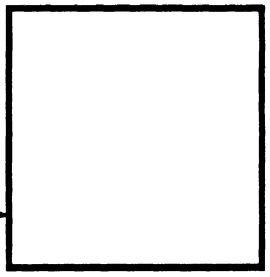
17. You are driving on a rural road approaching a farm vehicle from behind driving much slower than you.

The symbol should be →



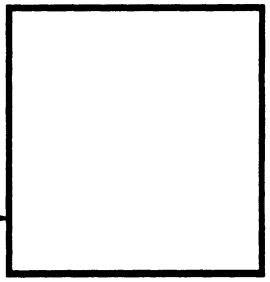
18. You are driving on the expressway approaching a truck hauling a house and occupying most of both lanes.

The symbol should be →



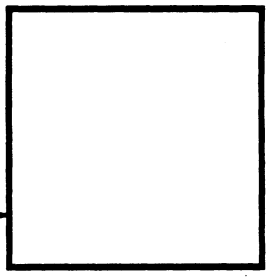
19. You are driving on a suburban street. A mail delivery vehicle is driving along the edge of the road ahead of you and may stop at any moment.

The symbol should be →



20. You are driving on a suburban street. A trash truck is driving ahead of you and may stop at any moment.

The symbol should be →



Situation: Special Vehicles continued

21. You are driving in the winter approaching a plow/gravel vehicle plowing and/or sanding the road ahead of you.

The symbol should be →

22. On the road ahead of you a utility company vehicle (phone, gas, electric, water, cable, etc...) is parked on the road and workers are working near it.

The symbol should be →

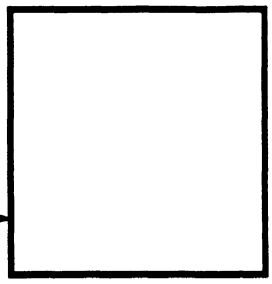
23. You are approaching a tow truck on the roadside with its flashers on hooking up a disabled vehicle.

The symbol should be →

Situation: Driving on a City Street: unexpected signals and signs

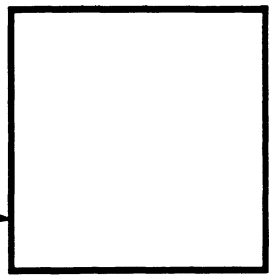
24. The traffic light you are approaching is out of order.

The symbol should be →



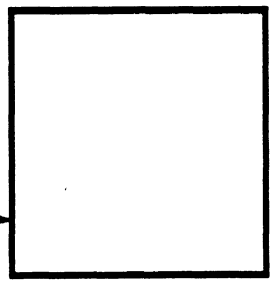
25. At the next intersection is a traffic light that you are not expecting because it was just installed.

The symbol should be →



26. At the next intersection is a stop sign that you are not expecting because it was just put up.

The symbol should be →



Situation: Generic Hazard, Lane and Direction Information

27. You are driving on a three lane expressway, ahead of you the right lane will be closed or blocked and the two left lanes will be open.

The symbol should be →

28. You are driving on a two lane expressway, ahead of you both lanes will shift/jog to the right.

The symbol should be →

29. You are driving on a four lane highway, the hazard is ahead of you but in the lanes going in the opposite direction.

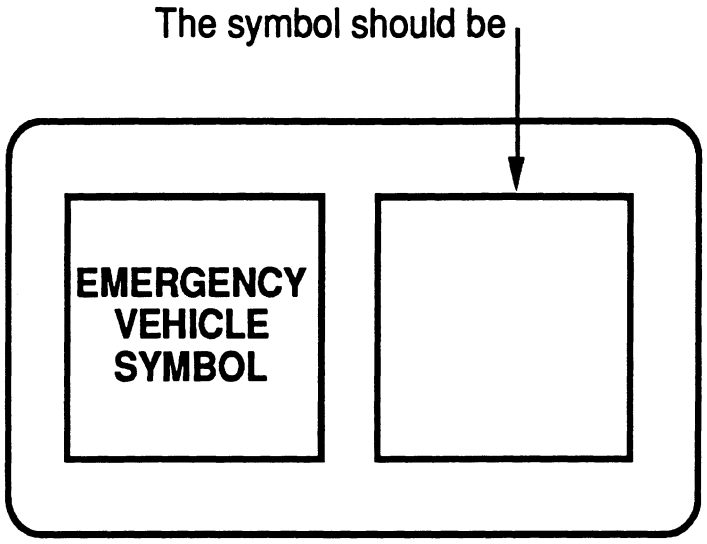
The symbol should be →

30. The hazard is exactly 1 mile ahead of you.

The symbol should be →

Say the design of the system is as follows:

The display shows two icons, one is the type of warning and the other is extra information regarding the warning. In the case of an emergency vehicle the left hand icon would indicate which kind of vehicle and the right hand icon would indicate the direction of the emergency vehicle's approach to your car. Draw how you think the icon should appear if the emergency vehicle is approaching you from the right.



Name _____

Age _____

Male Female

How long have you been a licensed driver? _____

Number of miles driven yearly? _____

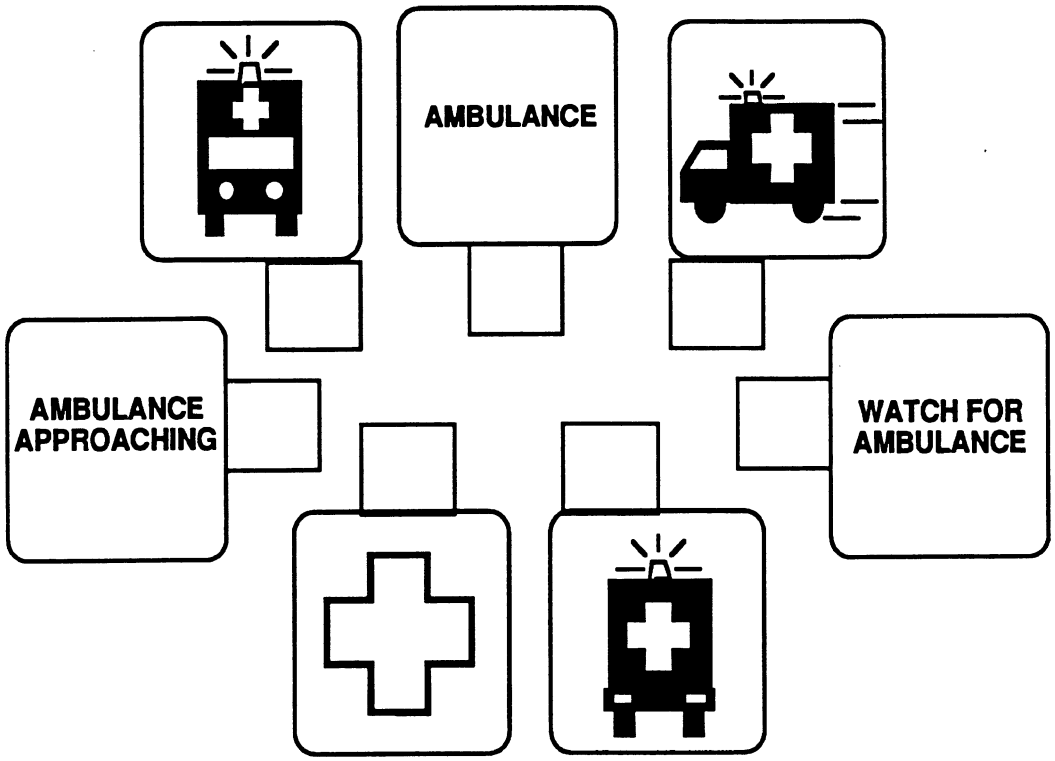
Primarily drive on what kind of roads?
City Rural Expressway

What percent of your driving is at night? _____

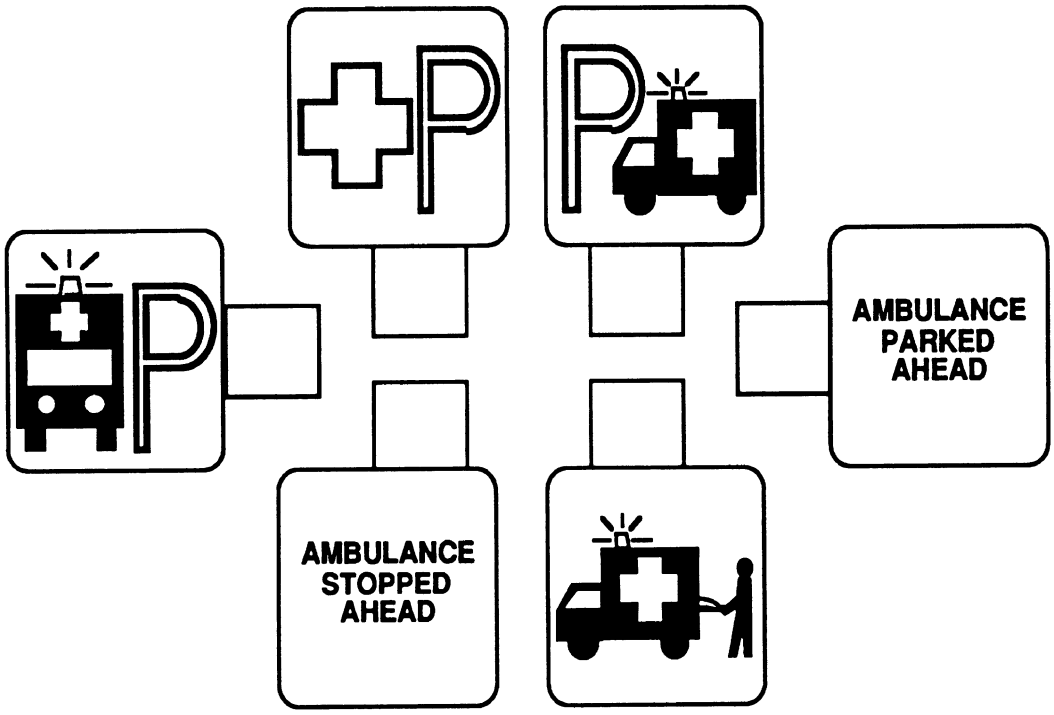
Appendix B - IVSAWS Testing at Driver Licensing Office Ranking Forms

IVSAWS Emergency Vehicles Preference Form

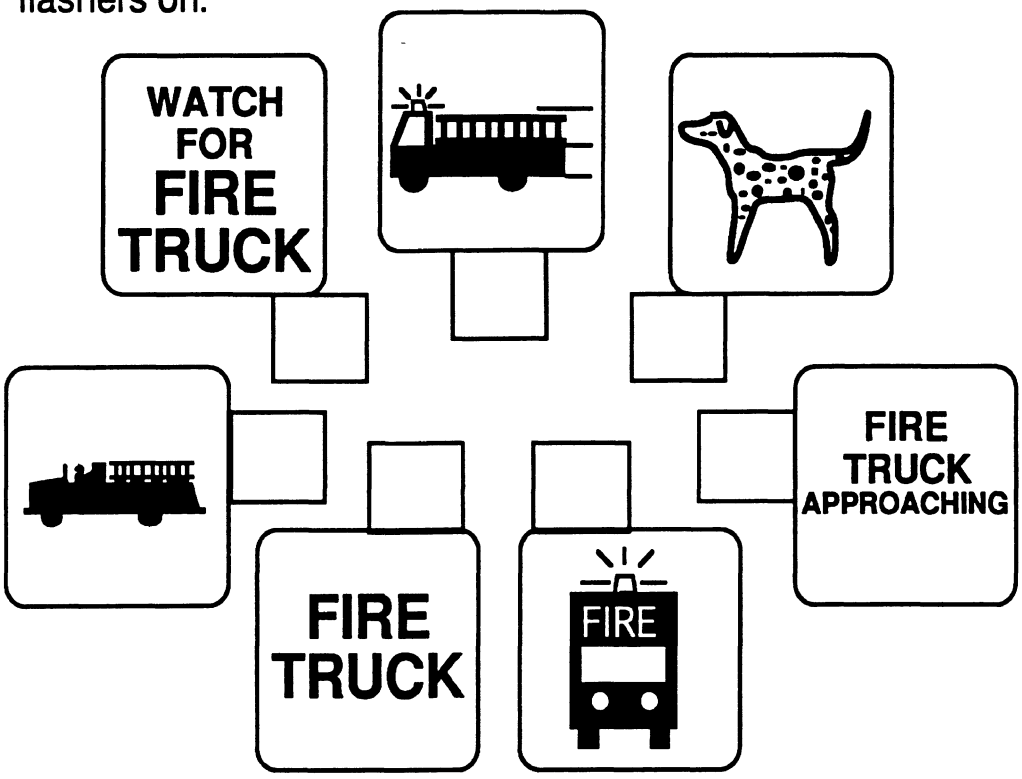
1. An ambulance is approaching you at high speed with its flashers on.



