A Driver Interface for a Road Hazard Warning System: Development and Preliminary Evaluation

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ABSTRACT

This paper concerns in-vehicle warnings for accident-provocative situations (accidents ahead, new traffic signals, police cars on emergency runs, etc.). Candidate warnings were developed for 30 hazards based on drawings from 10 drivers. Subsequently, 75 drivers ranked these warnings. Preferred warnings were not always in the standard U.S. highway sign set. In general, text warnings were slightly preferred over symbolic warnings.

In a third experiment, 20 drivers were shown 10 hazard location cue designs: 2 text, 4 arrow, 3 overview, and 1 inside-out. Of the location cues, text ("on right," "behind," etc.) was best understood.

1. INTRODUCTION

This paper summarizes a detailed technical report concerning the driver interface for a prototype in-vehicle warning system (Hoekstra, Williams, and Green, 1993) to which readers are directed for additional details. This study was part of a large multi-year project concerning the safety and ease of use of new driver information systems. The objectives were to develop human factors guidelines (Green, Levison, Paelke, and Serafin, 1993), methods for testing the safety and ease of use (Green, 1993b), and a model to predict human performance (Levison, 1993; Levison and Cramer, 1993) while using these interfaces. A complete list of the project reports and other publications is included in the final overview report (Green, 1993a). To focus this research on applications, pre-competitive interfaces were designed for five systems, including the warning system described in this paper.

As currently envisioned, low power radio beacons would be placed on or near fixed hazards (e.g., narrow underpasses), mobile hazards (e.g., police cars on a run) or temporary hazards (e.g., accidents). The beacon would transmit a hazard-specific message. Nearby vehicles would receive these messages and a warning system, such as IVSAWS (In-vehicle Safety and Advisory Warning System), would display a warning to drivers.

The rationale for IVSAWS, and its predecessor, SHAWS (Safety Hazard Advance Warning System) are described in the literature (Peterson and Boyer, 1975; Meyer, Reaser, Keller, Wilson, and Vadeboncoeur, 1982). Prior to this project, only one experiment has been conducted pertaining to the driver interface (Erlichman, 1992). In that experiment, 13 Hughes employees where shown eight symbols on a color display in a laboratory. In general, subjects preferred colored icons over monochrome, warning tones over none at all, and wanted spoken text to accompany the presentation.

Given the state of knowledge when this effort was initiated, three questions were examined:

1. Which hazards need warnings?
2. What graphics best represent those hazards?
3. How well are various location cues for hazards understood?

It was decided to make the warning system visual, rather than auditory (primarily speech). This was done to minimize competition with existing auditory warnings, promote international use by avoiding language-specific (spoken) messages, and minimize development cost. Also, past experience suggested driver reaction to new speech-based warning systems would be poor. ("Your door is ajar." "No, a door is a door, not a jar.")

2. WHICH HAZARDS NEED WARNINGS?

Hazards needing warnings were identified from the benefit scores in Green, Serafin, Williams, and Paelke, 1991 and Serafin, Williams, Paelke, and Green, 1991, the Streff, Ervin, and Blower, 1991 review of selected accident case files, and the discussion in Meyer, Reaser, Keller, Wilson, and Vadeboncoeur, 1982. The empirical data was supplemented with discussions with people the warnings should protect (postal vehicle drivers, hearse drivers, fire fighters, etc.). These efforts led to the identification of 30 hazards for which warnings should be considered. (See Tables 1, 2, and 3.)

Table 1
In-vehicle signing hazards

Accident ahead.
Hazard 1 mile ahead.
Hazard approaching in opposite direction.
Lanes shift/jog to the right.
New stop sign.
New traffic light.
Right lane closed, merge into left 2 lanes.
Road construction area, speed limit 45 mi/hr.
Road construction.
Sharp curve, speed limit 30 mi/hr.
Traffic light out of order.
Train approaching railroad track.

Table 2
Atypical vehicle hazards

Farm vehicle.
Mail delivery truck.
Parked utility company vehicle.
Plow/gravel vehicle plowing or sanding.
School bus loading or unloading children.
Slow moving vehicle.
Tow truck with flashers & disabled vehicle.
Trash truck.
Wide load.

Table 3
Emergency vehicle hazards

High speed ambulance with siren & flashers.
High speed fire truck with siren & flashers.
High speed police car with siren & flashers approaching from behind.
High speed police car with siren & flashers approaching from right.
High speed police car with siren & flashers in pursuit.
High speed police car with siren & flashers.
Parked ambulance with flashers.
Parked fire truck with flashers.
Parked police car with flashers.