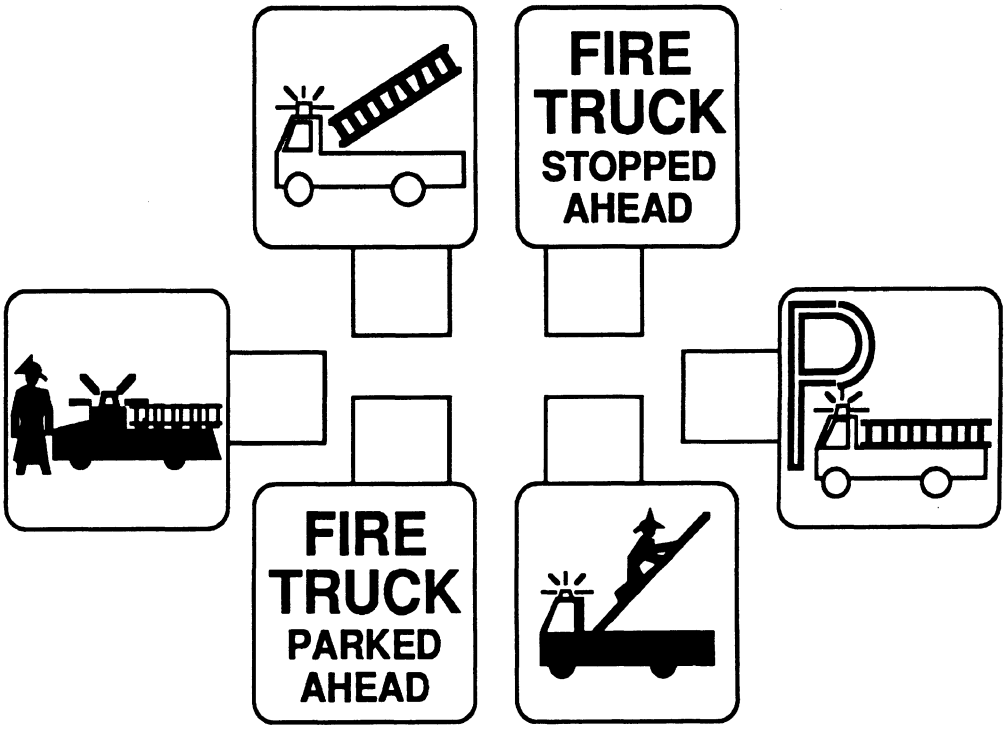
2. An ambulance is by the side of the road ahead.



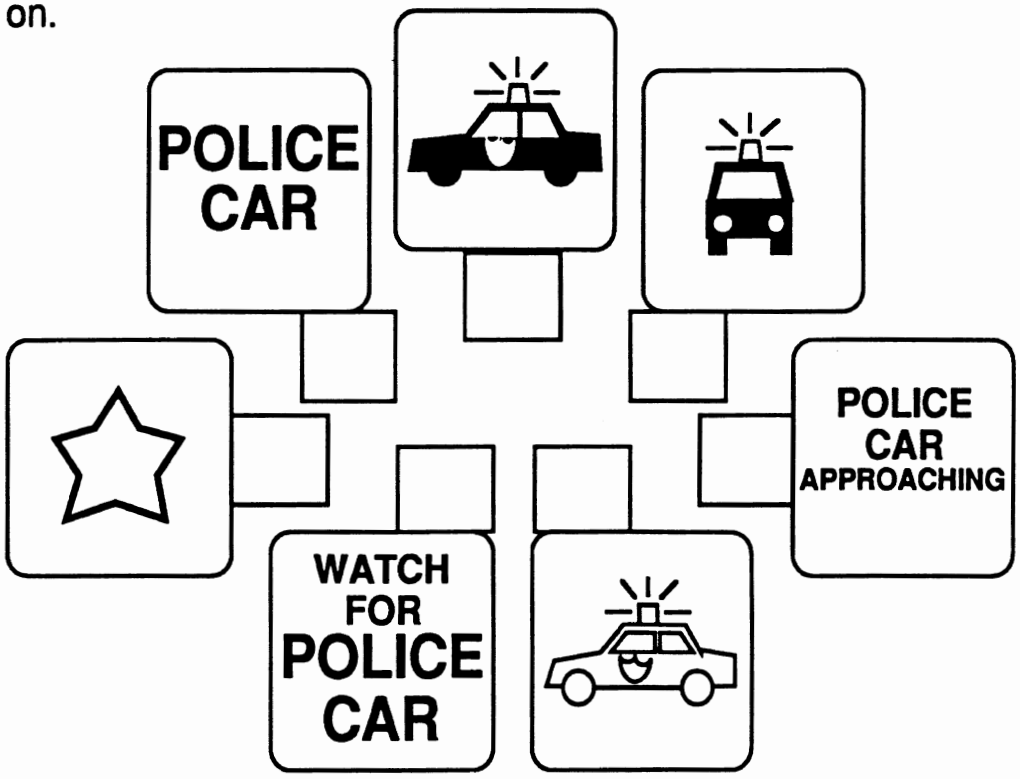
3. A fire truck is approaching you at high speed with its flashers on.



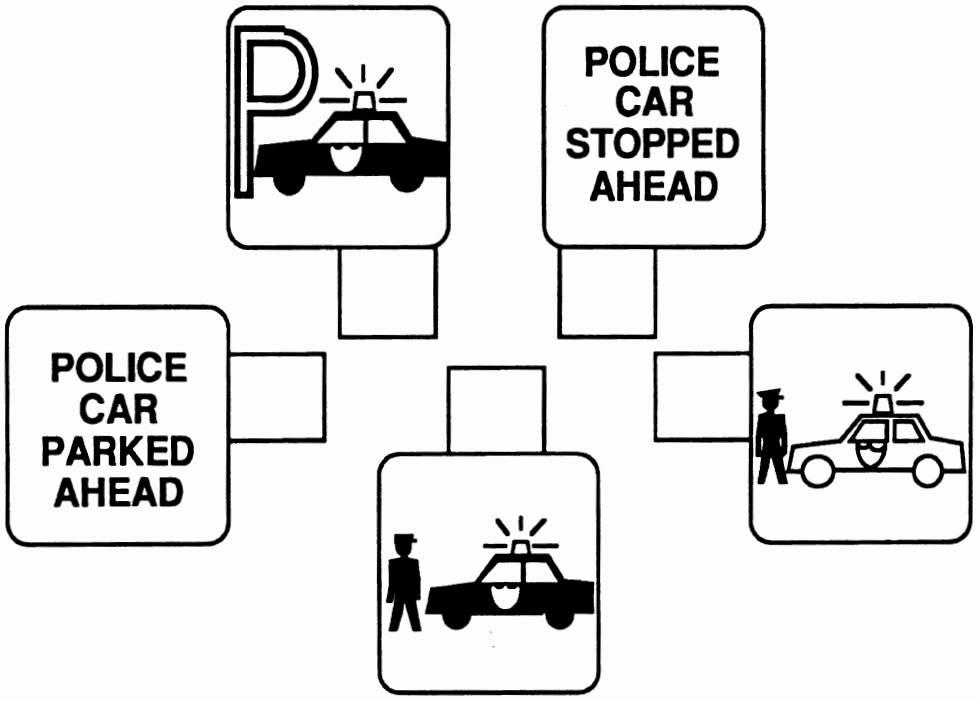
4. A fire truck is by the side of the road ahead.



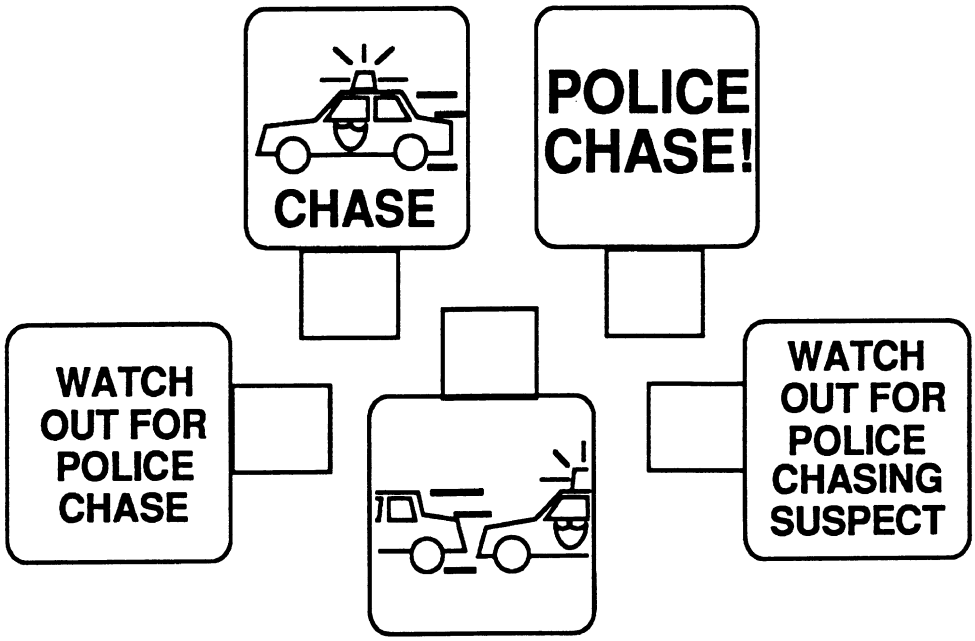
5. A police car is approaching you at high speed with its flashers on.



6. A police car is by the side of the road ahead.

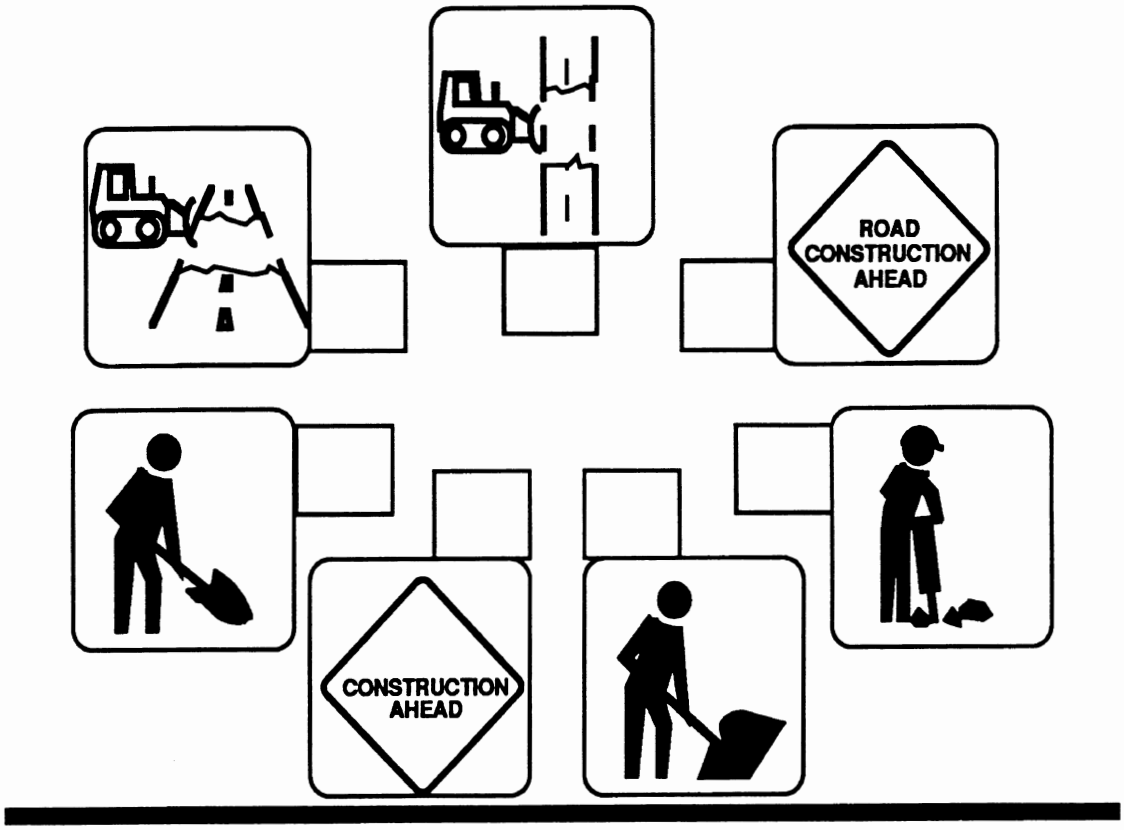


7. A police car chasing another vehicle is approaching you at high speed with its flashers on.

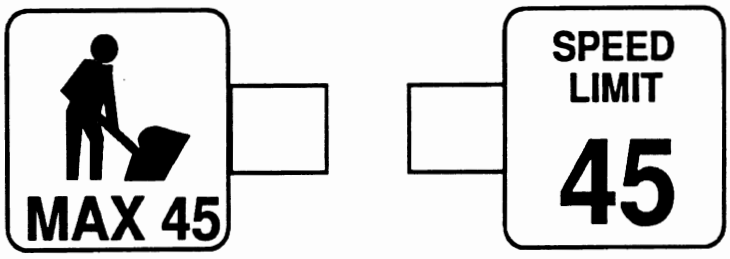


IVSAWS In-Car Signing Preference Form

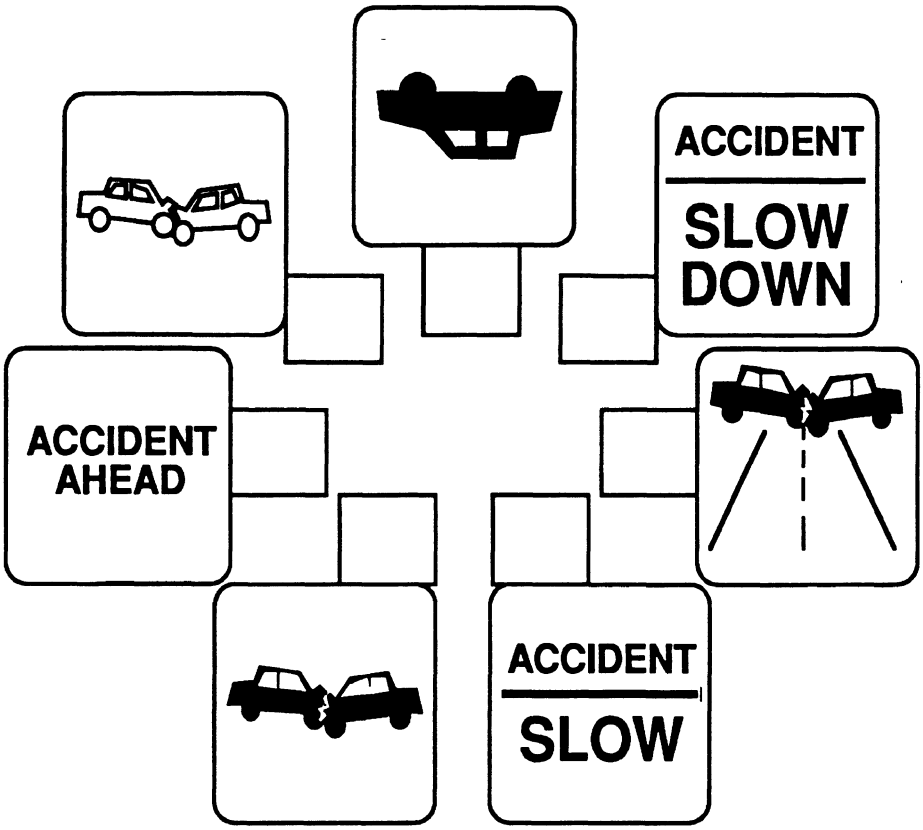
1. Approaching an area where there is road construction.



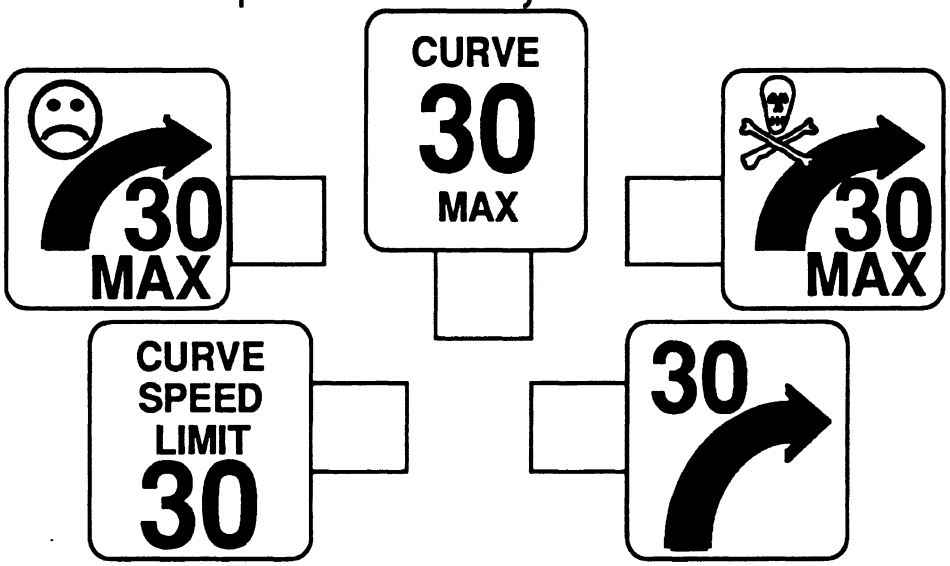
2. Approaching construction where speed limit is a maximum of 45 miles per hour.



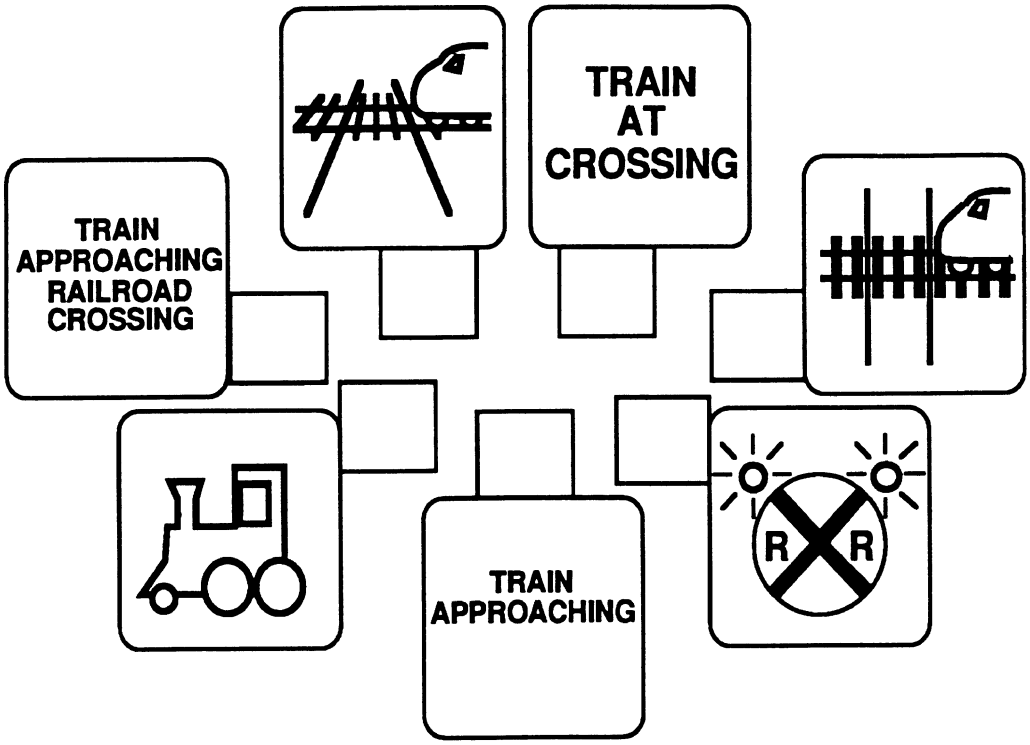
3. There is an accident ahead of you.



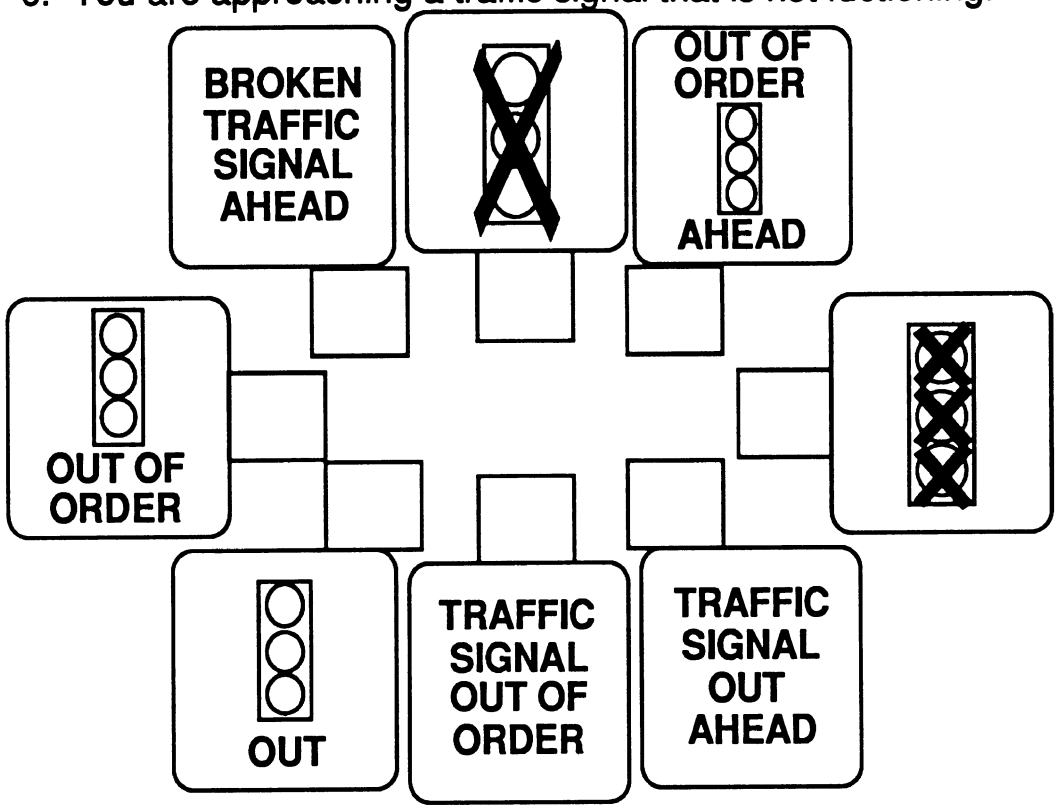
4. There is a sharp curve ahead of you.



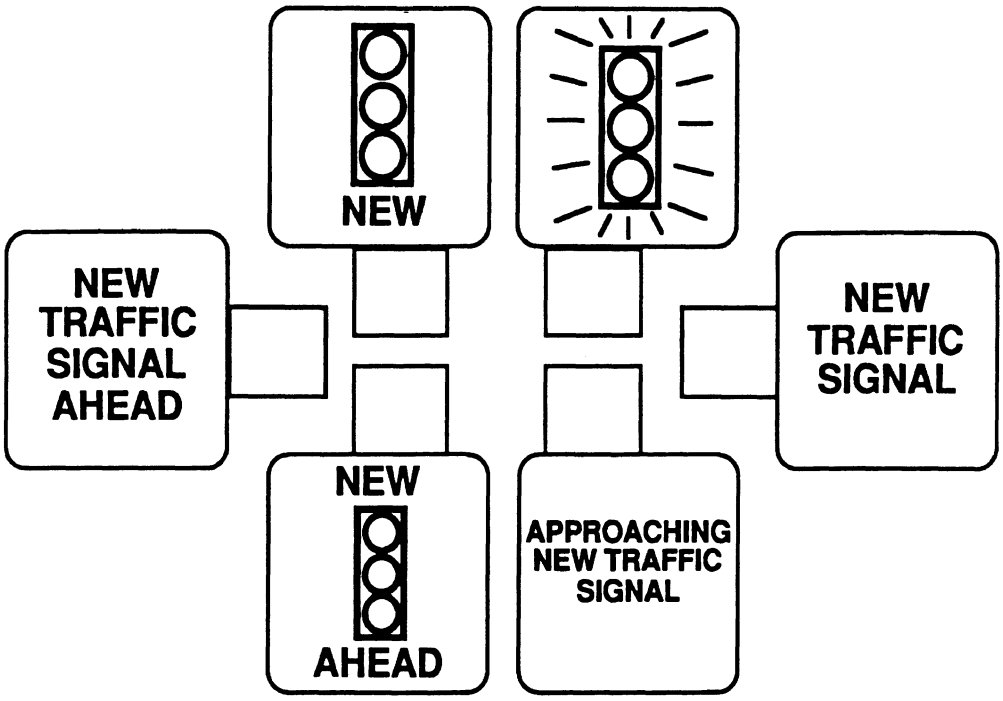
5. Ahead of you is a railroad track with a train approaching.



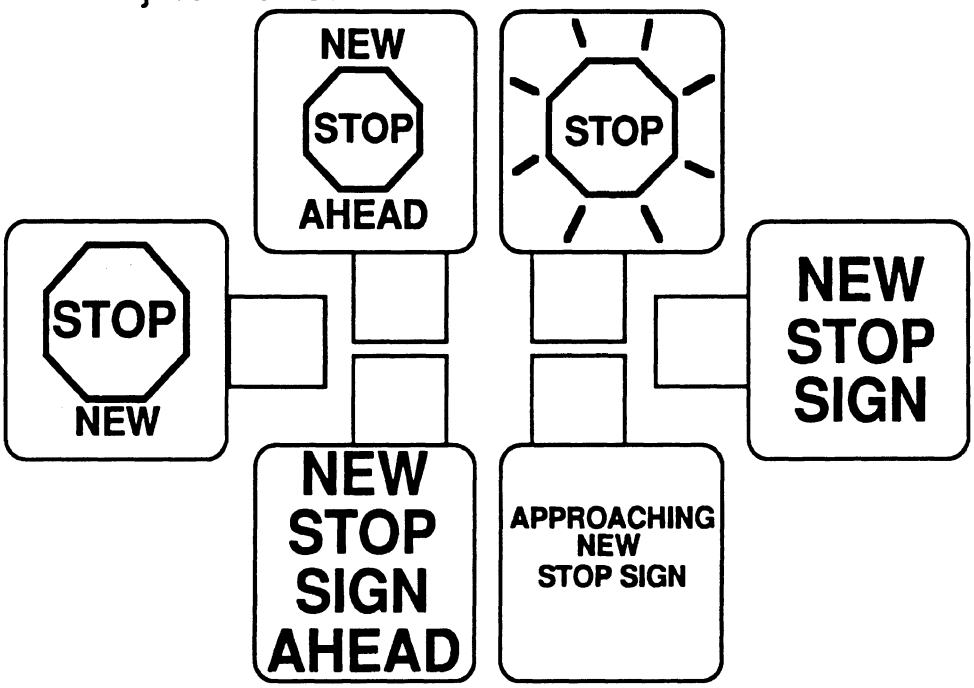
6. You are approaching a traffic signal that is not fuctioning.