3. WHAT GRAPHICS BEST REPRESENT THOSE HAZARDS?

3.1 Experiment 1 - Symbol Production

To obtain ideas for candidate warning graphics, 10 drivers drew images for the 30 situations of interest and a hazard location indicator. ("You are approaching an area where there is road construction. The symbol should be...") Subjects ranged in age from 21 to 47, with a mean age of 33.

Figure 1 shows some typical responses. Drawings represented a wide variety of concepts, even for warnings for which there is a standard highway sign. 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. Likewise, for the railroad crossing hazard, only three people drew the indicative R's inside of the large X. Those who drew the RXR were not the same people who drew the highway worker for construction.

Figure 1 Responses to question concerning high speed fire truck with siren and flashers.

3.2 Experiment 2 - Testing at a Driver Licensing Office

The purpose of this experiment was to determine driver preferences for pictorial warnings developed from the production experiment, along with warnings based on highway signs and text. Subjects (3 groups of 25 [42 men and 33 women]) responded while waiting at a local driver licensing office. They were from 17 to 81 years old, with a mean age of 30.

Subjects completed one of three surveys, each of which concerned a particular class of warnings (in-vehicle signing, atypical vehicles, and emergency vehicles), along with three general questions. This approach was chosen due to the limited availability of subjects. Each survey contained a series of alternatives for each warning, which subjects ranked from best (=1) to worst. Figure 2 shows an example.

Results from this experiment are summarized as a series of figures, each of which shows the mean ranks for each graphic along with explanatory text. See Figure 3 for partial example.

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

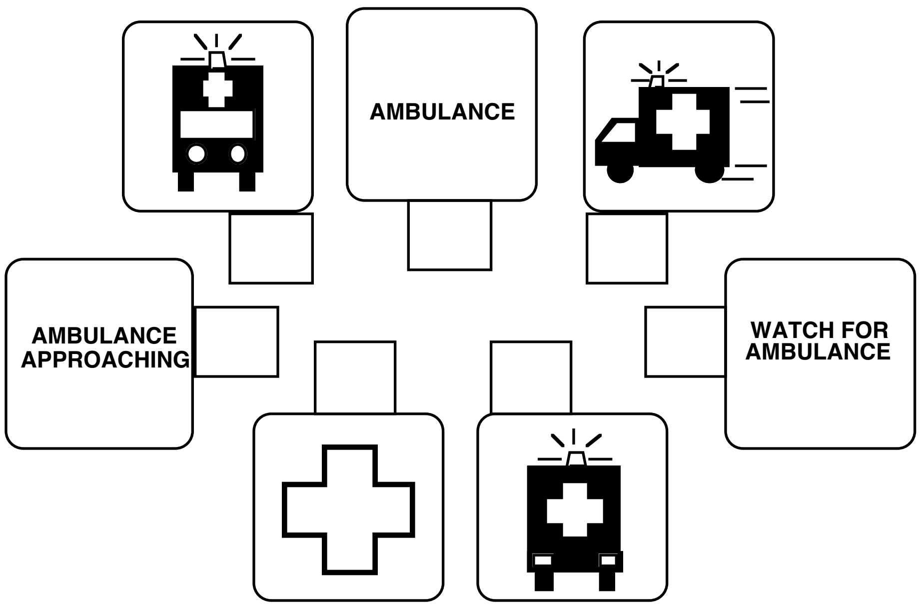

Figure 2 Example ranking question.

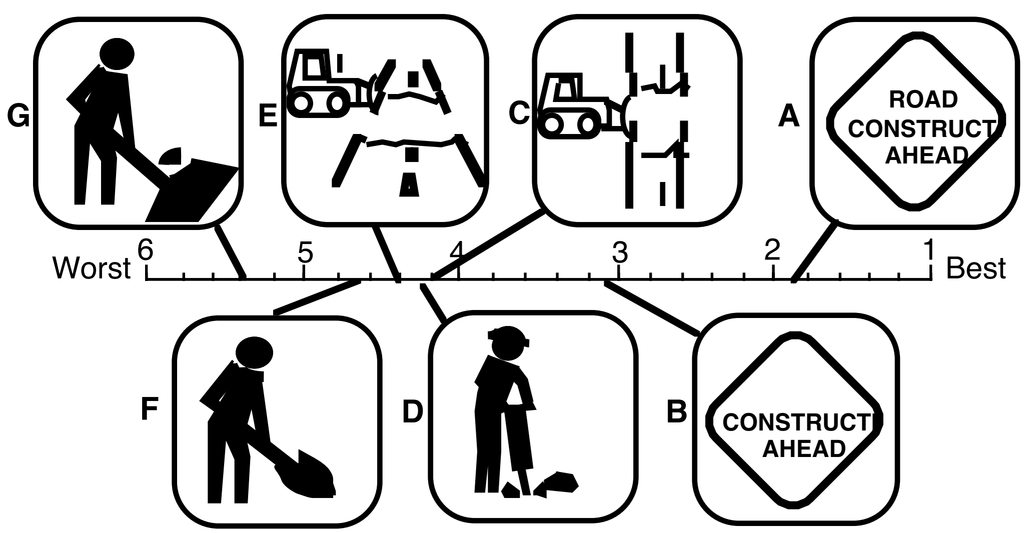

Figure 3 Mean ranks for road construction warnings.