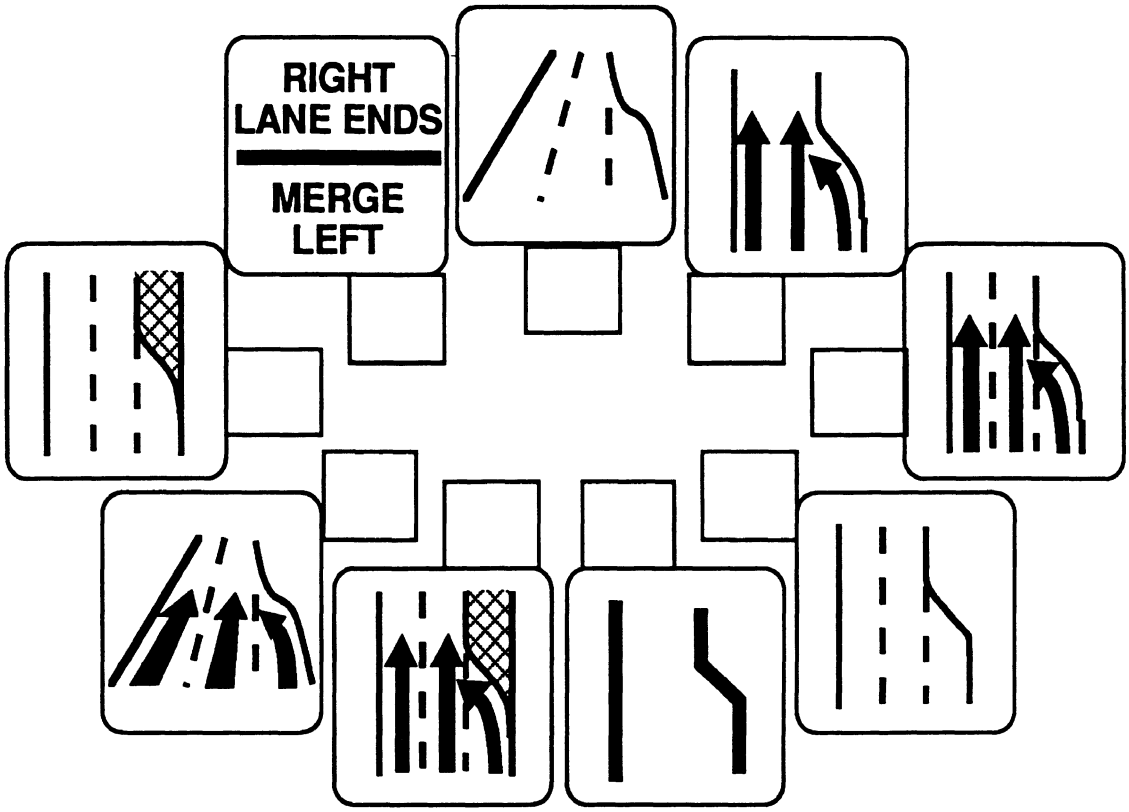
7. You are coming to a traffic signal you are not expecting because it was just installed.



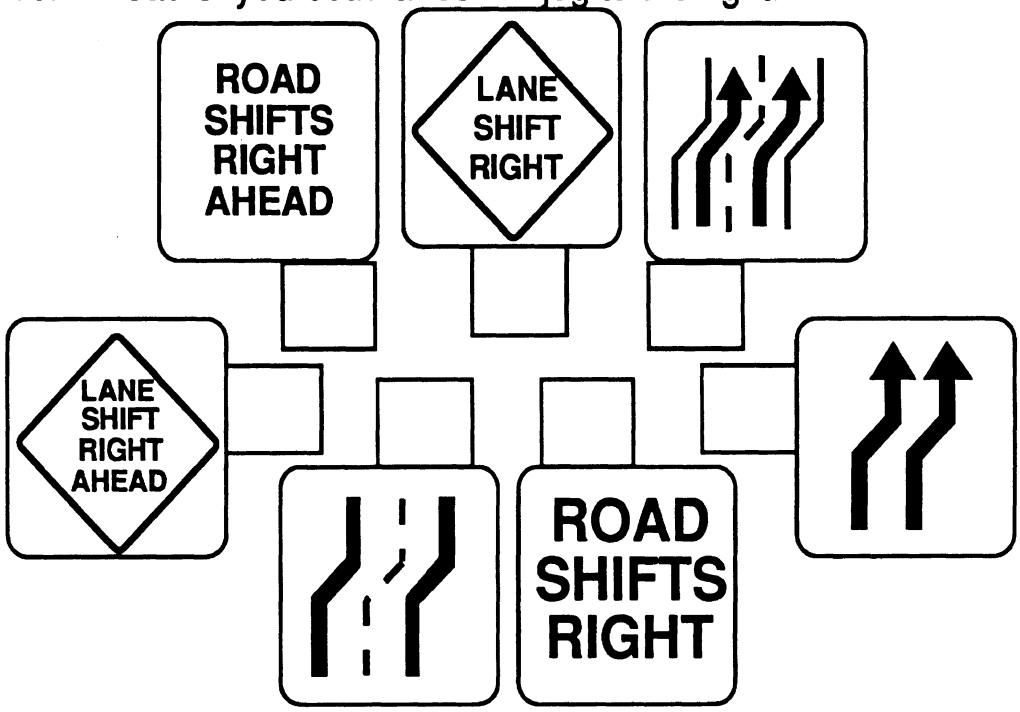
8. You are coming to a stop sign you are not expecting bacause it was just installed.



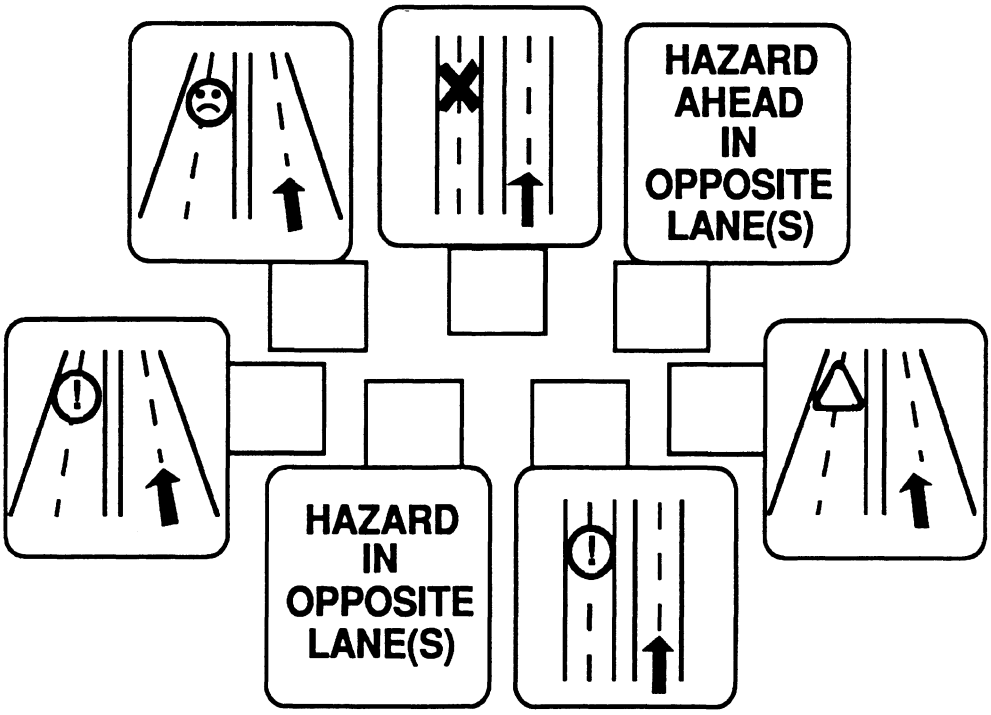
9. Ahead of you the right lane is going to merge into the center lane.



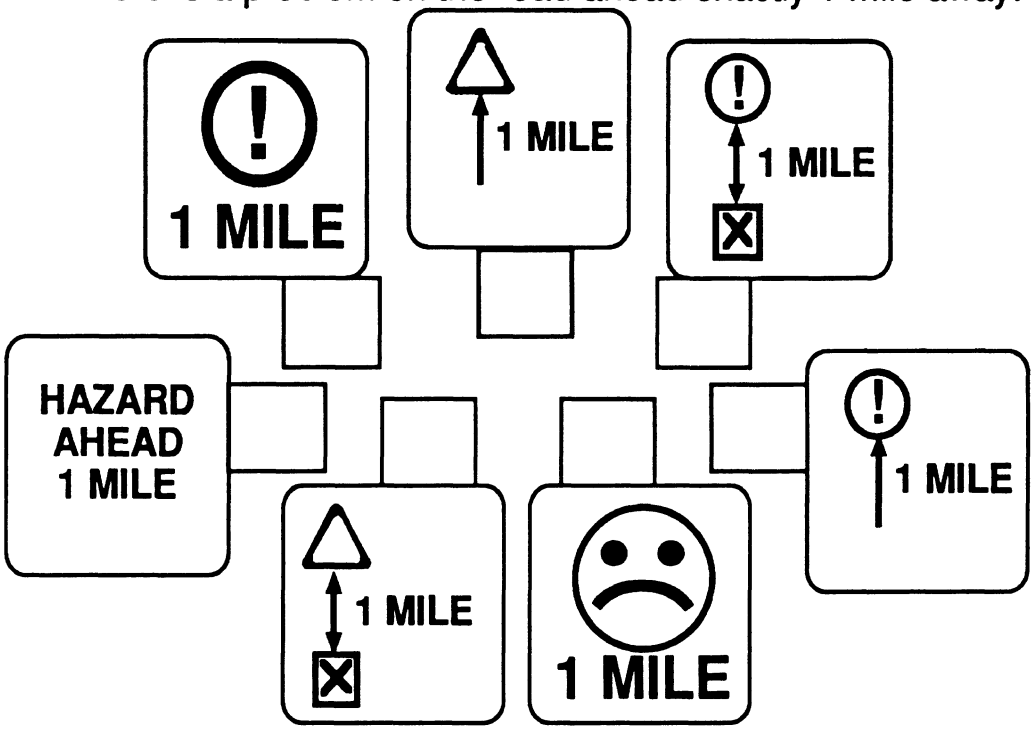
10. Ahead of you both lanes will jog to the right.



11. There is a problem ahead of you, but it is only in the traffic lanes going the other way.

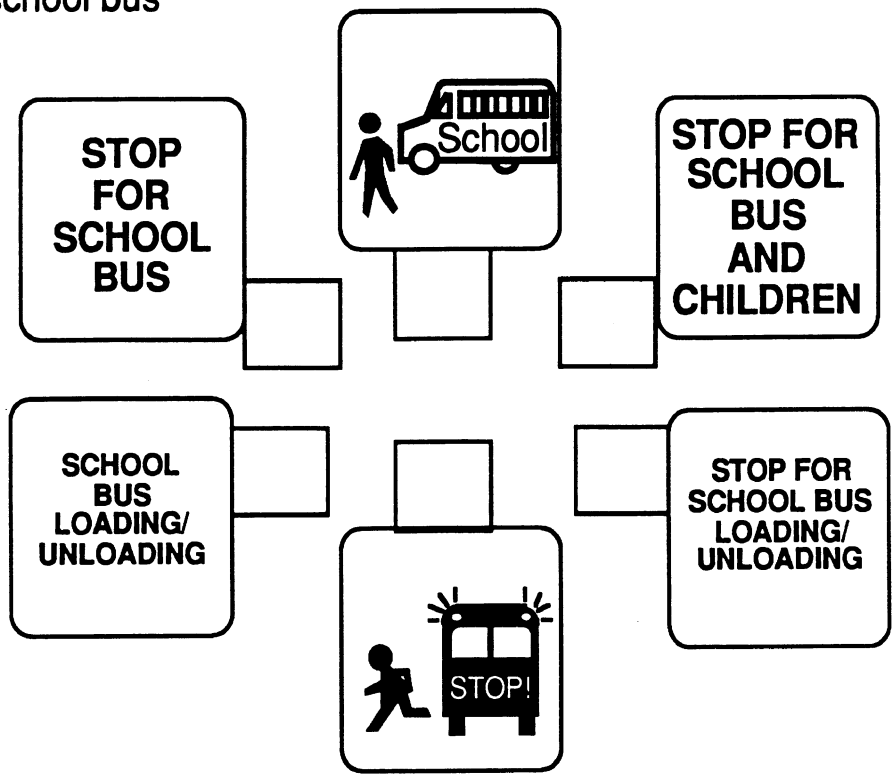


12. There is a problem on the road ahead exactly 1 mile away.

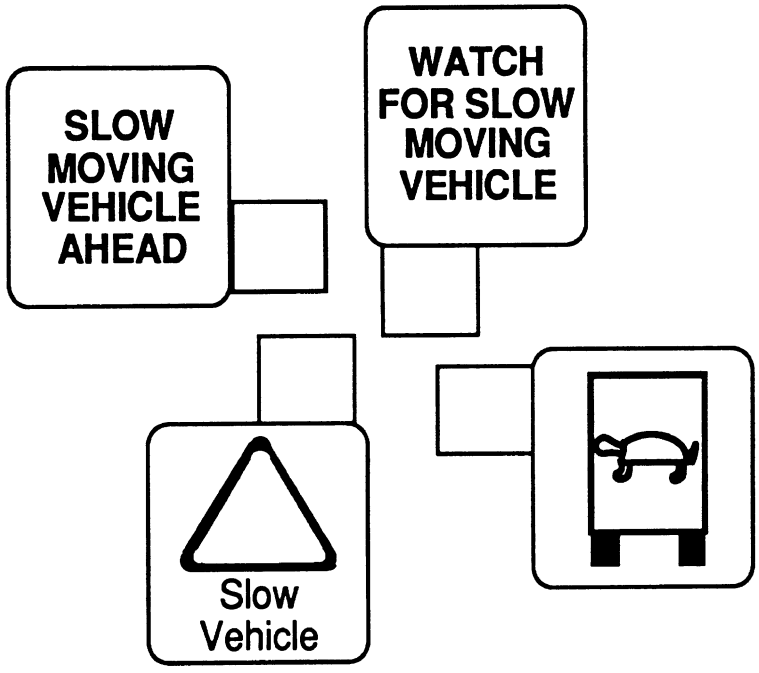


IVSAWS Atypical Vehicles Preference Form

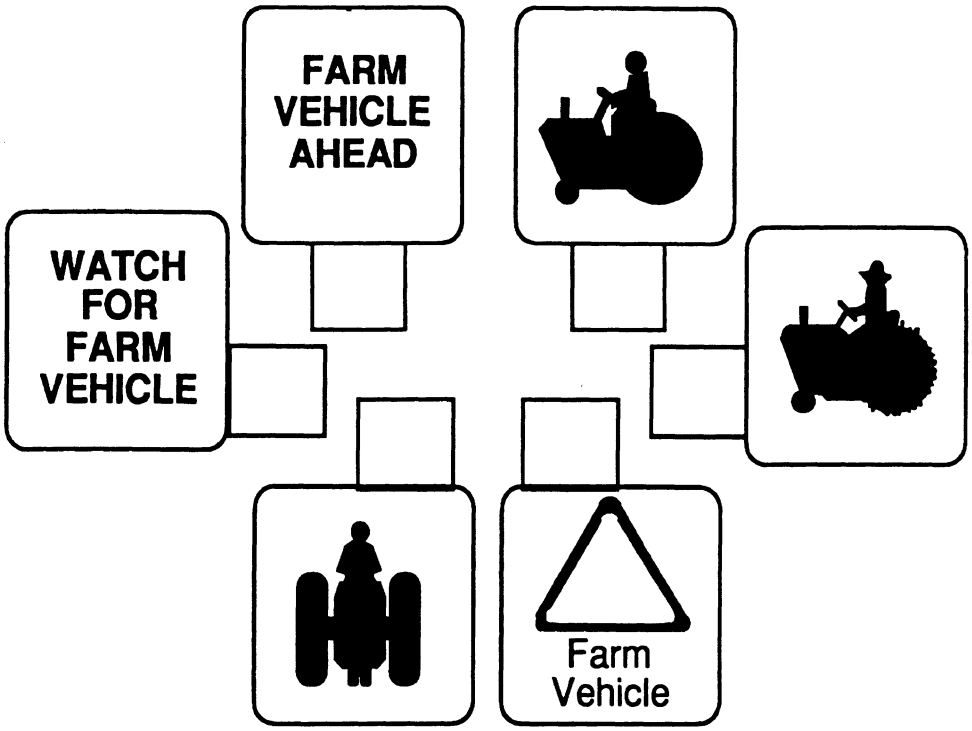
1. Ahead of you children are boarding or unboarding from a school bus



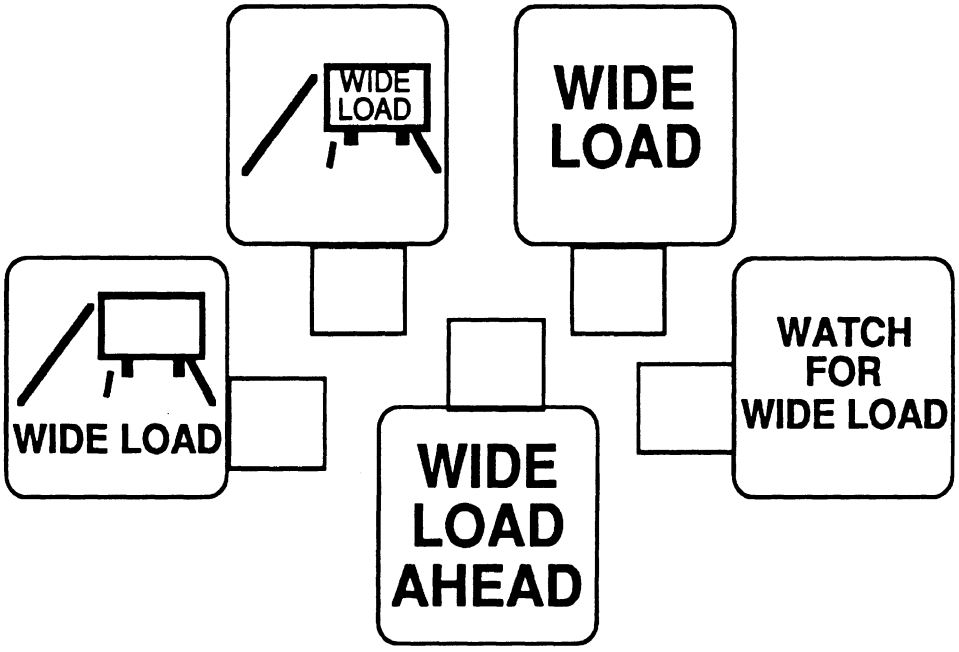
2. You are approaching a slow moving vehicle.



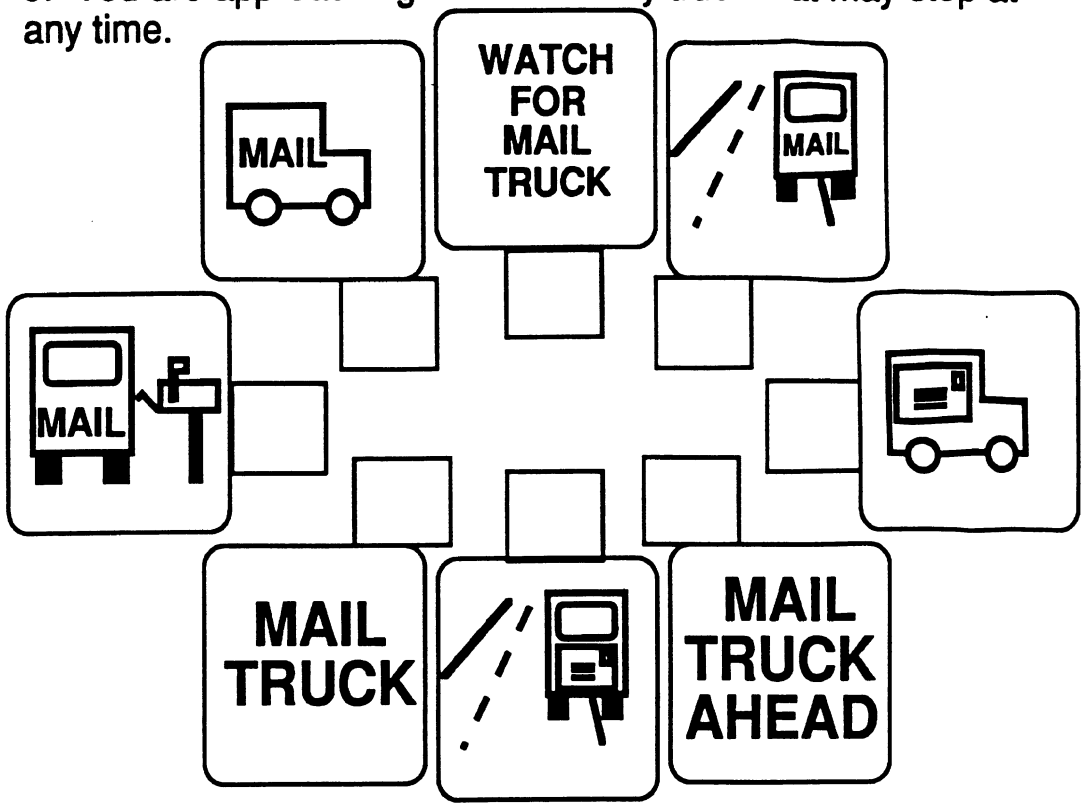
3. You are approaching a farm vehicle.



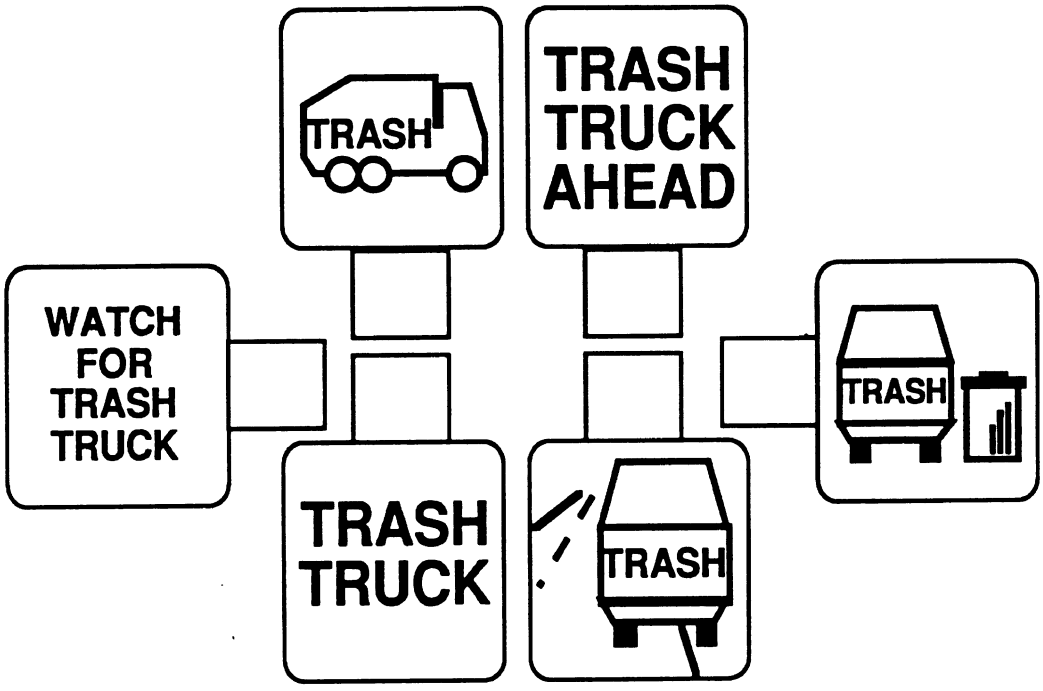
4. You are approaching a wide vehicle in the road ahead.



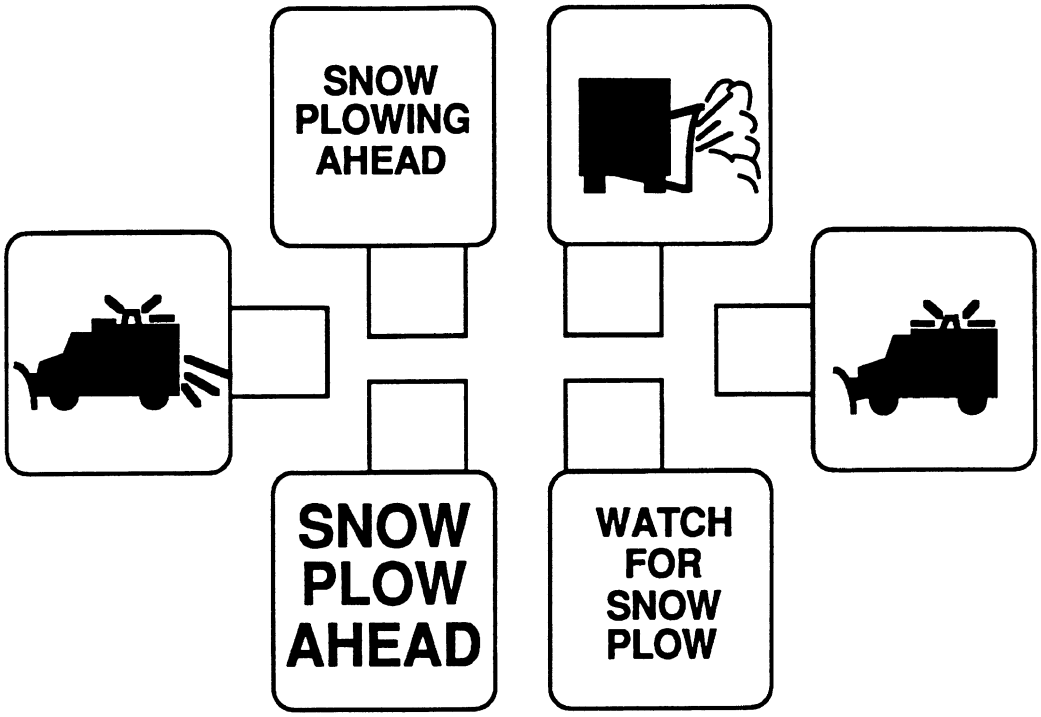
5. You are approaching a mail delivery truck that may stop at any time.