Based on the results of the ranking experiment and consistency constraints, recommended warnings were developed. For some warnings, both text and graphic versions were developed. (See Table 4 for examples.)

Table 4
Recommended warnings for traffic control devices.

Format	Mixed	Text
Disabled traffic signal	OUT OF ORDER AHEAD	BROKEN TRAFFIC SIGNAL AHEAD
New traffic signal	NEW AHEAD	NEW TRAFFIC SIGNAL AHEAD
New stop sign	NEW STOP AHEAD	NEW STOP SIGN AHEAD

4. HOW WELL ARE VARIOUS LOCATION CUES FOR HAZARDS UNDERSTOOD?

4.1 Field Experiment on Hazard and Hazard Location Understandability

Twenty licensed drivers participated in this experiment, 10 young (21 to 29 years old), and 10 older (59 to 73). Equal numbers of men and women were in each age group.

This experiment examined understanding of hazard warnings, understanding of location cues, and their combined understanding. Parts 1 and 2 were conducted while driving a 1991 Ford Taurus station wagon on a fixed route through a residential neighborhood. In part 3, subject imagined they were driving through an intersection. (The car was actually parked.) Simulated IVSAWS displays were printed on 4x6 inch cards and mounted near the middle of the instrument panel.

In Part 1, drivers were shown the 10 hazard warnings in Figure 4 and drivers said what each meant. At least two warnings were examined in each of the 3 categories (in-vehicle signs, atypical vehicle, emergency vehicle) Hazard warnings were either text, graphics, or mixed. In Part 2, they were shown the moving police car warning and a location cue, and said what they jointly meant. Figure 5 shows the location cues for ahead. Six locations were actually examined (ahead, ahead to the left, ahead to the right, to the left, to the right, and behind). In Part 3, drivers were shown 40 hazard type-location cue pairs constructed by combining the 10 hazards with 4 of the 6 directional cues. (See Figure 6.) Drivers identified the hazard and pointed to its location. It was believed that informing the driver of the hazard and its location (rather than having drivers search for it) would improve warning system effectiveness. The experiment ended (in the laboratory) with subjects ranking the location cues from best to worst.

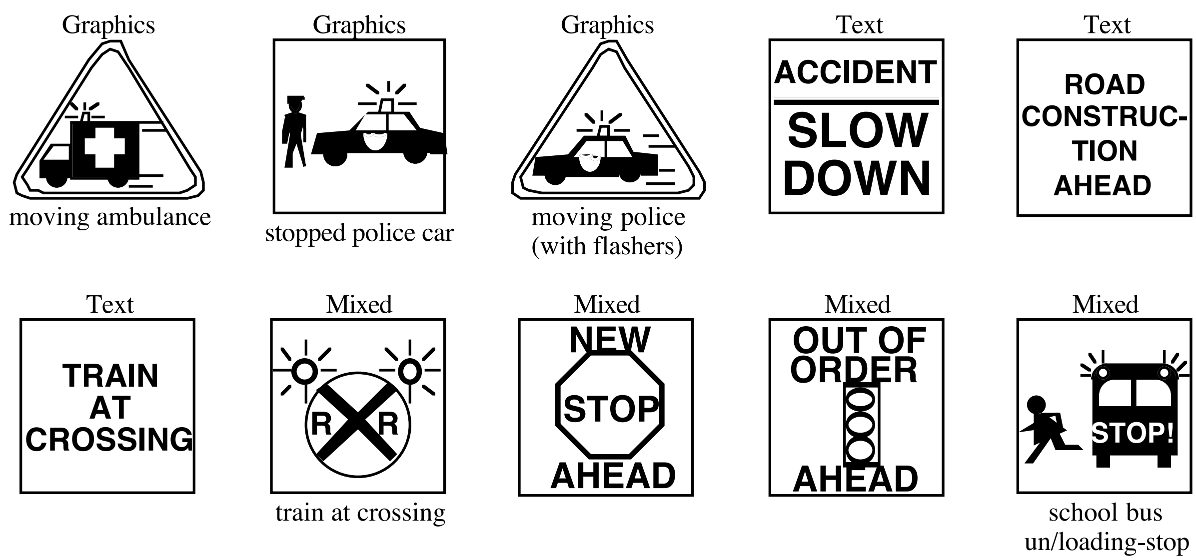

Figure 4 IVSAWS warnings examined in the field experiment.