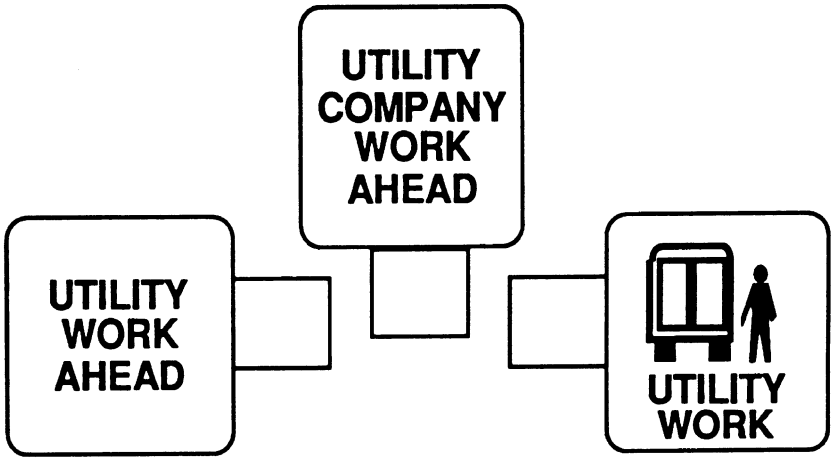
6. You are approaching a trash truck that may stop at any time.



7. You are approaching a snow plow/salt truck that is plowing or salting the road ahead.



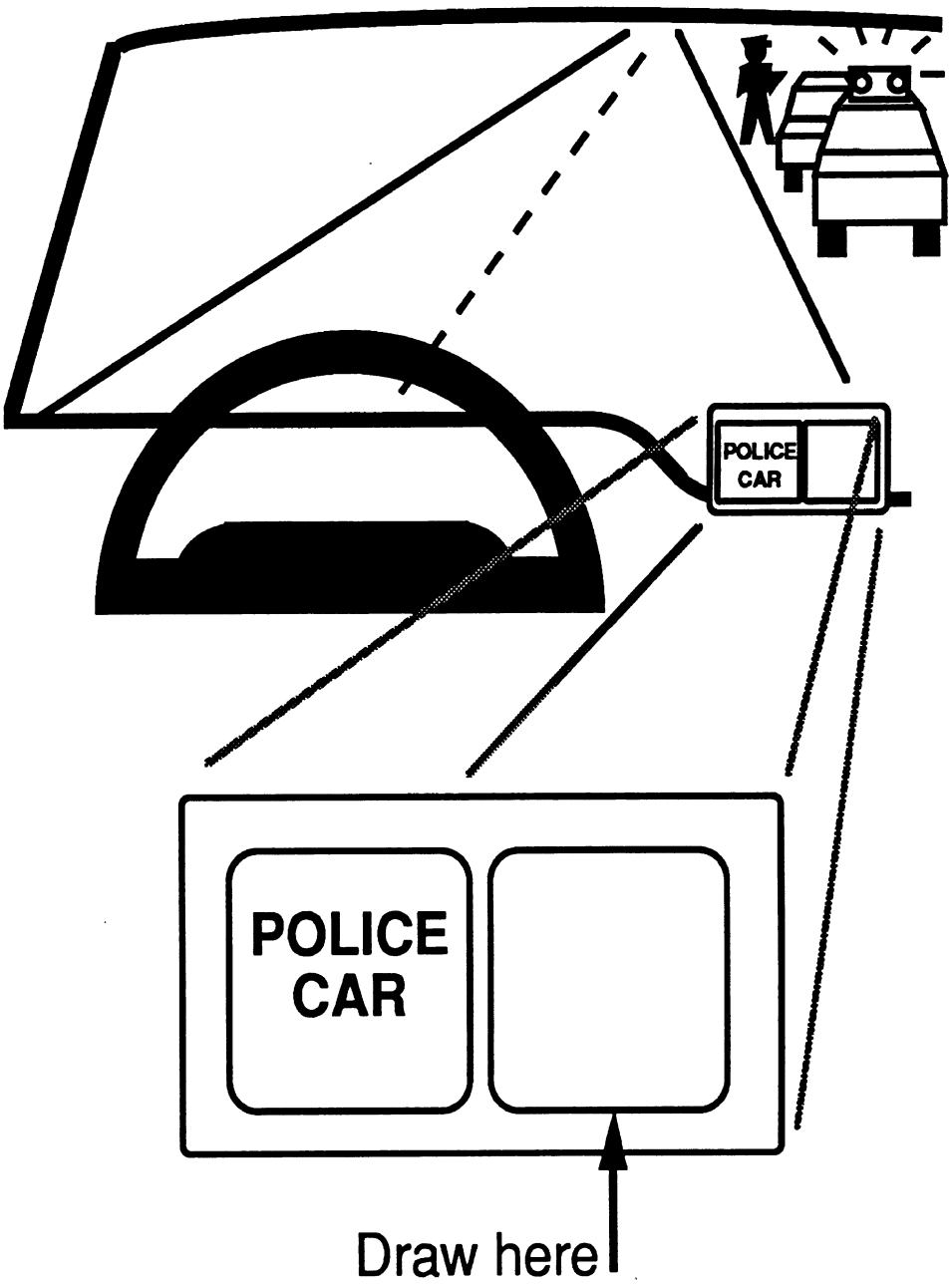
8. Ahead of you a utility company (gas, electric, cable, etc) is working near the road.



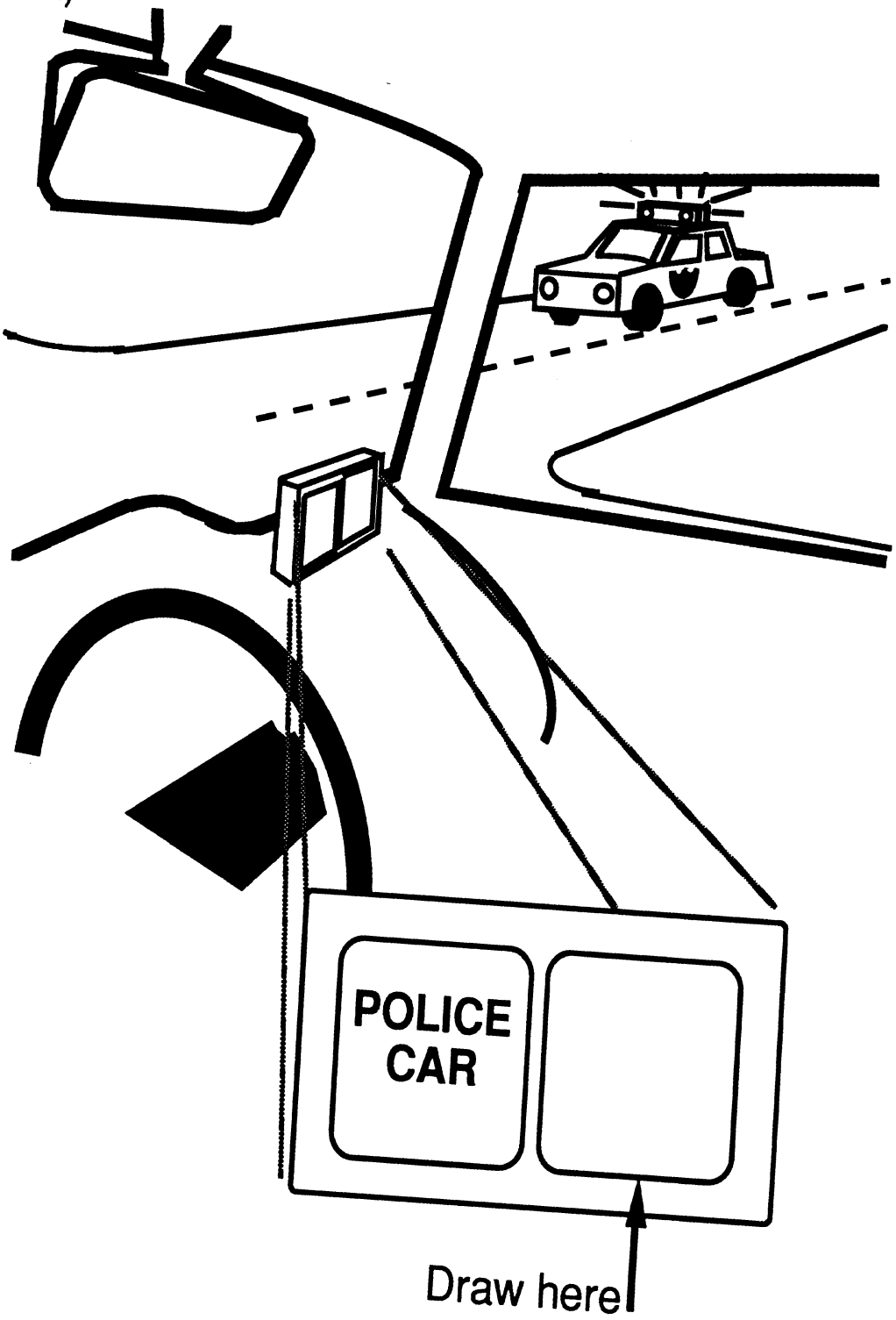
IVSAWS Directionality Population Stereotype Form

For items 1 through 3, draw what you feel would best warn you of the situation shown.

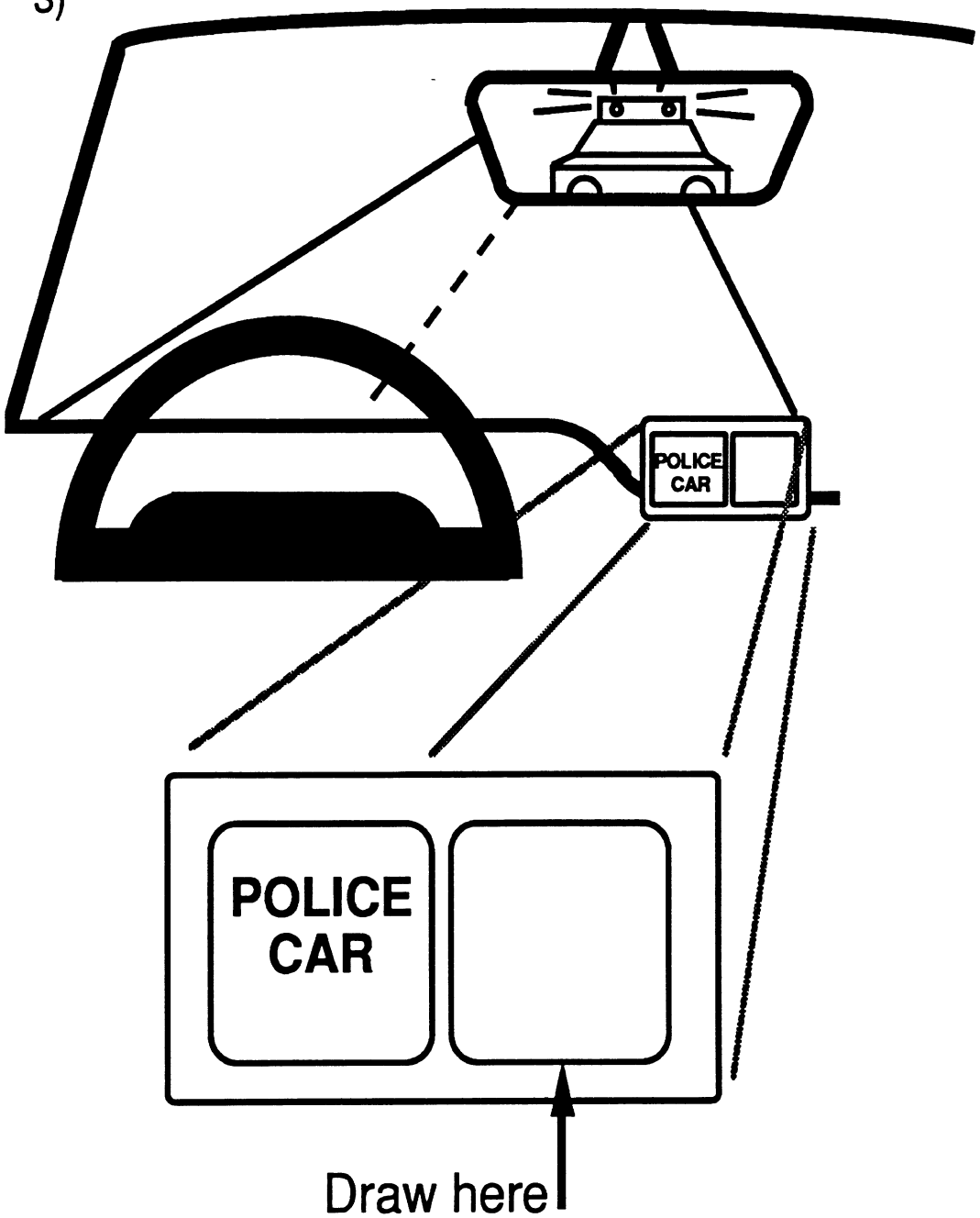
1)



2)



3)



Appendix C - IVSAWS Testing at Driver Licensing Office
Subject Instructions & Forms

University of Michigan
Transportation Research Institute
Human Factors Division

INSTRUCTIONS for IVSAWS TESTING

Hi. My name is _____ and I'm from the University of Michigan. We're designing a hazard warning system for cars and need drivers' input. I have a questionnaire that takes about 10 minutes to complete and I was wondering if you would be interested in doing it while you wait. *If no,* okay.

If yes, great, let me tell you a little bit more about it. This system will warn drivers about situations on the road ahead, such as a fire truck is on the side of the road, and will look something like this. *Show them the picture of the car interior and point to the display and the dashboard when you mention them.* It will be a display on top of the dashboard and will warn the driver of a situation using symbols and/or words. *Put the picture away.* We're at the stage now where we need your help in identifying symbols for the display.

Point to the example on the cover of the questionnaire. In this questionnaire we have situations (*point to and read the example statement*) and then a set of symbols (*point to the symbols*). Here, symbols can be pictures or words. We want you to rank the symbols for the situation from best to worst with (*point to where this is listed in the instruction*) 1 being best, 2 second best, and, for the example here, 3 worst.

Lift up the cover page and point to the second symbol set on the first page. When you're ranking, though, there are going to be a different number of symbols and we want you to rank all of the symbols. For this one there are *6* symbols *(or however many there are)*, so you would rank all of the symbols using the numbers 1 through 6 with 1 being the best, 2 second best, 3, 4, and 5, and 6 being the worst. There should always be a number next to the picture.

Show them the bio form. Before you get started I would like you to fill out this biographical form. It will tell us about yourself and the kind of car you drive.

Do you have any questions? *If no,* great. *If yes, answer them.*

University of Michigan Transportation Research Institute
Human Factors Division

Biographical Form Date:

Name: _____

Male Female (circle one) Age: _____

What is your native language? (circle one)

English Chinese Japanese Korean Spanish

Other: _____

Occupation: _____
(If retired or student, note it and your former occupation or major)

Education (circle highest level):

some high school	high school degree
some trade/tech school	trade/tech school degree
some college	college degree
some graduate school	graduate school degree

What kind of car do you drive the most?

year: _____ make: _____ model: _____

Annual mileage: _____

Do you have a car phone?

yes no -----> Have you ever used a car phone? yes no

Does your car have a Head-Up Display (HUD)?
(If you don't know what it is you probably don't have one.)

yes no -----> Have you ever **driven** a car with a HUD? yes no

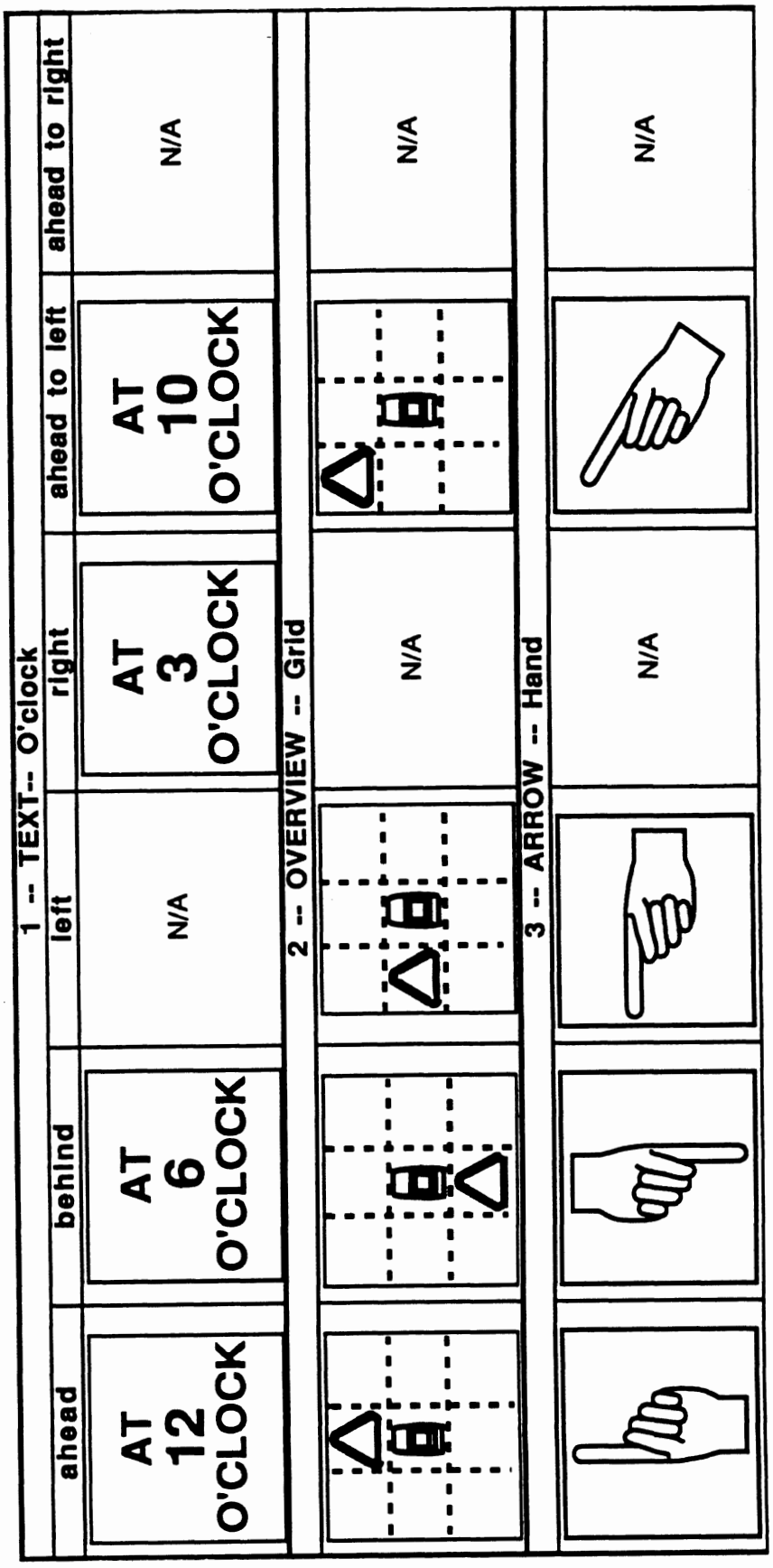
How often do you use a computer? (circle one)

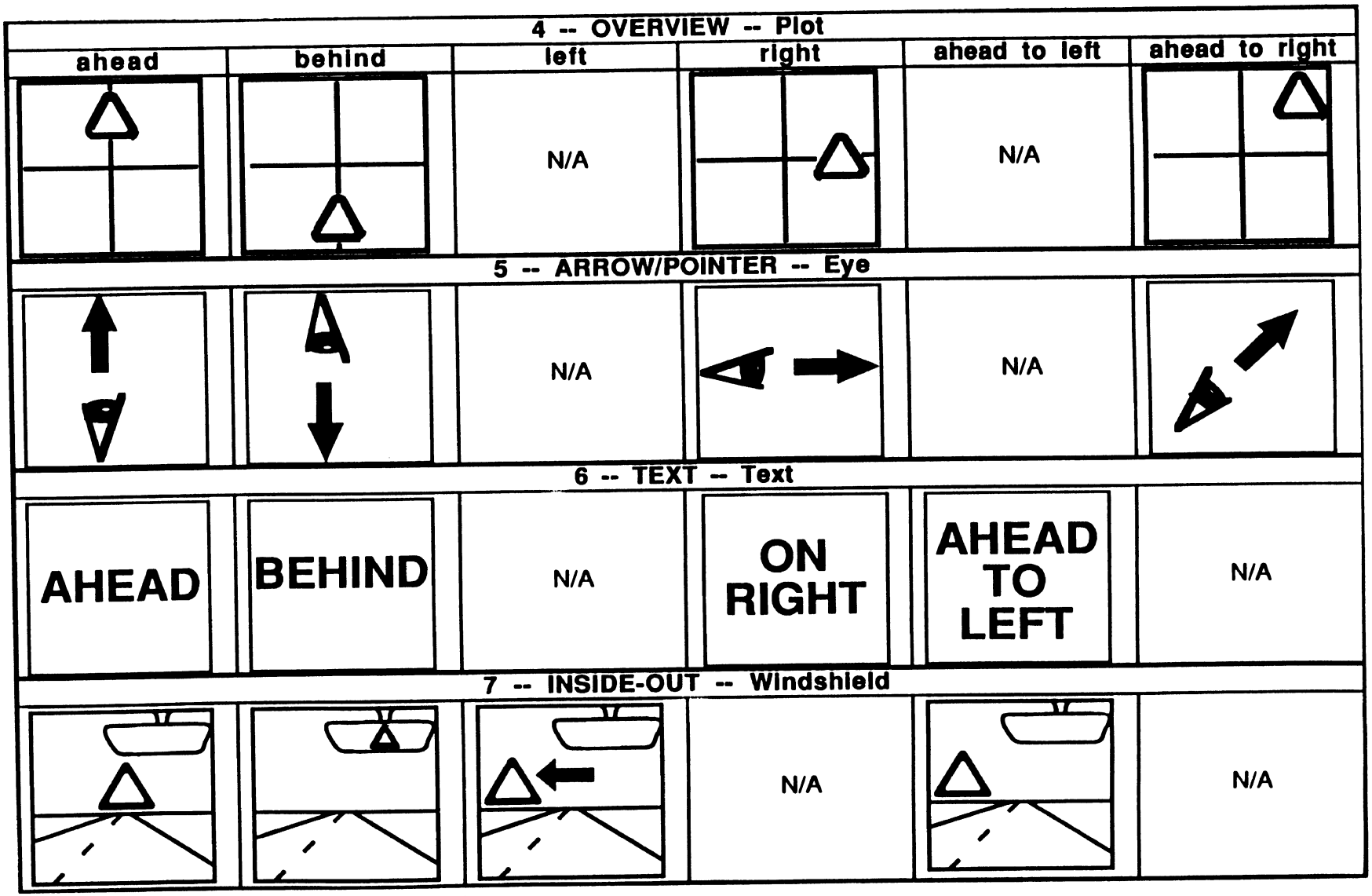
daily a few times a week a few times a month once in a while never