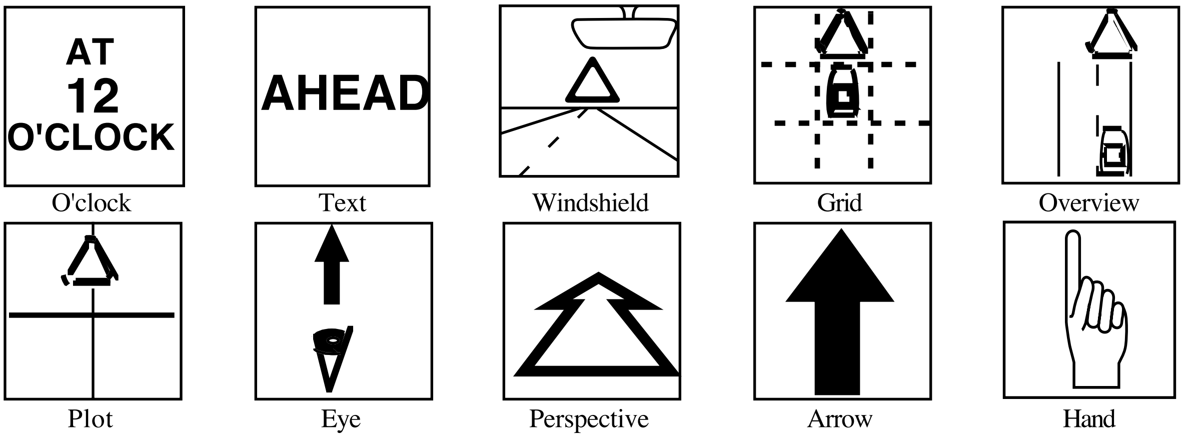

Figure 5 Warning location cues.

Figure 6 Example IVSAWS message.

The graphics 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. When vehicles were depicted (stopped police car, moving police car, moving ambulance, and school bus un/loading), drivers were able to identify the type of vehicle shown but sometimes missed the motion cues (stopped versus moving vehicle). Of the two "train at crossing" hazard symbols, the text message was most widely understood.

Overall, the text-based location cues (o'clock and text) were most clearly understood, followed by the overview, inside-out, and arrow formats. (See Table 5.) The text design had the most number one rankings (seven), and the highest overall mean rank (3.3). However, Kruskal-Wallis analysis indicated that differences in design preferences were not statistically significant. For the overview designs (plot, grid, overview), the lines representing quadrants around the vehicle were sometimes interpreted too literally, leading drivers to believe the lines represented an intersection. For the arrow designs (perspective and regular arrow), some subjects interpreted the arrow as a command to move in that direction, not as an indication of hazard location. Some subjects thought the arrow was a vector representing vehicle speed and/or direction.

Table 5
Location cue understandability & preferences.

Design	Format	Percent Correct	Mean Preference Rank (1=best, 10=worst)
Text	Text	100	3.3
O'clock	Text	94	6.5
Plot	Overview	93	6.3
Overview	Overview	84	4.8
Grid	Overview	83	5.6
Windshield	Inside-out	78	7.0
Hand	Arrow	75	4.8
Eye	Arrow	68	7.9
Perspective	Arrow	66	5.6
Arrow	Arrow	59	3.5

5. CONCLUSIONS

This paper describes three experiments concerning the development and preliminary evaluation of warnings for road hazards. In the first experiment, ideas for warning were obtained from a small sample of drivers by having them draw suggestions. These ideas proved helpful in developing candidate warnings and the experiment was easy to conduct.

In the second experiment, candidate warnings developed from subject drawings were ranked from best to worst, allowing the set of alternatives to be reduced. This experiment proved to be quick and easy to conduct. The preferred warning format (text or graphics) varied from warning to warning. Also, warnings based on existing standard highway signs were not always preferred.

The third experiment, conducted in a vehicle (sometimes moving, sometimes stationary) using cards to represent warnings, provided a low-cost method for evaluating warning alternatives, while still providing a real-world context. In general, text (ahead, to the left, etc.) was the cue preferred by drivers to indicate the location of a hazard and led to the highest understandability.

The purpose of this study was to demonstrate methods for developing and evaluating warnings in vehicles, and to provide a reasonable set of alternatives for further evaluation. (See Green, Williams, Hoekstra, George, and Wen, 1993 for a subsequent on-road experiment in which eye fixation data was collected.) This effort was not intended to develop a set of warnings ready for incorporation in a national or international standard, though it does provide an excellent beginning. Should standards be desired, additional development and testing should be carried out.

6. REFERENCES

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7. ACKNOWLEDGMENTS

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