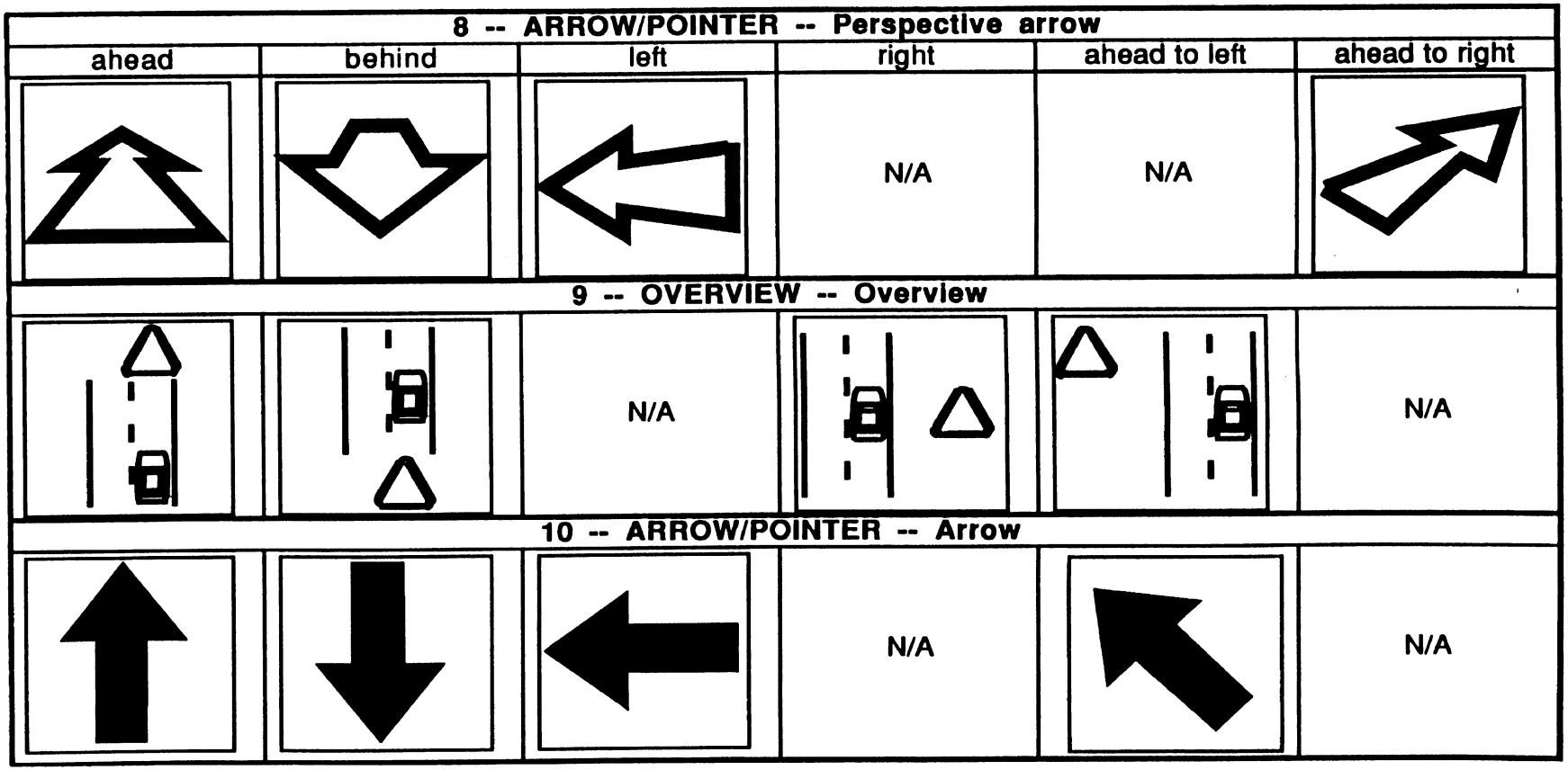
Did you ever use a computer with a touch screen?

no yes -----> Give example/situation: _____

Appendix D - IVSAWS Field Experiment: Part 3 Location Cues




4 -- OVERVIEW -- Plot
ahead
behind
left
right
ahead to left
ahead to right
N/A
N/A
5 -- ARROW/POINTER -- Eye
N/A
N/A
6 -- TEXT -- Text
AHEAD
BEHIND
N/A
ON RIGHT
AHEAD TO LEFT
N/A
7 -- INSIDE-OUT -- Windshield
N/A
N/A


8 -- ARROW/POINTER -- Perspective arrow
ahead
behind
left
right
ahead to left
ahead to right
N/A
N/A
9 -- OVERVIEW -- Overview
N/A
N/A
10 -- ARROW/POINTER -- Arrow
N/A
N/A

Appendix E - IVSAWS Field Experiment Subject Instructions & Forms

EXPERIMENTAL PROCEDURE

Before participant arrives

Have ready the participant money ($15), the correct flash cards, biographical form, consent form, data collection sheets, and car keys.

When participant arrives

Go to conference room. Briefly explain what experiment is about:

Thank you for coming. Let me tell you what you will be doing today.

We are testing some symbols that may be used in an in-vehicle safety advisory and warning system, that may be used in the future. With this system you would have a small monitor (3x4 inches) on the dashboard in your car. It would provide you (the driver) with information on various hazards around you. Today I will be showing you some symbols from this system and you will tell me what they mean to you.

Using one of UMTRI's cars, a Ford Taurus wagon, you'll drive us down Huron Parkway to a neighborhood just past Washtenaw Avenue. I'll show you 11 symbols while you drive around that neighborhood, and you just tell me what they mean to you. Then we'll park on the side of the road at a certain spot there, next to a church, and go through some more of them. Do you have any questions?

Ask participant to read and sign the consent form. Fill out biographical form. Go through eye test for far vision:

I am going to check your vision now. If you look through the vision tester, can you see in the first diamond that the top circle is complete, but that the other three are broken? Looking at diamond number two, can you tell me which circle is complete?

Continue until two consecutive answers are incorrect. Record the last correct answer on the biographical form. Before going down to the car, check driver's license.

At the car

Have participant adjust the seat, mirrors, and steering wheel until comfortable. Point out card holder. Explain how cards will be presented.

Since we don't have a monitor installed in this car, I will be presenting the symbols to you printed on cards, from this holder. You should still consider this your In-Vehicle Safety Advisory Warning System. When we get into the neighborhood I'll start presenting the cards to you, briefly, one at a time, with a

few seconds in between presentations. You just need to tell me what they would mean to you, if they appeared on your monitor. I'll tell you where to turn, and there we'll stop for the next part. Let me remind you to stay within the speed limit. Any questions?

Turn left onto Huron Parkway, toward Washtenaw. When you get to Washtenaw, remind them that when we turn into the neighborhood, you will be showing them the cards, and they will just say what they mean. Make a left turn onto Edgewood Drive.

Parts 1 & 2

While driving around that neighborhood, present Part 1 and Part 2 cards. Ask: **What does this mean to you?** Record responses.

Part 3

For Part 3, pull over by the church, on Norwood at Fernwood facing west. Put car in park, and turn off (weather permitting).

Ok, I think you now get the idea of what this system does. So, for this part we're not going to drive, we'll just sit here. You should still pretend that you are driving, however. I'm going to show you 40 more cards which will look more like the last one you saw (show the card from part 2). **This** (point to the left side of the card) **will identify the hazard, and this** (point to the right side) **will give you some information about where the hazard is.**

For each of these, you should imagine that you are driving on this road, at this particular spot when that message comes up on your in-vehicle monitor. What I want you to do for this part is tell me 1) what the hazard is, 2) where it is, and 3) to point to where it is. Keep in mind that each card is a separate event, that is, they are not related to each other. Do you have any questions?

Flip to the first card. **Please tell me what and where the hazard is, and point to it.** Continue to do the same for all 40 cards.

Ok, we're done with that part. Can you please tell me what the triangle on the cards meant to you, in general? Record the response.

Finally, here is a stack of cards showing you an example of each of the designs that told you where the hazard was. Using these, can you rank these from best to worst, in terms of what you thought was easiest to understand where the hazards was. An easy way to do this is to make a pile with best on top, and worst on the bottom. Record the order of the cards.

Ok, we can go back to UMTRI, and then fill out the payment form.

Direct participant back to UMTRI. Have participant complete payment form. Pay and thank them.

IVSAWS Field Experiment Biographical Form

University of Michigan Transportation Research Institute
Human Factors Division

Subject: ☐

In-Vehicle Safety Advisory Warnings
Biographical Form

Date: ☐

Name: _____

Male Female (circle one) Age: _____

Occupation: _____

Education (circle highest level completed):

some high school	high school degree
some trade/tech school	trade/tech school degree
some college	college degree
some graduate school	graduate school degree

Retired or student: note it and your former occupation or major) _____

What kind of car do you drive the most?

year: _____ make: _____ model: _____

Annual mileage: _____

Have you ever driven a vehicle with an in-vehicle traffic information or navigation system? (not in an experiment)

yes no

Does your car have a Head-Up Display (HUD)?
(If you don't know what it is you probably don't have one.)

yes no -----> Have you ever driven a car with a HUD? yes no

TITMUS VISION: (Landolt Rings)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
T	R	R	L	T	B	L	R	L	B	R	B	T	R
20/200	20/100	20/70	20/50	20/40	20/35	20/30	20/25	20/22	20/20	20/18	20/17	20/15	20/13

Vision correctors? Yes / No _____ if yes, name type

IVSAWS Field Experiment Subject Consent Form

PARTICIPANT CONSENT FORM

We are conducting a study to investigate the understandability of an In-Vehicle Safety Advisory and Warning System (IVSAWS). The government may require a system similar to this in cars of the future, cars you might drive. This system warns drivers about certain hazards in their proximity. It does this by displaying a message or symbol to a driver on a monitor in the car. You will be helping us determine if these symbols and messages are useful and easy to understand.

While driving along a short route (about 5 minutes) through a local neighborhood, I'll show you various symbols and you'll tell me what they mean. Afterwards, we'll stop the car and do the same for some more symbols.

This experiment will take approximately 1 hour, for which you will be paid $15. If for any reason you cannot finish this experiment, please inform the experimenter; you will be paid regardless.

I have read and understand the above statement.

_____	_____
Your name (printed)	Date
_____	_____
Your signature	Witness (Experimenter)

Appendix F - IVSAWS Field Experiment Transcript of Single Subject Responses

Responses to part 1 (Hazards) for subject 10, an older male, are listed in table 20. Responses to part 2 are in table 21.

Table 20. Responses to part 1 for subject 7.

Hazard	Response
Train at crossing (graphic)	That means that there's a railroad track, and there's a flashing light, a train is coming.
Moving police car	That's a police car with lights on, flashing.
Traffic light out of order ahead	That means that your red stop and go lights ahead are out of order, so beware.
Road construction	This sign is warning you that there's road construction ahead, be prepared to slow down at any time.
Schoolbus un/loading	That means that there's a school bus ahead, with its lights on to tell you you're supposed to stop because they're letting children off.
Moving ambulance	This is an ambulance with its lights on, telling you to pull over and let them pass.
Train at crossing (text)	This is, I've never seen that one, there's a crossing, and there may be a train at the next crossing, be cautious.
Stopped police car	That means that you stop or be aware that there's a police car ahead with its siren going, so there's something happening. Be prepared to stop.
New stop sign ahead	That means that there's been a new stop sign posted ahead, so be aware and ready to stop when you see it. I guess that was the stop sign.
Accident ahead-slow down	Means slow down or be prepared to stop, there's an accident ahead.

Table 21. Responses to part 2 for subject 7.

Moving police car--ahead (text)	Be prepared. There's a police car ahead with its siren on, be prepared to stop. I'm just going to guess that there's a school zone.

Part 3: Hazard and Location

Responses to all hazard and location cues by subject 7, a younger female, are listed in table 22.

Table 22. One subject's responses to all hazard and location cues.

Key to table 22

Code	Location	Code	Location
A	Ahead	B	Behind
AL	Ahead to left	AR	Ahead to right
L	Left	R	Right

Design	Card #	Loc	Response
Windshield	1	A	Ambulance straight ahead, moving ambulance.
	2	AL	Moving ambulance to the left.
	3	B	Moving police, behind me.
	4	L	Moving police to my left, up ahead and to the left.
Perspective Arrow	1	A	Moving ambulance way ahead, or speeding ahead, I'm not sure.
	2	L	Moving police coming from the right going to the left.
	3	AR	Moving ambulance coming from my back left moving to my far right.
	4	B	Moving ambulance coming toward me.
Overview	1	R	Moving police on the right, like stationed, hold on, I don't know, ambulance moving, no... police, on the shoulder of the road on the right.
	2	A	Moving ambulance up ahead of me.
	3	AL	Moving police car, ahead and to the left.
	4	B	Moving police right ahead of me in the same lane.
Arrow	1	B	Moving ambulance coming toward me.
	2	A	Moving ambulance coming behind me.
	3	L	Moving ambulance coming from the right going to the left, about to cross me.
	4	AL	Moving police car coming from the back right, going to me left front, diagonally.
O'clock	1	AL	Moving ambulance at 10 o'clock so, over there, to my left.
	2	R	Moving ambulance at 3 o'clock, right to the right of me.
	3	B	Moving ambulance coming from behind me.
	4	A	Moving police car right in front of me.

Table 22. One subject's responses to all hazard and location cues (continued).

Design	Card #	Loc	Response
Grid	1	B	Moving ambulance, **right** behind me, same lane, same side of the road.
	2	L	Moving ambulance right to the left of me (next to me).
	3	AL	Moving police to my front left.
	4	A	Moving ambulance directly in front of me.
Hand	1	L	Moving police going left, its coming from the right and going to the left.
	2	AL	To the left of me. [*When you say to the left, what do you mean...]* Good question, I guess it is over there, although that is not consistent with...
	3	A	Moving police right in front of me.
	4	B	Moving ambulance right behind me.
Plot	1	A	Moving police right in front of me.
	2	R	Moving police right to my right. *[When you say right to your right, do you mean..]* Like perpendicular to my right, 3 o'clock, right there [pointing next to the car].
	3	B	Moving police coming from behind me.
	4	AR	Ambulance diagonally to the right.
Eye	1	AR	Moving police, [laugh] diagonally to the right.
	2	R	Moving ambulance directly to my right.
	3	B	Moving police directly behind me.
	4	A	Moving ambulance directly in front of me.
Text	1	AL	[Laugh], moving police car ahead to my left, so kind of diagonally I guess.
	2	B	Moving police directly behind me.
	3	A	Moving ambulance directly ahead of me.
	4	R	Moving police on the right.

Triangle meaning

Well I put the triangle where the, if it were on ambulance symbol over here, that's like where that car was, or like where that vehicle was. Like a caution symbol I guess. That's what I was supposed to look for, whatever was in the triangle.

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